



Cognitive function among first division KwaZulu-Natal Rugby Union players and its associations with duration of exposure to the sport and a history of concussion

By

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Declaration of originality

This is to certify that the work is entirely my own and not of any other person, unless explicitly acknowledged (including citation of published and unpublished sources).

The work has not previously been submitted in any form to the Durban University of Technology or to any other institution for assessment or for any other purpose.

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Dedication

I dedicate this dissertation to my family and friends

Thank you for being my pillars of strength throughout this life journey and for believing that I could be anything and do anything I put my mind to.

Thank you for never giving up on me and for the unconditional love and support.

I love you all,

Forever & Always.

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Abstract

Background

Rugby union ('rugby') is a popular sport that is also associated with a higher-than-average risk of concussion injury compared with other popular team sports. A recent study in New Zealand found that a history of rugby participation or concussions were associated with neurocognitive deficits, as measured by CNS Vital Signs (CNSVS) test battery. Although it is a vastly different context, rugby is just as popular in South Africa as in New Zealand. Despite this, no study to date has quantified the effects of rugby exposure and concussion history as measured by CNSVS.

Aim

The aim of the study was to determine the association between cognitive function and rugby exposure and/or concussion history among adult first division rugby players in South Africa.

Research methodology

The research conducted was a cross-sectional survey which targeted first division rugby players in KwaZulu-Natal. The research tools used were the CNSVS test battery and the General Health Rugby (GHR) questionnaire which were used in a similar study in New Zealand.

Results and discussion

This study revealed a weak Pearson coefficient -0.24 ($p = 0.05$) between the number of years of rugby playing experience and neurocognitive index (NCI) score, which indicated that every additional year of rugby played resulted in a minor decrease in the NCI score of the respondents. However, multiple regression analyses revealed that the association between rugby playing experience and NCI score was attenuated ($p = 0.41$). Despite the multiple regression association not being significant ($p = 0.53$), this study reported medium to large effect size inverse associations between the number of concussions sustained by the players and their NCI domain scores.

Conclusion and recommendations

Rugby is a physically demanding team sport played in South Africa as well as across the globe, therefore the need for research pertaining to neurological health in rugby is necessary. This study indicated a weak negative association between the number of years of rugby playing experience and the respondents' NCI scores. Furthermore, this study reported a medium to large effect size inverse association between the number of concussions sustained by the players and their NCI domain scores, and as such warrants further exploration in more prospective studies. There is a need for additional research with regards to neurological health in rugby players, taking into account concussive and sub-concussive exposure.

Keywords

Rugby Union, cognitive functioning, mild traumatic brain injury, sports concussion, CNSVS testing, NCI.

Table of Contents

Declaration of originality	ii
Dedication	iii
Acknowledgements	iv
Abstract.....	v
Table of Contents	vii
List of Figures	xi
List of Tables	xii
List of Appendices	xiii
Definitions	xiv
Abbreviations	xv
CHAPTER 1: INTRODUCTION	1
1.1 Background	1
1.2 Aim of the study	2
1.3 Objectives of the study	2
1.4 Rationale for the study.....	3
1.5 Outline of the dissertation.....	3
CHAPTER 2: LITERATURE REVIEW.....	5
2.1 Introduction	5
2.2 Rugby	5
2.3 Common injuries associated with rugby	6
2.4 Concussion	8
2.4.1 Definition.....	8
2.4.2 Anatomy and pathophysiology	9
2.4.3 Side-line evaluation and diagnosis	12
2.5 Risk factors for sport related concussion	13

2.5.1	History of SRC.....	14
2.5.2	Mechanism of injury	15
2.5.3	Match play versus practice	15
2.5.4	Playing position	16
2.5.5	Protective equipment	16
2.6	Short-term risks of continued exposure after concussion or premature return to play.....	17
2.7	Long-term risks after concussion	18
2.8	Management and prevention of sport related concussion	20
2.9	Cognitive functioning	23
2.9.1	Definition and background	23
2.9.2	Neurocognitive testing	24
2.10	Summary	26
CHAPTER 3: METHODOLOGY		28
3.1	Introduction	28
3.2	Research design	28
3.3	Study setting	28
3.4	Study population	28
3.5	Permission to conduct research.....	29
3.6	Inclusion and exclusion criteria	29
3.7	Sampling process	29
3.8	Participant recruitment.....	30
3.9	Sample size.....	30
3.10	Measurement tools	30
3.11	Data collection process	32
3.12	Data analysis.....	33
3.13	Ethical considerations.....	33

3.14 Summary	34
CHAPTER 4: RESULTS	36
4.1 Introduction	36
4.2 Participation rate	36
4.3 The research instrument.....	36
4.4 Reliability Statistics	37
4.5 Sections A and B - Biographical data and other general details	38
4.6 Section C - Rugby experience.....	39
4.7 Section D - Injury and concussion history.....	40
4.7.1 Injury history	40
4.7.2 Concussion experience.....	42
4.8 Section E - Health, lifestyle and well-being.....	45
4.8.1 Health status	45
4.8.2 Smoking status.....	46
4.8.3 Psychological well-being.....	47
4.9 Section F - Alcohol Use Disorders Identification Test (AUDIT).....	48
4.10 Section G – CNS Vital Signs Test.....	50
4.11 Regression analysis of the General Health Rugby Questionnaire.....	52
4.11.1 Multiple linear regression of the General Health Rugby Questionnaire .	55
4.11.2 Logistic regression relating to the respondents sustaining a concussion and the number of injuries the respondents have experienced	56
4.12 Univariate analysis of variance.....	57
4.13 Summary	58
CHAPTER 5: DISCUSSION	59
5.1 Introduction	59
5.2 Cognitive function	59
5.2.1 Rugby playing experience / Age and cognitive function	59

5.2.2	Concussion history and cognitive function	62
5.2.3	Rugby playing position / Body weight and cognitive function	65
5.3	Concussion history	66
5.3.1	Rugby playing experience / Age and concussion history	66
5.3.2	Rugby playing position / Body weight and concussion history	67
5.3.3	Other injury history and concussion history	68
5.4	Summary	69
CHAPTER 6: CONCLUSION, LIMITATIONS AND RECOMMENDATIONS		71
6.1	Introduction	71
6.2	Key findings.....	71
6.3	Strengths of the study	72
6.4	Limitations	72
6.5	Recommendations	73
References		75
Appendixes		85

List of Figures

Figure 2.1: The primary and secondary phases of injury leading to cognitive dysfunction following TBI.....	10
Figure 4.1: Injury type history (n = 70).....	41
Figure 4.2: Injury experience (n = 70).....	42
Figure 4.3: Frequency of concussions sustained (n = 70)	43
Figure 4.4: Medical conditions (n = 70)	45
Figure 4.5: Smoking status (n = 70)	47
Figure 4.6: Frequency of alcohol consumption (n = 70)	49
Figure 4.7: Volume of alcohol consumption (n = 70)	50
Figure 4.8: Matrix scatter plot graph reflecting the numerical variables therein (n = 70)	53
Figure 4.9: Scatter plot graph reflecting the relationship between body weight and the number of concussions sustained by the respondents (n = 70)	54

List of Tables

Table 4.1: Cronbach's alpha score (n = 70)	37
Table 4.2: Biographical characteristics (n = 70)	38
Table 4.3: Rugby experience (n = 70)	39
Table 4.4: Concussion experience (n = 70)	44
Table 4.5: Rate of substance usage (n = 70)	46
Table 4.6: Psychological well-being (n = 70).....	47
Table 4.7: Domain scoring pattern.....	51
Table 4.8: Neurocognitive functioning domain standard scores (n = 70)	51
Table 4.9: Regression analysis of between-subject effects with the NCI score as the dependent variable (n = 70)	52
Table 4.10: Regression analysis of between-subject effects with the number of concussions sustained by the respondents as the dependent variable (n = 70) .	54
Table 4.11: NCI regression model coefficients (n = 70).....	55
Table 4.12: Logistic regression of whether the respondents have sustained a concussion whilst playing/practising rugby and the number of injuries they have sustained (n = 70)	56
Table 4.13: Univariate analysis of between-subject effects relating to the number of concussions the respondents have sustained with their neurocognitive domain scores (n = 70)	57

List of Appendices

Appendix A: Letter of Information (research participant)	85
Appendix B: Recruitment flyer	88
Appendix C: General Health Rugby Questionnaire	89
Appendix D: CNS Vital Signs Brief Interpretation Guide	103
Appendix E: Respondents Letter of Consent	118
Appendix F: IREC Approval Letter.....	121
Appendix G: IREC Recertification approval letter	122
Appendix H: Gatekeeper's permission letter	123
Appendix I: Coach/manager Permission Letter	124
Appendix J: Email from KZNRU Club Administrator permission to conduct research at clubs	125
Appendix K: Editing Certificate	126

Definitions

Chronic traumatic encephalopathy (CTE): Chronic traumatic encephalopathy is a progressive tauopathy that occurs as a consequence of repetitive mild traumatic brain injury (McKee *et al.* 2013: 43).

CNS Vital Signs (CNSVS): The CNSVS test battery is a brief computerised neurocognitive clinical evaluation that was developed as a routine clinical screening instrument (Boyd 2015).

Cognition: Cognition is responsible for processing explicit information including thinking, memory, perception, motivation, skilled movements and language (Trivedi 2006: 10).

Concussion: Concussion is a subset of mild traumatic brain injury (mTBI), and is a term defined as a “traumatically induced transient disturbance of brain function that involves a complex pathophysiological process” (Harmon *et al.* 2019: 213).

Mild traumatic brain injury (mTBI): A patient with mild traumatic brain injury is a person who has had a traumatically induced physiological disruption of brain function (Kay *et al.* 1993: 86).

Neurocognitive index (NCI): A measure of an average score derived from the five domain scores (Composite Memory, Psychomotor Speed, Reaction Time, Complex Attention, and Cognitive Flexibility) which represents a form of a global score of neurocognition, or a general assessment of the overall neurocognitive status of a patient (Boyd 2015).

Neurocognitive testing: Neurocognitive testing is a way to measure brain function non-invasively (BrainCheck 2020).

Rugby: Rugby is a high-intensity collision team sport that is played with an oval ball that may be kicked, carried, and passed from hand to hand. *The two teams try to score points by carrying an oval ball across a particular line or kicking it between the two posts and over the crossbar of the opponents' goal* (Cambridge Advanced Learner's Dictionary & Thesaurus 2020).

Abbreviations

The following abbreviations appear in this study:

CNSVS	CNS Vital Signs
ImPACT	Immediate post-concussion assessment and cognitive testing
NP	Neuropsychological
mTBI	Mild traumatic brain injury
NCI	Neurocognitive index
CTE	Chronic traumatic encephalopathy
CISG	Consensus in sport group
KZN	KwaZulu-Natal
SD	Standard deviation
n	Frequency
Kg's	Kilograms
cm	Centimetre
BMI	Body mass index
SRC	Sports related concussion
U.S.	United States
VIF	Variance inflation factor

CHAPTER 1: INTRODUCTION

1.1 Background

Rugby is a high-intensity collision team sport that is played with an oval ball that may be kicked, carried, and passed from hand to hand. As stated by the Cambridge Advanced Learner's Dictionary & Thesaurus (2020), rugby consists of “the two teams trying to score points by carrying an oval ball across a particular line or kicking it between the two posts and over the crossbar of the opponents' goal”. The game of rugby includes powerful tackling of the ball carrier by the tackler/s, and aiming to halt forward momentum is an essential part of the game (Patricios and Kemp 2013: 77). In a professional match approximately 450 tackles/contact events can be seen, of which approximately 200 are tackles (Cross *et al.* 2019: 1). Rugby players have a higher-than average risk of injury compared with participants of other popular team sports (Williams *et al.* 2013: 6). Unintended head-to-head collisions as well as head impact with the ground is responsible for a large proportion of concussions seen in rugby (Patricios and Kemp 2013: 76-79).

According to the 2019 American Medical Society for Sports Medicine (AMSSM) position statement on concussion in sport, sports-related concussion (SRC) is a common injury in recreational and organised sport (Harmon *et al.* 2019: 213). Concussion is a term defined as representing the immediate and transient symptoms of traumatic brain injury induced by biomechanical forces (McCrory *et al.* 2018: 840). A concussion can result in symptoms such as headaches, “feeling like in a fog” and loss of consciousness. That are not necessarily related to a pathology but are due to mechanical injury to the brain (McCrory *et al.* 2013: 297). The topic of concussion is covered extensively in the media due to the potentially dangerous long-term side-effects, such as neurological deficits and chronic traumatic encephalopathy (Viljoen, Phys and Schoeman 2017: 1). Currently, research in New Zealand has reported small to moderate cognitive deficits in previous elite and community level rugby players (Hume *et al.* 2017: 1218-1219).

Additionally, other studies have also confirmed cognitive vulnerability amongst rugby players compared to athlete's participating in non-contact sports, with the most frequently impaired cognitive function being processing speed (Zoccola *et al.* 2020: 129). Therefore, it is valuable to know the impact that traumatic brain injury has on rugby players to protect the players and their welfare (Walker and Tesco 2013: 1).

There are many aspects and risk factors that make playing rugby in South Africa different, compared to countries such as New Zealand, Australia and England. Firstly, South Africa remains a dual economy with one of the highest inequality rates in the world and therefore finances and sponsors for first division rugby teams are minimal (World Bank Group 2020). This inequality could result in infrequent access to high quality management (sports doctors, medics, physiotherapists and chiropractors) in less-privileged rugby players. This unjust management of players could result in long term complications with the health of less-privileged rugby players.

1.2 Aim of the study

The aim of this research study was to determine cognitive function among first division Kwazulu-Natal rugby players, and to assess whether years of exposure to the sport and/or concussion history has an association with cognitive function.

1.3 Objectives of the study

The study's objectives were:

- To measure the cognitive function in first division KwaZulu-Natal rugby players;
- To establish the association, if any, between the duration of exposure to rugby and cognitive function;
- To demonstrate the association, if any, between concussion history (one or more concussions) and cognitive function.

1.4 Rationale for the study

Cognition is responsible for processing explicit information including: memory, skilled movements, language, perception and motivation, (Trivedi 2006: 10-20). A recent study by Zoccola *et al.* (2020) investigated whether multiple concussive events sustained during long-term rugby participation can cause persistent neurocognitive effects. This study was performed on a group of community level rugby players in South Africa. Zoccola *et al.* (2020) reported similar findings to those of Hume *et al.* (2017) (mentioned above in Section 1.1) which revealed poorer performance within the processing speed modality for the rugby group. It is therefore imperative to explore what the impact of playing contact rugby has on a players cognitive functioning over time, and to investigate whether persistent cognitive effects caused by multiple sports related concussive events do occur amongst rugby players, so that players can be informed and protected during their years of participating in rugby (Walker and Tesco 2013: 1). This information will assist medical professionals, organisers, managers and coaches to better understand the effect rugby has on players and in so doing be appropriately prepared to implement injury/concussion prevention strategies, and develop monitoring systems to prevent severe traumatic brain injuries and second-impact syndrome to perhaps regulate/guide the extent of participation. This could lead to safer training and successful management of rugby players.

It is therefore vital to explore what the impact of playing contact rugby has on players cognitive functioning, so that players can be informed and mechanisms for protection of the players can be implemented during their years of participating in rugby (Walker and Tesco 2013: 1).

1.5 Outline of the dissertation

Chapter 1: Introduction and background to the study. This chapter provides brief information on the sport of rugby, cognitive functioning and concussion and justifies the need for the study. This provides an orientation to the study and presents the aim and objectives.

Chapter 2: In-depth review of the available literature regarding the topic. This chapter comprises the literature on how exposure to rugby and concussions has an effect on the players cognitive functioning.

Chapter 3: This chapter explains the procedure and study design of the research study, the methods that were implemented as well as the research tools that were used to gather the relevant data for this study.

Chapter 4: Includes the study's results which are demonstrated by means of figures and tables.

Chapter 5: In-depth discussion of the results in relation to documented literature. The implications of our findings are highlighted.

Chapter 6: Summary and conclusion of the study. The chapter also identifies the strengths and limitations of the research study and provides recommendations for future studies.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter reviews the current literature available and contains the following: an over-view of the sport of rugby, common injuries associated with rugby, cognitive functioning and its association with exposure to rugby and a history of concussion. This chapter details the risk factors for SRC and serves to provide the reader with information on the long-term sequelae of SRC and premature return to play. Additionally, this chapter elaborates on the importance of management and prevention of concussion.

2.2 Rugby

Rugby is a strenuous team sport that delivers a significant variety of physical, mental and social benefits (Griffin *et al.* 2021). Rugby falls under the rubric of a 'collision' or field contact sport where players are vulnerable to sustaining mild traumatic brain injury (MTBI), frequently referred to as concussion (Shuttleworth-Edwards and Radloff 2008: 511). A rugby game is played over 80 minutes with two 40 minute halves and involves frequent tackles and collisions (Hind *et al.* 2020: 253). The sport of rugby is one of the most popular team sports with 8.5 million rugby players worldwide and 467,856 rugby players in South Africa (World Rugby 2016). Rugby consists of two variations, rugby union and rugby league. Rugby league is played with 13 players in two different teams, while rugby union is played with two teams of 15 players. The main goal of both variants of the game is for players to get the rugby ball onto their opponents side of the field by carrying, passing and kicking the ball and to then score a try by grounding the ball behind the tryline (Yeomans *et al.* 2018: 838). The contest for possession is vital and is most clearly seen with the frequent contact events that characterise this unique game. Tackling or attempting to tackle an opponent above the line of the shoulders is not permitted under current laws of the game (Law 9) (World Rugby 2020). However, there are still many illegal tackles being performed that are not sanctioned appropriately, therefore it is critical to enhance injury prevention efforts

which can be enforced by the means of the referees consistently implementing all rugby laws during match play (Brown *et al.* 2018: 631). Unintended head-to-head collisions occur, as well as head impacts with the ground, which is responsible for a large proportion of concussions seen in rugby (Patricios and Kemp 2014: 77). Rugby union has been known to have one of the highest rates of concussion of all full-contact sports (Gardner *et al.* 2014: 1718). This review's main focus is rugby union (hereafter 'rugby') due to the two variants consisting of different laws, as well as the differing nature of the contact events that occur in both variants. Rugby has gained international popularity, becoming the third most popular team sport in the world and is played in more than a hundred countries (Brown, Guthrie, and Growden 2011: 4). Currently, there are more than 8.5 million active rugby players across 121 countries (Hind *et al.* 2020: 2). Rugby players these days are much heavier, faster and involved in substantially more contact events per match than their predecessors. This is reflected in an increase in concussions; Murray, Murray and Robson (2015: 75) claimed that concussion is the third most common match injury in amateur and professional rugby, while Tucker *et al.* (2017) stated that concussion is now the most common match injury in the professional game of rugby, accounting for 25% of all rugby match injuries. After soccer, rugby is the most popular sport in South Africa with a following of 10 million in a population of close to 50 million people. Rugby players in South Africa have typically played the sport since their early primary school years (approximately the age of 10 years), consequently by the end of their high school stage (approximately the age of 18) they will have been playing rugby in every winter season for roughly eight to ten years (Shuttleworth-Edwards and Radloff 2008: 513). There are three levels of activity in South African rugby: amateur (played by community level first, second and third divisions), semi-professional (played by the non-professional premium teams) and professional (played by the provincial and national teams) (SA Rugby 2020).

2.3 Common injuries associated with rugby

The fast-paced and full-contact nature of rugby appears to have a higher risk of sustaining injuries than in many other sports but comparable with other contact sports (Brooks *et al.* 2005a: 757). In a professional rugby match the tackle is the

most injurious incident, with high speeds and high tackle height increasing the risk of injury within the tackle (Cross *et al.* 2019: 1). A recent review conducted by Kaux *et al.* (2015: 22) stated that in professional players the head (including concussions) is the most often affected part of the body (25%), thereafter the knee is the second most affected part of the body (14%-20%). Due to the higher frequency of being involved in the scrums and the higher exposure to contact activities, such as tackles, rucks and mauls, the incidences of neck and spinal injuries were significantly higher for forwards than for backs (Kaux *et al.* (2015: 22). It has been demonstrated that forwards are at a greater risk of injury than backs because forwards have to absorb and transmit greater forces when subjected to scrummaging. Rugby positions such as the hooker and fly-half, are reported to have the highest injury rate while positions such as the right lock and open-side flanker, suffer from the most severe injuries. According to Brooks *et al.* (2005), the playing positions that were at the greatest risk for injury are hookers and outside centres.

Brooks *et al.* (2005: 758) found that amongst English professional rugby union players the lower limb was the most common injury location and that the main diagnostic groups were joint/ligament injuries and muscle/tendon injuries. Thigh haematomas were the most common injury and the second most common injury was hamstring injuries. Due to backline players having to perform greater acceleration, deceleration and highspeed running demands, the hamstring injury incidence was higher for backline players than forwards. Anterior cruciate ligament (ACL), medial collateral ligament (MCL) and knee meniscal/articular cartilage injuries were particularly severe for both forwards and backs (Brooks *et al.* 2005: 762). Additionally, the highest total days of absenteeism was due to knee injuries for forwards and backs. According to Brooks *et al.* (2005: 762) SRC is a complex injury to diagnose and they are under reported regularly. However, concussion was still the third most common injury reported in Brooks *et al.* (2005) study.

In a study conducted by Hind *et al.* (2020) it was found that in community level rugby, injury incidence was reported at 47 injuries per 1000 player match-hours, and in elite level rugby, the injury incidence was 81 injuries per 1000 player match-hours. The study investigated retired United Kingdom (UK) rugby players which

included both rugby variants (rugby union and rugby league) and reported on the players frequency of total injuries, their collective injury load levels as well as their long-term effects, and compared these results to retired non-contact sport athletes. The authors found that over 50% of the players from both rugby variants had sustained a minimum of one: SRC, rib bruising/fracture, hand/wrist/arm fracture, back injury and a hamstring or calf strain/tear whilst playing rugby (Hind *et al.* 2020: 5). When investigating the injury incidence, the average number of injuries per player was higher for the elite level rugby players than the community level rugby players, and more than five times larger than the non-contact sports group (Hind *et al.* 2020: 4). One of the noteworthy findings of this study was that a SRC was the most regularly reported injury in both the elite (81%) and community level rugby codes (76%) (Hind *et al.* 2020: 5). Additionally, a SRC was the injury with the greatest cumulative load, therefore signifying one of the higher rate's of reoccurrence (Hind *et al.* 2020: 5). Overall, concussive injuries have been reported to be responsible for almost 25% of all reported time-loss match injuries during a professional season of rugby (Cross *et al.* 2019: 1). This high frequency of concussion occurrence makes the primary prevention of SRC a key priority.

2.4 Concussion

2.4.1 Definition

According to the AMSSM position statement, concussion is a subset of mild traumatic brain injury which is defined as a “traumatically induced transient disturbance of brain function that involves a complex pathophysiological process” (Harmon *et al.* 2019: 213). The key problem is that, until now, concussion has not always been taken seriously enough by players, coaches and medical staff (Murray, Murray and Robson 2015: 75). Concussion typically results in a rapid onset of short-lived neurological impairments (Singla *et al.* 2019: 310-318). It presents clinically with cognitive (particularly in memory, learning, attention and other higher-order executive functions), physical and behavioural signs and symptoms (Walker and Tesco 2013: 1). The diagnosis of SRC is complex as non-specific symptoms of concussion can also be due to other aetiologies, these symptoms include headaches, neck pain, fatigue, changes in mood, a feeling of ‘foggy’ and dizziness as well as visual changes (Harmon *et al.* 2019: 213).

According to Murray, Murray and Robson (2015), the sports that are linked to an increased risk of concussion include those involving collisions or contact. Rugby, American football, boxing and soccer, as well as high-velocity sports, such as cycling, snow skiing, and equestrian sports are sports where the athletes are more vulnerable to sustaining a SRC (Murray, Murray and Robson 2015: 75).

According to Singla *et al.* (2019), chronic traumatic encephalopathy is a chronic brain injury which is the result of repeated unrecovered concussions. CTE is associated with athletes that experience progressive neurological deterioration following repetitive brain trauma (Gardner, Shores and Batchelor 2010: 174-175). Originally described due to the sport of boxing in 1928 and termed dementia pugilistica, the term CTE was devised to define this neuropathological entity and to encompass those who developed it as a result of playing contact sports. Initial clinical manifestations of CTE affect attention, concentration, episodic memory and behaviour including amplified levels of anger, irritability and apathy. In severe cases, the chronic stages of CTE are characterised by movement and speech conditions (Magioncalda *et al.* 2016). A recent review by McKee *et al.* (2009) suggested that athletes that are actively participating in contact sports are not immune to the disease, and it was reported that 33.3% of the athletes were symptomatic when retiring from the sport they participated in. This suggests that the initial stages of the neurodegenerative process that are associated with CTE may become evident earlier than initially suspected (Gardner, Shores and Batchelor 2010: 174-175).

2.4.2 Anatomy and pathophysiology

For those engaged in contact sports such as rugby, mild TBIs (traumatic brain injury) in the form of a concussion, without or with loss of consciousness is a substantial risk (Walker and Tesco 2013: 1). Concussion pathophysiology is complex and not completely understood but the AMSSM position statement on concussion characterised it as “force delivered to the brain causing disruptive stretching of neuronal cell membranes and axons resulting in a complex cascade of ionic, metabolic and pathophysiological events” (Harmon *et al.* 2019: 214). Advanced neuroimaging techniques have currently been used in studies and have demonstrated the association between SRC and the variations in the athlete’s

structure and functioning of their brain, which are associated with the deficits that are noticeable in cognitive testing during the acute phase post-TBI (McCrory *et al.* 2018: 841).

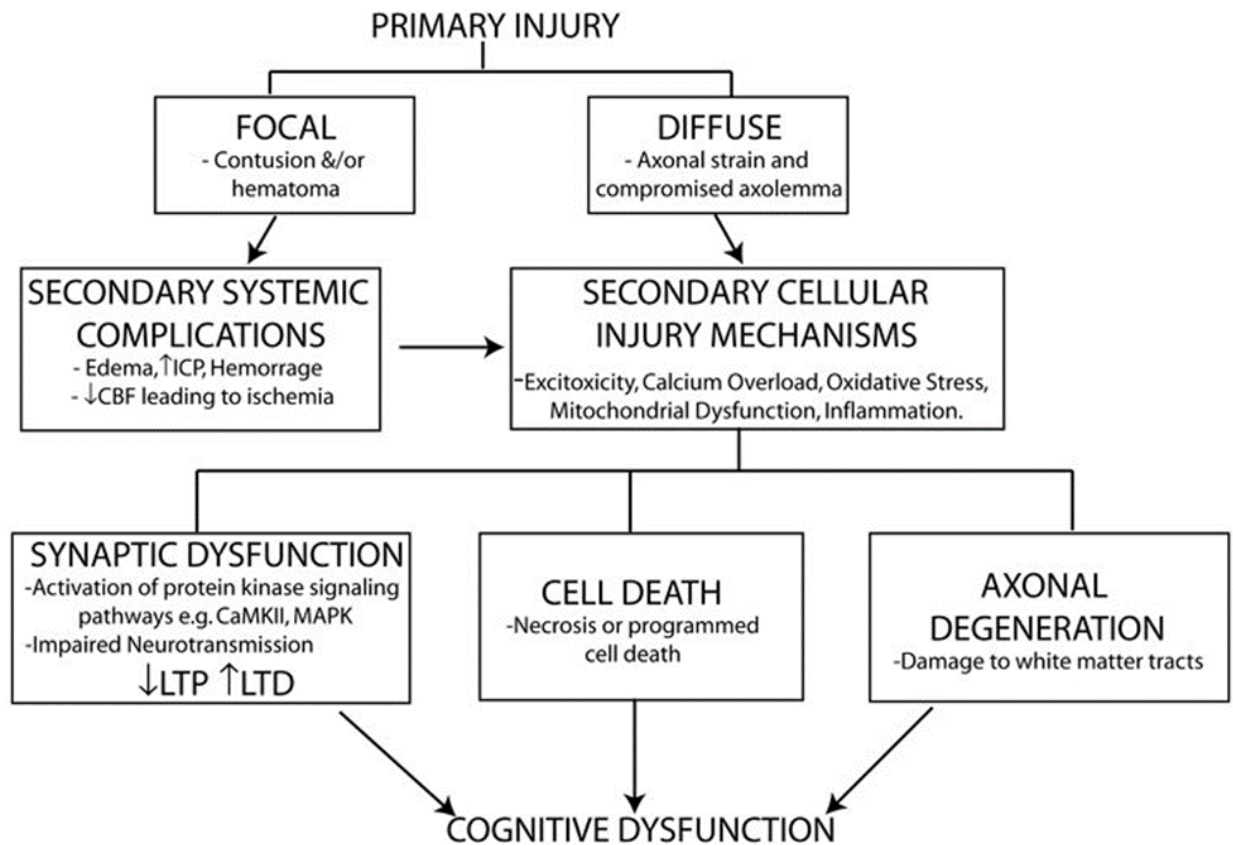


Figure 2.1: The primary and secondary phases of injury leading to cognitive dysfunction following TBI

Source: Walker and Tesco (2013: 3).

As illustrated in Figure 2.1, TBI can be classified as focal/subdural haemorrhage. A focal TBI occurs when a direct physical impact to the brain causes a contusion or subdural haemorrhage to develop. A TBI can also be diffuse, where rapid acceleration/deceleration forces cause diffuse axonal injury (Walker and Tesco 2013: 2). The pathophysiology of TBI observed in humans is predisposed by multiple limitations, which are associated with the primary injury together with the specific brain regions affected and the type and severity of the brain trauma (Walker and Tesco 2013: 2). Cognitive deficits post-TBI can be the cause of brain trauma to specific brain regions which includes the medial temporal regions, dorsolateral prefrontal cortex as well as the sub-cortical white matter tracts (McAllister 2011: 289). The hippocampus is the brain region which plays an important role in declarative memory formation, and can reveal wasting via MRI in

a substantial amount of TBI patients who sustain moderate to severe TBI's (Walker and Tesco 2013: 1).

According to Walker and Tesco (2013: 2-3), the extent of neurocognitive dysfunction experienced after sustaining a TBI is determined by the degree of damage to the brain from both the primary and secondary injuries. It appears that direct physical impact to the brain from the primary injury (as a result of rapid angular acceleration/deceleration) causes direct mechanical damage to the vasculature, strains axons, neuronal and glial cells. The primary injury force gives rise to either a focal or diffuse injury. This focal/diffuse injury initiates a vicious cycle of secondary injury effects that include both systemic complications and cellular injury mechanisms, which arise over the development of hours to several weeks following the primary injury (Walker and Tesco 2013: 2-3). Systemic impairments include oedema, enlarged intracranial pressure (ICP) and haemorrhage, all of which contribute to reduced cerebral blood flow (CBF) and impaired metabolism resulting in ischaemia. The ischaemia induced by these systemic impairments contributes to the initiation of biochemical and cellular cascades leading to changes in the patient's intracellular ion concentrations, release of neurotransmitters, and mitochondrial dysfunction. In the subacute and chronic stages of concussion, axonal degeneration, impaired synaptic plasticity and inflammatory cell activation may occur which contributes to the cognitive dysfunction observed following a TBI. This then leads to the production of reactive oxygen species, and increased utilisation of glucose to restore sodium and potassium balance (Harmon *et al.* 2019: 214). According to Walker and Tesco (2013) decreased cognitive functioning is caused by the contribution of neurological inflammatory cell activity, which results in neuronal cell loss by means of necrosis and programmed cell death. The degree of cell death and axonal injury are greatly associated with the patients neurological outcome following brain injury. TBI induces weakening of neurotransmitter systems such as cholinergic and catecholamine, which play vital roles in cognition (Walker and Tesco 2013: 2-3).

2.4.3 Side-line evaluation and diagnosis

According to the latest Concussion in Sport Group (CISG) consensus statement SRC is considered to be one of the most complex injuries in sport to diagnose and manage (McCrory *et al.* 2018: 839). The diagnosis of SRC is complicated by a lack of validated, objective diagnostic tests, a reliance on self-reported symptoms, and confounding symptoms caused by other common conditions (Harmon *et al.* 2019: 214). In addition, the challenging aspect to recognising and evaluating SRC in an athlete is that it often involves a rapid assessment mid game with heavy time constraints, and is further impacted with the athlete excited and eager to carry on playing the game (McCrory *et al.* 2018: 840). Symptoms are the most sensitive indicator of SRC but the reliability of athlete-reported symptoms depends on accurate reporting, which may be affected by a lack of recognition of the signs and symptoms of concussion or conscious false reporting to avoid loss of playing time. Additionally, symptoms may not occur immediately after sustaining a concussion and often become obvious at a later stage, reiterating the complexity of SRC (Harmon *et al.* 2019: 214). In all suspected cases of concussion, the player should be removed from the game and assessed by a physician or licensed healthcare professional. The AMSSM consensus statement on concussion states the following reasons for immediate removal and prompt evaluation: loss of consciousness (LOC), impact seizure, tonic posturing, gross motor instability, confusion or amnesia (Harmon *et al.* 2019: 214). The side-line evaluation is based on recognising the injury, assessing the athletes' signs and symptoms, as well as their cognition (McCrory *et al.* 2018: 840). According to McCrory *et al.* (2018) the following clinical domains are used to make a diagnosis of an acute SRC.

- a) Somatic, cognitive and emotional symptoms (e.g., headache, "fogginess", anxiety)
- b) Physical signs (e.g., unconsciousness)
- c) Balance impairment (e.g., gait unsteadiness)
- d) Behavioural changes (e.g., irritability)
- e) Cognitive impairment (e.g., loss of memory)
- f) Sleep/wake disturbance (e.g., drowsiness)

The AMSSM position statement states that history, balance testing and cognitive function is required to be assessed, whereas the CISG consensus statement

suggests that testing of cognitive function is of most importance (McCrory *et al.* 2018: 841). The Sport Concussion Assessment Tool 5th edition (SCAT5) is the evaluation tool recommended by the CISG for the assessment of a suspected SRC (Harmon *et al.* 2019: 216). The SCAT5 evaluation covers a cognitive assessment (e.g., “What day is it today?” and “Say the months of the year in reverse-order?”), a neurological examination, balance testing as well as a basic symptom checklist (Brown *et al.* 2016: 7). Typical orientation questions such as time and place questions are unreliable in the sporting environment when compared with a memory assessment. Abbreviated testing paradigms are used for speedy field-side SRC screening and are not designed to substitute comprehensive neurological assessments. After sustaining a concussion which was caused by a significant head impact or if players manifest clear signs of a concussion (e.g., loss of consciousness, tonic posturing, balance disturbance) they should immediately be removed from participation in any physical activity. A healthcare practitioner should then proceed to perform field-side screening on the athlete, using a suitable concussion assessment tool such as the SCAT5 (McCrory *et al.* 2018: 840). Players should then progress to a detailed diagnostic assessment, which the medical practitioner should perform in an environment that is free of distractions such as a change room or first aid room (McCrory *et al.* 2018:839). At present, the SCAT5 represents the most trustworthy and rigorous screening instrument available for side-line assessment. The practicality of the SCAT5 appears to decrease 3 to 5 days after injury, therefore the SCAT5 is only beneficial and its use should be limited to directly after the injury to help differentiate between concussed from non-concussed athletes (McCrory *et al.* 2018: 840).

2.5 Risk factors for sport related concussion

Risk factors in sport are any factors that may increase the possibility of injury (Meeuwisse 1991). The risk factors that play a role in sport can be divided into two groups, namely, extrinsic and intrinsic risk factors (Massey 2015). Intrinsic risk factors include history of a previous concussion and mechanism of injury (Massey 2015). The extrinsic risk factors outline the following match versus practice,

playing position, and protective equipment (Sinclair *et al.* 2014: 31-36; Murphy, Connolly and Beynon 2003: 15).

2.5.1 History of SRC

According to a systematic review conducted by Abrahams *et al.* (2013), 10 of the 13 studies that were examined reported that athletes with a history of previous concussion were at an increased risk of concussion. Regarding junior ice hockey players, four studies reported that the players who have sustained a previous concussion also had an increased risk of sustaining future concussions. Similarly, a larger risk was also observed in rugby players who have sustained one or more than two concussions. Three studies investigating the risk of previous concussions in American football and soccer players observed a 2-fold to 11-fold increased risk of sustaining a concussion. A unit of athletes participating in various sports with at least one previous concussion were 3 times greater at risk of sustaining a SRC compared with those who reported zero concussion's (Abrahams *et al.* 2013: 3). According to McCrory *et al.* (2018: 843), a risk factor for experiencing a SRC is having sustained a concussion in the past, and having sustained multiple SRC's in the past is linked with experiencing more cognitive and physical symptoms prior to participation in a sport. Some studies claim that participants who have sustained three or more concussions have an increased risk for sustaining future concussions, and are more likely to have a prolonged recovery period from their next concussion (Gardner, Shores and Batchelor 2010: 178). In addition, Cross *et al.* (2016: 4) reported a direct link between concussion and injury and elaborated that players were 60% more likely to suffer with a subsequent injury after being diagnosed with a concussion, compared to athletes that have not sustained a concussion before. Furthermore, evidence is accumulating that supports the concept that multiple concussions (three or more concussions) may also be linked with a detrimental effect in patients' neuropsychological performance (Gardner *et al.* 2010: 175). Concussion history as a significant risk factor has been supported by multiple Level 1 and Level 2 studies (Brett *et al.* 2018: 989).

2.5.2 Mechanism of injury

In rugby, tackling is the most common mechanism of injury (Quarrie and Hopkins 2008: 1706). Cross *et al.* (2019: 3) investigated the association between tackle characteristics and clinically diagnosed concussion, and established that 70% of tackle associated concussions were sustained by the tackler and only 30% by the ball carrier. According to Cross *et al.* (2019), the following four tackle characteristics had the greatest likelihood for impacting the risk of concussion within a tackle: the accelerating player, tackler speed, head contact type and tackle type. Concussion risk increased significantly if the tackler accelerated into the tackle or moved at a fast speed rather than at a slow speed. The speed that the tackler was running and the accelerating ball carrier had the greatest influence on whether the tackle caused a concussion. Head contact with the opposing player's head, ground and knee had substantially a greater risk of concussion compared to the trunk, which was the most common location. Furthermore, a high tackle resulted in a player being 36.5 times more likely to sustain an SRC, in comparison to being tackled by means of a passive shoulder tackle. All illegal tackle types were associated with the highest risks of concussion (Cross *et al.* 2019: 2-3). In most studies which report on SRC mechanisms of injury, an accidental or intentional collision with another player is frequently the key mechanism of SRC (Abrahams *et al.* 2013: 4-5).

2.5.3 Match play versus practice

Literature shows that there is a greater risk for concussion amongst athletes in match play than in practice. According to Murphy, Connolly and Beynnon (2003) athletes may be more susceptible to risk taking behaviour in matches as well as being more aggressive while playing matches than during practices, thus increasing the risk for injuries such as concussion to occur during matches. According Abrahams *et al.* (2013: 4) research study, all 29 studies indicated that there was a higher risk of concussion in matches compared with practices. The increased risk of high-impact collisions that occur during match play, in comparison to rugby practices, is the key motive for the amplified risk of concussion. Thus, game play was allocated a high level of certainty to cause an increase in the risk of sustaining a concussion (Abrahams *et al.* 2013: 4).

2.5.4 Playing position

Playing position is often investigated as a risk factor for sustaining a concussion, specifically in sports such as rugby, ice hockey and American football. According to Abrahams *et al.* (2013) who reported on six studies, which two were high-quality level I studies, there is no significant effect of the different rugby positions on concussion. Both rugby studies (rugby union and rugby league) reported no negative effect of rugby playing position on concussion risk. Due to varying findings among reviewed studies, the certainty that playing position is a risk factor for concussion is low (Abrahams *et al.* 2013: 5).

2.5.5 Protective equipment

According to Harmon *et al.* (2019) differing evidence concerning mouthguards and concussion reduction exists (Harmon *et al.* 2019: 222). Abrahams *et al.* (2013: 6) investigated the capability of protective gear to decrease the risk of concussion in 13 studies. Six studies explored the effect of mouth guards and 5 on padded headgear to assist with reducing the risk of concussion. The effect of mouth guards on concussion risk is not clear, however it has been shown that mouth guards do have a protective effect against orofacial injuries. Unexpectedly, a tendency for an increased concussion risk was revealed in American football players wearing protective equipment such as mouth guards. A probable explanation may be due to athletes taking greater risks since protective equipment encourages a surge in dangerous behaviour that contradicts the effect of protective equipment (Harmon *et al.* 2019: 222). In 5 of the 6 studies that Abraham *et al.* (2013) reported on, it was found that the use of mouth guards had no significant effect on concussion risk. According to the American position statement on concussion in sport, mouthguards should not be used primarily to prevent SRC but rather be used to prevent dental trauma (Harmon *et al.* 2019: 222). Additionally, a study conducted by McCrory *et al.* (2018: 845) presented mixed evidence for the concept of mouthguard usage assisting with SRC, but a non-significant trend was suggested by meta-analysis towards the protective effect in collision sports

Headgear has played a significant role to help decrease the risk of abrasions and lacerations, help prevent trauma to the skull as well as help prevent intracranial bleeding. However, the protective effects of headgear against SRC are less obvious and needs to be ascertained (Harmon *et al.* 2019: 222). Two of the five studies investigated by Abrahams *et al.* (2013) reported that headgear had no significant effect on the risk of concussion in rugby. On the contrary, in a large level 2 prospective cohort study of adult amateur rugby players, it was revealed that the practice of wearing padded headgear was found to help decrease the athlete's risk of sustaining a concussion. Additionally, it was reported in a level 1 study that comprised of 81 SRC, padded headgear was revealed to remarkably lessen the risk of concussion in professional rugby teams. Therefore, in summary protective equipment such as mouth guards and headgear may play an important role in decreasing SRC risk but the overall effect of protective equipment is inconclusive (Abrahams *et al.* 2013: 6).

2.6 Short-term risks of continued exposure after concussion or premature return to play

A sports related concussion may not be an obvious injury to sporting participants, coaches and those watching on the side-line, but if a concussed player continues to participate in their dedicated sport or they return to sport before recovering fully, the player becomes at risk for sustaining further concussions which may be accompanied with more severe and prolonged symptoms (Brown *et al.* 2016: 7). According to the *American position statement on concussion in sport*, if a player continues to play their sport directly after sustaining a concussion it increases their risk of prolonged recovery time, severe symptom burden and worsening of the injury to the brain (Harmon *et al.* 2019: 221). A temporary window of brain vulnerability that furthers the extent of injury exists during the recovery period, therefore it is imperative that players be immediately removed from the field of play after experiencing a concussion. Cognitive and physical rest for a certain period of time is essential until the athlete becomes asymptomatic (Murray, Murray and Robson 2015: 76).

There has been research that has established that players who return to sport after sustaining a concussion and have followed standard return to sport protocols,

have been reported to have an increased rate of sustaining musculoskeletal injuries (Harmon *et al.* 2019: 221). A research article by Rafferty *et al.* (2019: 1136) stated that injury risk was 38% greater following concussion than after a non-concussive injury. Injuries to the head and neck, upper limb, pelvic region and the lower limb were more likely following concussion than after a non-concussive injury, indicating that concussions have a negative impact on a player's wellbeing and suggesting that return to play protocols require intensive investigation to ensure that it is safe for a player to return to the game of rugby (Rafferty *et al.* 2019: 1136). Mismanagement within a rugby team, can lead to problems for players such as a syndrome commonly called, second impact syndrome or scientifically known as diffuse cerebral swelling (Murray, Murray and Robson 2015: 76). Some researchers have considered second impact syndrome to be a possible life-threatening complication, which is caused by reinjury during the initial postinjury concussion time period. It is both rare and controversial, and not completely understood and research on this topic seems to be limited (Harmon *et al.* 2019: 221).

2.7 Long-term risks after concussion

A scoping review by Griffin *et al.* (2019: 1) regarding the relationship between rugby union and health found that longer-term health outcomes of rugby include cognitive deficits post-retirement, decreased neuropsychological performance, and increased rates of osteoarthritis. According to Walker *et al.* (2013), significant long-term emotional and cognitive deficits have been the apparent effect of athletes suffering with mild and repetitive TBI's. These cognitive deficits classically occur in behaviour which includes learning, attention, higher order executive functions and commonly memory (Walker and Tesco 2013: 1). A study by Alexander *et al.* (2015) reported such deficits in rugby players, when investigating the neurocognitive test performance differences amongst young male rugby players and young non-contact sports participants over three years correlated with academic achievement over 6 years. Compared with controls, both rugby groups failed to increase their academic aggregates in their school leaving examinations thus demonstrating a measure of cognitive vulnerability in the rugby group.

Moderate to severe TBIs are recognised as causing long-term persistent neurocognitive deficits in sufferers, while mild TBIs are commonly linked with short-term neurocognitive dysfunctions that tend to conclude within a 90 day period. However, a subgroup of mild TBI patients have been recognised to develop a syndrome called, post-concussion syndrome (Walker and Tesco 2013: 1). Post-concussion syndrome or the preferred term, persistent post-concussive symptoms (PPCS) is defined as “symptoms that persist beyond the expected recovery time frame (>2 weeks in adults, >4 weeks in children)” (Harmon *et al.* 2019: 220). However, according to the AMSSM position statement, chronic symptoms do not automatically signify a continuing concussive injury to the brain. Therefore, history taking and baseline evaluation is encouraged in order to comprehend pre-existing or coexisting symptoms in the management of athletes who may suffer with persistent post-concussive symptoms (Harmon *et al.* 2019: 220).

Dementia pugilistica (DP) or commonly known as “punch drunk syndrome” is a phenomenon that is caused by repetitive head trauma and first labelled in 1928 due to the sport of boxing. DP is now recently referred to as a variant of CTE that can lead to cognitive decline in athletes (Walker and Tesco 2013: 6). According to Harmon *et al.* (2019: 222) CTE-associated symptoms may be associated with the following factors: “impact load and type, duration of career, underlying genetic factors, or other lifestyle behaviours including alcohol, drug and anabolic steroid use, general health and psychiatric disease”. Currently, the most extensively delineated risk factor for neurodegenerative disease is substantial exposure to repetitive head impacts/trauma as well as to sustaining multiple concussions. However, the degree of necessary exposure may be subjective to multiple factors as well as specific to the athlete (Harmon *et al.* 2019: 222).

Even though exercise is extremely beneficial to an individual’s wellbeing and lifestyle, in some circumstances the risk factors associated with the sport can offset the benefits of participating in the sport. Thus, it is vital for an athlete to make informed decisions regarding participation in their sport, and to also reflect on the long-term consequences of high-injury-rate sports on their overall health (Hind *et al.* 2020). However, more investigations are needed to help researchers

understand CTE and other neurological conditions that are the result of being exposed to contact sports and concussion. Furthermore, it is also important to better understand the degree to which these neurological conditions relate to concussions sustained in sports.

2.8 Management and prevention of sport related concussion

As stated by Murray, Murray and Robson (2015: 76), the main obstacles to effectively managing SRC include players underreporting TBI, under recognition by those observing, and mismanagement of recognised SRC. Only 50% of all concussions are estimated to be reported by athletes that participate in contact sport, for reasons such as players being unaware that they were concussed, not believing that a concussion is a serious enough injury to warrant reporting to medical staff or management, and distress of being left out of the team and not being allowed to play the game (Murray, Murray and Robson 2015: 76). Contrary to best practice, 58% of rugby players were not removed from the field after sustaining a concussion, which is a common occurrence in the game of rugby and is clearly unacceptable (Murray, Murray and Robson 2015: 76). The complicated concept of a concussion is that it is invisible, compared to other common and frequent time-loss rugby injuries, such as a meniscal tear, which are physically restrictive and prevents the rugby player participating further in the game (McCrory *et al.* 2018: 845). Therefore, convincing the “rugby culture” the importance of recognising a concussion can be challenging because of its imperceptibility and the perception that most athletes who sustain a concussion give the impression to recover without obvious consequences, due to the invincible nature of a SRC (Murray, Murray and Robson 2015: 76).

Even though it is near impossible to eradicate concussion from the sporting world, concussion-prevention strategies are able to help decrease the amount and severity of SRC (Brown *et al.* 2016: 7). Ultimately, prevention is the key and ultimately more effective in reducing the number of SRC sustained while playing sport, than treatment of concussion (Harmon *et al.* 2019: 222). According to the AMSSM position statement, the primary focus on prevention should be and currently is: “rule changes, enforcement of existing rules, technique changes, neck strengthening and equipment modifications” (Harmon *et al.* 2019: 222). Tackle

technique has been a main focus for concussion prevention since the majority of concussions occur in the tackle (Cross *et al.* 2019: 1). It is critical to help assist with reducing the cases of unreported concussions, those that are watching the game and especially on field medical staff, coaches and referees, take on some level of responsibility for recognizing suspected cases of SRC (Brown *et al.* 2016: 7). It is also of great importance for on field medical staff to discuss each player's SRC history. This history taking may help to identify the athletes who fall under a high-risk category and therefore assists the healthcare practitioner with an opportunity to inform the athlete about the significance and consequence of sustaining a concussive injury (McCrory *et al.* 2018: 844). Therefore, education and awareness on SRC is a critical topic that needs to be discussed for all those involved in rugby in order to ensure progress in this field (Brown *et al.* 2016: 7).

It is of the utmost importance to encourage concussion awareness within the rugby community, this includes web-based resources, educational videos and international outreach programmes. Additionally, ethical values such as fair play and respect should be encouraged in all sporting participation. Sporting committees, coaches, managers and parents play a vital part in guaranteeing that implementation of these ethical values is instilled in the players (McCrory *et al.* 2018: 845). Programmes like the BokSmart National Rugby Safety Programme in South Africa and other programmes like Activate in England, and Tackling Rugby and RugbySmart in New Zealand, have been created to help prevent and reduce injuries in rugby participation (Hind *et al.* 2020: 2). The aim of the BokSmart programme is to implement evidence-based exercise research and sports medicine to prevent injury and to enhance performance of rugby players at all levels in South Africa. The BokSmart programme has four main elements: BokSmart Rugby Safety Workshops, BokSmart Rugby Medic Programme, a freely accessible online educational resource www.boksmart.com, and a toll-free BokSmart SpineLine number. The elements of the programme demonstrate the practical application of an injury prevention and rugby safety programme using an evidence-based approach. The ultimate outcome of the programme is aimed at safer rugby and fewer catastrophic injuries (Viljoen and Patricios 2012: 692-693).

The CISG consensus statement uses an expert consensus-based approach that provides a logical flow of clinical concussion management including the CISG's 11 'R's of SRC management (McCrory *et al.* 2018:838). The 11 'R's are: "Recognise; Remove; Re-evaluate; Rest; Rehabilitation; Refer; Recover; Return to sport; Reconsider; Residual effects and sequelae, and Risk reduction" (McCrory *et al.* 2018: 839). Depending on the severity of injury, the CISG consensus guidelines recommend 24-48 hours of rest, which includes physical as well as cognitive rest (Harmon *et al.* 2019: 220). The reason for endorsing this symptom-limited rest is that it may help decrease distress during the athlete's recovery period by alleviating SRC symptoms, as well as assisting with the athlete's recovery by reducing brain energy demands (McCrory *et al.* 2018: 842). Emerging data suggests that concussion patients can be encouraged to include activities of daily living and aerobic exercise, such as walking, to help gradually increase their activity. These activities should be performed after a brief period of rest (24 to 48 hours) during the acute recovery phase, but without exacerbating their concussion related symptoms (Harmon *et al.* 2019: 220).

While managing concussion patients, it is vital that medical personnel be aware of the potential for conditions like CTE and other long term neurological problems. The potential for developing CTE must be a consideration as this condition appears to represent a distinct tauopathy with an unknown prevalence in athletic populations (McCrory *et al.* 2018: 844). Although considerable steps have been taken to improve management and educate all involved, a fundamental cultural change in the perception of this condition is needed (Murray, Murray and Robson 2015: 76). Finally, the consequence of repetitive concussive head impacts on the athlete's quality of life, specifically in the athlete's later years after retirement, may be of overwhelming concern. Therefore, additional high-quality level 1 research studies are required to improve the management of high-risk athletes, reduce concussion incidence, and prevent serious health complications in the future (Shuttleworth-Edwards and Radloff 2008: 319).

2.9 Cognitive functioning

2.9.1 Definition and background

Cognition is vitally important for everyday decision making and is responsible for processing explicit information including thinking, memory, perception, motivation, skilled movements and language (Trivedi 2006: 10). According to McCrory *et al.* (2018), concussions can have great negative effects on an athletes cognitive functioning as well as their balance in the first 24-72 hours after sustaining a concussion. Concussed athletes have been reported to outline various cognitive, emotional and physical signs and symptoms during the initial days after sustaining a SRC (McCrory *et al.* 2018: 843). A study conducted by Hume *et al.* (2017) investigated cognitive functioning amongst retired New Zealand Rugby union players compared with former non-contact sport players, using the CNSVS test battery. The study that the professional rugby group executed worse on was tests of complex attention, processing speed, executive function, and cognitive flexibility, than the non-contact sport group. Furthermore, the amateur-rugby group performed worse than the non-contact group on executive functioning and cognitive flexibility (Hume *et al.* 2017: 1214). These findings are similar to the study mentioned above in Section 1.4, that was performed in South Africa on amateur rugby players, which stated that the rugby group performed worse for the ImPACT (Immediate Post-concussion Assessment and Cognitive Testing) Visual Motor Speed and Reaction Time composites (Zoccola *et al.* 2020: 128). The results of the Zoccola *et al.* (2020) study revealed harmful cognitive performance in adult rugby community level players in comparison to non-contact sports controls.

In the Hume *et al.* (2016) study, the median concussions reported by the rugby players were greater for the professional rugby and amateur rugby groups than the non-contact sports group. Former players who reported one or more concussions (professional rugby 85%, amateur rugby 77% and non-contact sport 23%) scored worse on cognitive flexibility, executive functioning, and complex attention than players who did not report sustaining a concussion. Current studies have shown that past participation in rugby or a history of concussion has been associated with small to moderate cognitive deficits in athletes post retirement

from competitive sport (Hume *et al.* 2017: 1209). The long-term effects of neurotrauma have been a trending topic in recent years, and has mainly been fixated on brain injury in the form of SRC sustained by specific sportsmen such as those participating in contact sport. Recently a study by Walker and Tesco (2013) reported on National Football League (NFL) players, and demonstrated that athletes participating in American football have neurodegenerative mortality rates which are three times higher compared to the neurodegenerative mortality rates of the overall United States (US) population. The risk of cognitive dysfunction seems to become larger with an increase in the amount of concussions sustained, with one study which demonstrated a 5-fold increase in mild neurocognitive disorders and a 3-fold prevalence of substantial memory problems in athletes who have experienced three or more concussions (Walker and Tesco 2013: 7). United States Army soldiers who have a history of sustaining multiple concussions (three or more concussions) in the past have been reported as having a significantly greater post-concussive symptom score and traumatic stress symptoms, in comparison with those soldiers who have not sustained a concussion before, as well as those who have only sustained one and two prior concussions (Dretsch, Silverberg and Iverson 2015: 3). However, in the study by Dretsch, Silverberg and Iverson (2015) there were no significant differences on neurocognitive testing between the number of concussions. A study conducted by Gardner, Shores and Batchelor (2010: 178) verified that adult male rugby union players who reported three or more previous concussions revealed a sub-optimal performance on visual motor speed and processing speed, compared with rugby union players who reported no history of sustaining a concussion in the past. This research by Gardner, Shores and Batchelor (2010), which suggests that SRC may cause long-term effects, provides paramount information to the athlete and the athletes management and medical staff to help make responsible and informed choices concerning the risk of further involvement in contact sports (Gardner, Shores and Batchelor 2010: 179).

2.9.2 Neurocognitive testing

According to BrainCheck (2020), neurocognitive testing is able to measure the functioning of the brain in a non-invasive manner. Such testing uses paper-and-

pencil tests or computerised tests to evaluate important features of cognition such as memory, reaction time, attention, language and perception. Neurocognitive testing includes different tests that are specifically created to measure aspects of brain function. With the use of neurocognitive testing researchers and clinicians are able to gain a powerful insight into the athletes cognitive functioning by measuring subtle aspects of their brain function. The neurocognitive tests are objective and the scoring provides a useful way to compare an individual's neurocognitive functioning to other athletes, the general population or against themselves at another time period. The scores can be used in a clinical setting to assist with diagnosis of problems such as concussion.

Traditionally, neurocognitive testing has been done via paper-and-pencil, but recently computerised neurocognitive testing has demonstrated to be more sensitive and effective than the paper-and-pencil testing (BrainCheck 2020). Common baseline evaluations include the battery of standard sideline assessment tests found in the SCAT5 and/or computerised neuropsychological tests such as Central Nervous System Vital Signs (CNSVS), CogSport, Automated Neuropsychological Assessment Metrics, and Immediate Post-Concussion Assessment and Cognitive Testing (Harmon 2019: 214). Another neuropsychological test that has been developed to assist researchers and medical practitioners with evaluation of athletes cognitive functioning following concussion, is the ImPACT test (Immediate Post-concussion Assessment and Cognitive Testing) (Collins *et al.* 1999). The ImPACT test, which has been used in South Africa by Zoccola *et al.* (2020), produces four core composite scores, including Visual Memory, Verbal Memory, Visual Motor Speed, and Reaction Time (Iverson, Lovell and Collins 2003; 2005). The current study used the same measurement tool, CNSVS test battery, as Hume *et al.* (2016) in their study on retired athletes in New Zealand. The CNSVS and ImPACT tests are similar but the justification for the use of the CNSVS in comparison to the ImPACT test in this study is that the CNSVS has never been used in a South African study. Additionally, this study wanted to compare its results directly to those of Hume *et al.* (2017).

As reported in the 2017 CISC consensus statement, neuropsychological (NP) testing has an important clinical value, and can provide significant information regarding concussion's that an athlete sustains (McCrary *et al.* 2018: 841). Numerous organisations firmly encourage baseline evaluation preceding sports participation, specifically cognitive evaluation as well as an assessment of the athlete's coordination, gait, vestibular function and balance. Baseline evaluation's help to assist the diagnosis and the return-to-play decisions with regards to a player who is suspected to have sustained a SRC. This assists with overall management, including the diagnosis of a SRC and return-to-play protocols in an athlete who has been assumed of sustaining a concussion (Harmon *et al.* 2019: 2014). The CISC consensus statement reports that baseline or pre-season NP testing is not a compulsory aspect, however, it may be beneficial to the management of the athlete and may help to add useful data to the overall understanding of the athletes neurocognitive functioning (McCrary *et al.* 2018: 841). It also offers an educative and informative occasion for the treating physician to discuss the implications of concussions with the athlete. Early post-injury NP testing may assist in concluding certain aspects of the athlete's management, such as return-to-play decisions and returning to school or work as well as allowing tracking through time to assess recovery in concussion.

2.10 Summary

Rugby is a competitive collision team sport that many participate in across the world. Due to the nature of the game and the anatomical positions that the players need to repetitively undertake in order to gain ball possession, such as crouching and tackling another player, rugby players are often predisposed to a high risk of sustaining head injuries. Concussion has been discussed in depth as reflected in the current literature in terms of what it is, the prevalence in rugby, the possible mechanisms leading to traumatic brain injury, the risk factors, the sequelae of SRC, the importance of management and the implications if left unrecognised. Neurocognitive deficits and their associations in rugby have been discussed thoroughly according to the current literature, which shows many similarities and minor differences. Although the association between rugby playing experience and cognitive function has been studied in South African Premium League rugby

players before (Zaccola *et al.* 2020), it is difficult to compare the NCI findings of this study to other countries. The aim of this study is to make use of the same neurocognitive assessment that was performed in New Zealand rugby players in order to directly compare the two cohorts. In addition, there is a paucity of literature regarding the first division rugby union players in KwaZulu-Natal. To our knowledge, the literature on this subject is based in wealthier countries without equality issues such as New Zealand, Australia and the United Kingdom. Therefore, it is important to gain an of concussion, including the mechanisms of how they occur, the related risk factors, the management and treatment of concussion, the impact that concussion has on rugby players, and when the onset of cognitive deficits occur amongst South African rugby players, to help enhance safe participation in sports.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter highlights the methodology that was applied to the research study's question and hypotheses. According to Irny and Rose (2005) methodology is "The systematic and theoretical analysis of the procedures or techniques used to identify, select and process information relating to a specific topic". The areas of interest discussed within this chapter include: the research design, research procedures followed, the data collection tool, the sampling method, ethical considerations and the methods of data analysis.

3.2 Research design

A research design is used to perform a research study and encompasses the framework of methods and techniques used for the study (Kothari 2004: 31). This study was guided by a quantitative study using a cross-sectional descriptive survey as it allows the relationship between variables to be determined by the researcher (Babbie 2010: 24). Quantitative research focuses on measurable aspects of human behaviour, it also allows the researcher determine the relationships that exists between dependent and independent variable's (Brink, van der Walt and van Rensburg 2018: 3).

3.3 Study setting

The research study was conducted on an online platform, where two separate emails were sent to each participant. This setting was convenient for the respondents as they were able to complete the survey and test battery in their own time in the comfort of their home.

3.4 Study population

The estimated target population for this study was 475 first division KwaZulu-Natal rugby union players with the population age range set between 19 and 45 years of age (Chetty 2021).

3.5 Permission to conduct research

Full ethical approval was granted to conduct research by the

The Durban University of Technology (DUT) Institutional Research Ethics Committee (IREC) (Appendix F) granted the researcher full ethical approval to conduct this research study. In order to grant full ethical approval, IREC also required gate keeper permissions. These permissions were obtained from the KwaZulu-Natal rugby union as well as the four separate rugby clubs involved (Appendix E). This gave the researcher an opportunity to introduce herself and to also discuss the details regarding the research study with the respondents, as well as to the coaches and managerial staff of the rugby teams.

3.6 Inclusion and exclusion criteria

The following criteria were used to determine those eligible for inclusion in the study:

- 19 to 45-year-old competitive male contact rugby players (19 is the minimum age accepted by the first division Rugby Union).
- Rugby players who have played a minimum of 1 year at first division level.
- Players for whom rugby is the main sport that they are involved in.

The following criteria were used to determine those not eligible for inclusion into the study:

- Rugby players who do not complete the consent form.
- Rugby players who do not complete the questionnaire.
- Rugby players who are younger than 19 years of age as well as older than 45 years of age.
- Rugby players who have played rugby for less than a year.
- Players who have experienced concussions from incidents other than rugby.

3.7 Sampling process

According to Brink, van der Walt and van Rensburg (2018), sampling is a technique of selecting individual members from a certain population to make statistical inferences from them, in order to obtain information regarding a

phenomenon and estimate characteristics in a way that represents the whole population.

3.8 Participant recruitment

Once permission was granted from IREC (Appendix F) and the KwaZulu-Natal rugby union (Appendix J), communication was made with all four rugby club coaches via email or telephonically to discuss what the researcher was wanting to gain from the rugby players and to make arrangements for an information meeting.

An information meeting was held at each rugby club where the researcher discussed with the coaches, managers and players what the research topic was and what the researcher was expecting from the respondents.

A recruitment flyer (Appendix B) was given to each player with the researcher's contact details and other relevant information pertaining to the study.

3.9 Sample size

The sample size was determined using GPower version 3.1.9.2. At a 95% level of confidence and 80% power, the required sample size was 70. The primary end-point was to estimate the neurocognitive index (NCI) score among the rugby players (continuous measure). A sample size of 70 provided enough precision to estimate this prevalence within $\pm 5\%$ standard error.

3.10 Measurement tools

Measurement tool 1: Self-report rugby general health questionnaire (Appendix C).

The New Zealand Rugby Health General Health Questionnaire (NZRH GHQ) was developed for a previous validated study done by Hume *et al.* (2017) which discussed cognitive function in former rugby union players in New Zealand. This questionnaire provides data relating to concussions sustained by the respondents whilst playing rugby, current physical health and alcohol intake. It includes questions on demographics, general details, rugby experience, lower limb tasks, injury and concussion experience, health, lifestyle and well-being (medication use, smoking and social issues) and the AUDIT test. These factors could be

independently associated with cognitive functioning, although this could confound the relationship between rugby exposure and cognitive scores. For example, chronic drug abuse, such as long-term recreational cannabis use, has been recognised to have a negative effect on neuropsychological health (Hall and Degenhardt 2014: 40-41). Thus, if drug abuse was not measured in our cohort, one could inaccurately assume rugby exposure was associated with poor cognitive function, when in fact it was the drug abuse.

The AUDIT test was developed as a simple method of screening for excessive drinking and to assist in brief assessment (WHO 2018). This test was valid to use in this research procedure due to the link between alcohol consumption and cognitive impairment (Oscar-Berman and Marinkovic 2007: 244-245).

This questionnaire was marginally adapted to make it relevant to this study but remained primarily the same as the original questionnaire, so that comparisons could be made with research that has been conducted in other countries. This questionnaire was a validated questionnaire and has been used world-wide in the general rugby health research programme.

Measurement tool 2: The CNS Vital Signs test battery (Appendix D)

CNS Vital Signs (CNSVS) brief clinical evaluation battery is a computerised neurocognitive test battery that was developed as a routine clinical screening instrument. The CNSVS is comprised of seven tests that are used by numerous neuropsychologists and are known to be reliable and valid. The seven tests include: verbal and visual memory, finger tapping, symbol digit coding, the Stroop Test, a test of shifting attention and the continuous performance test. They consist of a suitable span of cognitive domains, and are sensitive to most of the causes of mild neurocognitive dysfunction. These tests provide clinicians and researchers with knowledge on neurocognitive and behavioural evaluation and management capabilities (Gualtieri and Johnson 2005: 361).

For the current study, this test was used to measure the NCI amongst players and was completed via an app on the respondents' computers.

Descriptions of the domains and the neurocognitive scoring process are provided in the CNSVS 'Brief Interpretation Guide' (Boyd 2015) (Appendix D). The CNSVS test was evaluated as follows:

- The following domains were calculated and recorded: composite memory, verbal memory, visual memory, psychomotor speed, reaction time, complex attention, cognitive flexibility, processing speed, executive function, simple attention and motor speed.
- Each domain was in the following manner, for each participant:
 - Above average: >109
 - Average: 90 - 109
 - Low average: 80 - 89
 - Low: 70 - 79
 - Very low: <70

3.11 Data collection process

Upon completion of the informed consent, each participant shared their details with the researcher which included email address and identity number. The researcher then emailed two separate links that would direct the participant to complete the self-report rugby general health questionnaire as well as the CNSVS test.

The NCI score was collected using the following neurocognitive tests:

- Verbal Memory (VBM)
- Visual Memory (VIM)
- Finger Tapping (FTT)
- Symbol Digit Coding (SDC)
- Stroop Test (ST)
- Shifting Attention (SAT)
- Continuous Performance (CPT)

The self-report rugby general health questionnaire took approximately 30 minutes to complete and the CNSVS test took 25 minutes to complete, therefore a maximum of an hour was needed from each participant.

3.12 Data analysis

Baseline characteristics of the study population were summarised overall and by their NCI scores using descriptive statistics such as mean (standard deviation) and median (interquartile ranges) for the continuous variables and frequency and proportions for the categorical variables. Excluding one outlier the distribution was normal ($p = 0.200$). Chi-square tests were used for the categorical variable (such as engagement in sport, general health, sports injuries and concussion history, and demographic information). Prevalence of decreased cognitive function was calculated as a binary variable (yes/no). Logistic regression models were used to examine correlates of deficit cognitive function among the players. Age adjusted odds ratios and 95% confidence intervals were calculated and presented from multivariable logistic models.

3.13 Ethical considerations

The following characteristics were considered to ensure ethical consideration:

- Full ethical approval was granted from the Institutional Research and Ethics Committee (IREC) at the Durban University of Technology (Ethics number: REC 102/17).
- Gatekeeper permission was granted from the KwaZulu-Natal rugby union (Appendix J) as well as the four separate rugby clubs.
- The self-report rugby general health questionnaire (Appendix C) was created for a previous study done by Hume et. al (2017) for cognitive function in former rugby union players in New Zealand. Professor Hume granted the researcher permission to use this questionnaire.
- Participants were provided with a letter of information (Appendix A) and needed to read and sign a letter of consent (Appendix E) to ensure autonomy.
- Non-maleficence states that the researcher has an obligation to not cause harm to the subjects (Jahn 2011: 225). The researcher in this study ensured that the two measurement tools (the self-report rugby general health questionnaire and the CNS vital signs test battery) would cause no harm to the participants. There would be no physical or emotional harmful stimulants involved in the research procedure. If the participant did find his

results to be upsetting, a qualified psychologist would assist him in treatment.

- The principle of beneficence is a moral obligation to act for the benefit of others (Jahn 2011: 225). The results of the research could lead to safer training and more successful management of rugby players, as well as ensuring that health care practitioners are better informed about cognitive deficits within rugby players (National Statement on Ethical Conduct in Human Research 2015).
- Justice was ensured throughout as the study was fair and impartial. No incentive or any other reward was given to the participants who completed this study and all participants were treated the same to ensure justice.
- Participants were able to withdraw from the study at any time as the process was voluntary and participants were not coerced into participation.
- The research data will be utilised by the researcher, the research supervisor and co-supervisor, the statistician and the psychologist only. Confidentiality will be maintained at all times.
- Each participant received their individual results if required via email. The researcher's contact details were made available on the email to allow a meeting to be made if the participant required one, to discuss his results.
- If a participant's cognitive score fell in the very low category (<70) and if the participant requested help, the qualified psychologist would analyse the participant's results. If the psychologist believed the participant needed treatment, a meeting was made with the psychologist to discuss his results and further treatment/consultations.
- The results were saved in a password protected file on a USB that would be kept by the researcher. Separate ballot boxes were used to store the informed consent forms (ballot box A)
- Data collected will be safely stored and kept for 5 years in the DUT Chiropractic department, after which it will be destroyed by shredding.

3.14 Summary

A quantitative, descriptive study was conducted, involving first division KwaZulu-Natal Rugby players. In order for the researcher to perform the research study

ethics approval was obtained from the DUT's IREC. All the participants were contacted via online methods such as e-mail. The study made use of an online self-report rugby general health questionnaire and the CNS vital signs test battery, as the research tools in this study. The data obtained during the research study was kept confidential and stored under password protection by the researcher.

CHAPTER 4: RESULTS

4.1 Introduction

This chapter presents and discusses the statistical data and results obtained from the General Health Rugby questionnaire (Appendix C) and the CNSVS test (Appendix D). The questionnaire (Appendix C) and the CNSVS test were the two primary tools used to collect data and was distributed to 80 participants. The data collected from the responses was analysed with SPSS version 26.0. Descriptive statistics were presented in the form of graphs, cross tabulations and other figures to report on the quantitative data that was collected in this study. Inferential techniques include the use of correlations and chi square test values, which are interpreted using p-values.

4.2 Participation rate

The target population consisted of 475 male rugby players currently playing for first division rugby clubs within KwaZulu-Natal. Using this target population, an initial study population size of 70 participants was calculated according to Wand (2018). Eighty rugby players from three randomly selected first division rugby clubs were invited to participate in the study. A total of 80 questionnaires and tests were administered. Of the 80 questionnaires despatched, 70 participants completed and returned their questionnaires. This resulted in a response rate of 87.5% of the study population.

4.3 The research instrument

Two measurement instruments were used in this research study, the one being the General Health Rugby questionnaire (Appendix D), and the second being the CNSVS test. The two-research instruments consisted of 363 items, with nominal or an ordinal level of measurement. The questionnaire was divided into multiple sections which measured various themes as illustrated below:

A: Biographical data

B: Other general details

- C: Rugby experience
- D: Injury and concussion experience
- E: Health, lifestyle, and well-being
- F: AUDIT test

The CNSVS test was a separate measurement tool used to measure the respondents' NCI (Section G) by means of measuring the following domains:

- Composite Memory
- Verbal Memory
- Visual Memory
- Psychomotor Speed
- Reaction Time
- Complex Attention
- Cognitive Flexibility
- Processing Speed
- Executive Function
- Simple Attention
- Motor Speed

4.4 Reliability Statistics

The two most important aspects of precision are reliability and validity. There are multiple forms of reliability and the one specific form is where reliability is calculated by capturing several measurements on the same subjects. A reliability coefficient that is 0.60 or higher is measured as “acceptable” for a newly developed construct (Peterson 2013: 382)

Table 4.1 reflects the Cronbach's alpha score for all the items that constituted the questionnaire.

Table 4.1: Cronbach's alpha score (n = 70)

	Section	Number of Items	Cronbach's Alpha
D24	Active daily living rating	10	0.789
D25	Recreational activities rating	10	0.927
F63	Difficulty with sleeping	4	0.874

F73	Occurrence of good and bad feelings that are related to overall life enjoyment	16	0.583
F87-F90	Involvement and attachment to family and friends	4	0.724
F93	Frequency of reactions or behaviours when angry/furious	14	0.793

The reliability scores for all sections exceeded or approximated the recommended Cronbach's alpha value. This indicated a degree of acceptable, consistent scoring for these sections of the research.

Section F73, "Occurrence of good and bad feelings that are related to overall life enjoyment" has a score marginally lower than the acceptable norm. The variation was mainly as a result of the interpretation of the statements with respect to having concussion.

4.5 Sections A and B - Biographical data and other general details

This section summarised the biographical characteristics of the respondents in terms of: ethnicity, age, height, body weight, education/qualifications and marital status.

Table 4.2 summarises the respondents' biographical characteristics.

Table 4.2: Biographical characteristics (n = 70)

	n (%)
<i>Ethnicity</i>	
Caucasian	61 (87.1)
Black African	8 (11.4)
Coloured	1 (1.5)
<i>Qualifications</i>	
School - No formal qualification	3 (4.3)
School - Bachelor's Pass	49 (70.0)
School - National Senior Certificate	18 (25.7)
Trade Certificate	4 (5.7)
Advanced Trade Certificate	5 (7.1)
Diploma	19 (27.1)
Bachelor's degree	22 (31.4)
Post-Graduate diploma	3 (4.3)
Post-Graduate Degree	5 (7.1)

Professional qualification	6 (8.6)
<i>Marital Status</i>	
Single	51 (73.9)
Married or living with a partner	15 (21.7)
Separated or divorced	3 (4.4)
<i>Current physical health rating</i>	
Poor	0 (0.0)
Not too good	6 (8.6)
Good	46 (65.7)
Very good or excellent	18 (25.7)

n = frequency

4.6 Section C - Rugby experience

This section summarises the rugby experience of the respondents in terms of the number of years of rugby playing experience; health problems associated with rugby participation; age of first rugby participation; highest level of competition competed in and the position played most often.

Table 4.3 summarises the respondents' rugby experience.

Table 4.3: Rugby experience (n = 70)

	n (%)	Chi Square goodness-of-fit p-value
<i>Number of years of rugby playing experience</i>		
3-4 years	1 (1.5)	< 0.001
5-9 years	11 (15.9)	
10-19 years	37 (53.6)	
20-29 years	18 (26.1)	
30+ years	2 (2.9)	
<i>Health problems associated to rugby participation that impact your ability to work</i>		
Yes	3 (4.3)	< 0.001
No	67 (95.7)	
<i>Age first played rugby</i>		
Less than 6 years	11 (15.7)	< 0.001
6-7 years	23 (32.9)	
8-9 years	10 (14.3)	
10-11 years	8 (11.4)	
12-13 years	8 (11.4)	
14-15 years	6 (8.6)	
16-17 years	3 (4.3)	
20 years or older	1 (1.4)	

<i>Highest level of competition competed</i>		
Club level	42 (60.0)	< 0.001
Regional	26 (37.1)	
National	2 (2.9)	
<hr/> <i>Position played most often</i>		
Forward	42 (60.0)	0.094
Back	28 (40.0)	

n = frequency

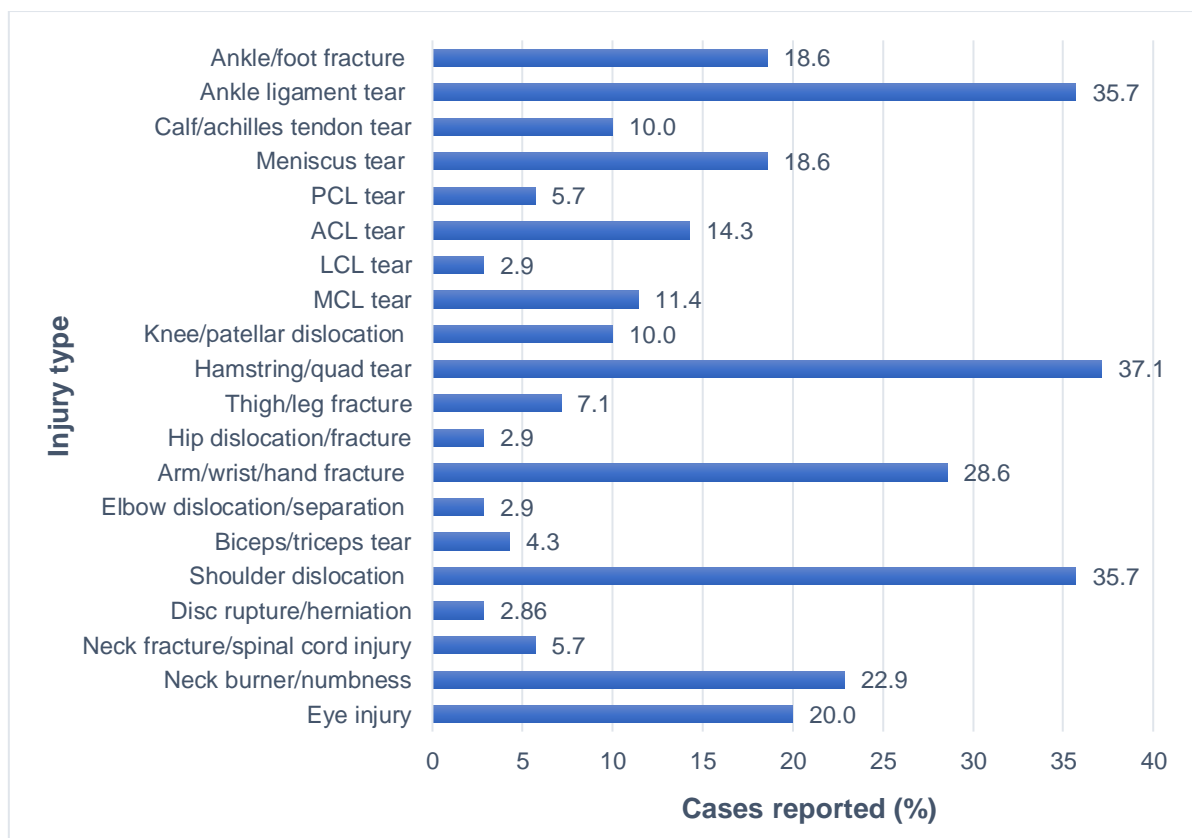
Chi Square goodness-of-fit p-value of < 0.05 implies there is a significant difference

The majority (53.6%, n = 37) of the respondents have played rugby for 10 to 19 years, with only two (2.9%) respondents having over 30 years of rugby playing experience. Very few (4.3%, n = 3) respondents have experienced rugby associated health problems that impact their ability to work. Most respondents (32.9%, n = 23) started playing rugby between the ages of six to seven years with 15.7% (n = 11) of players starting at younger ages of less than six years. There were significant differences between the level of competition played with the highest (60.0%, n = 42) being predominantly club level with only two respondents (2.9%) having competed at national level. A higher percentage of respondents (60.0%, n = 42), most often played a forward player compared to 40.0% (n = 28) who played in the backline.

4.7 Section D - Injury and concussion history

4.7.1 Injury history

This sub-section deals with the respondents' injury history and experience of injuries that have affected their participation in sport or continue to affect their health and everyday life. In the questionnaire, an injury was defined as a physical problem that caused the respondents: to miss at least one rugby game, and/or at least two rugby team practices or scheduled training sessions, and/or required assessment and/or treatment by a health professional.



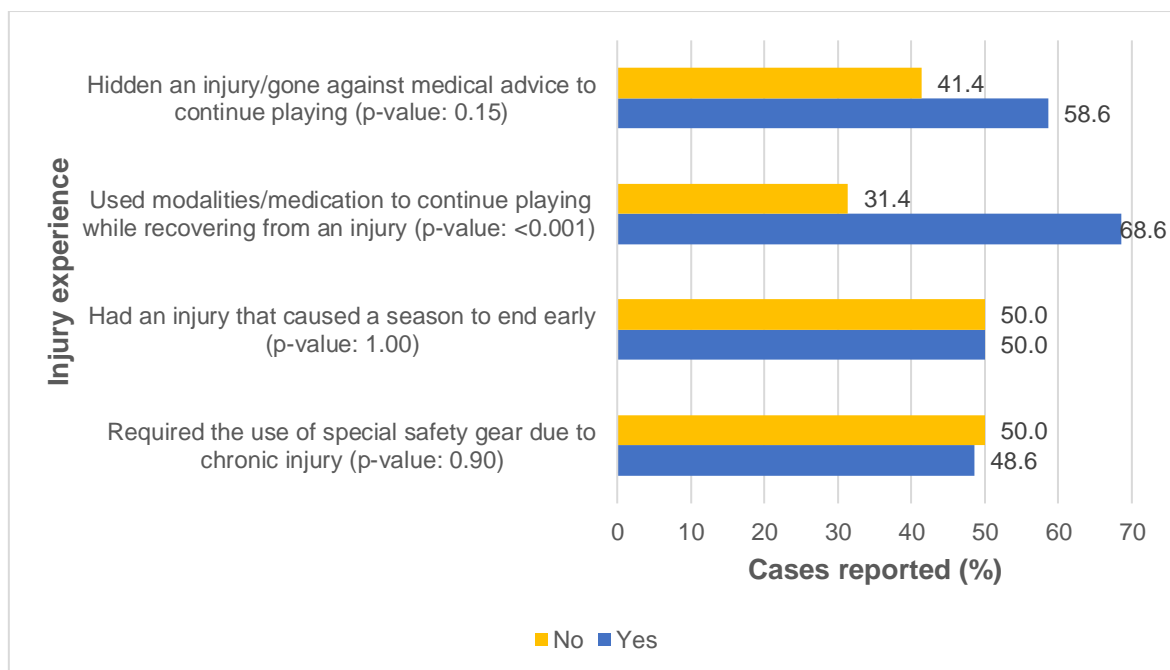
PCL = Posterior cruciate ligament, ACL = Anterior cruciate ligament, LCL = Lateral cruciate ligament, MCL = Medial cruciate ligament

Figure 4.1: Injury type history (n = 70)

Figure 4.1 illustrates the different types of injuries the respondents have sustained.

The 70 respondents reported 208 injuries in total whilst playing rugby, with a mean of 5.1 injuries per person (SD: 2.8, median: 5 and IQR: 3 – 7). In the case of the different injuries the respondents have endured (Table 4.4.), a hamstring or quadriceps tear was the most common (37.1%, n = 26), with shoulder dislocations and ankle ligament tears (35.7%, n = 25) being the second most common. Twenty respondents (28.6%) have suffered with either an arm, wrist or hand fracture, and a small number (5.7%, n = 4) have suffered a neck or spinal cord injury.

It was noted that the majority (62.9%, n = 44) of respondents reported having never suffered a medical condition whilst playing rugby.



Chi Square goodness-of-fit p-value of < 0.05 implies a significant difference between Yes and No.

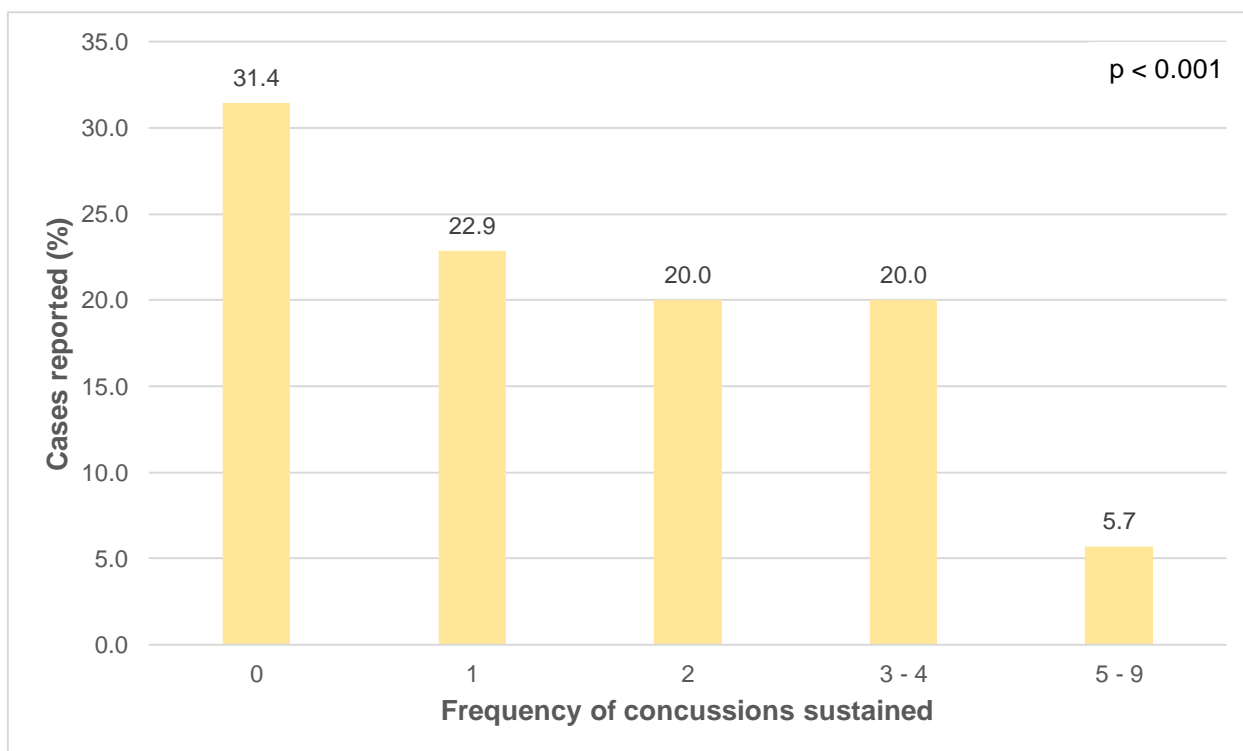
Figure 4.2: Injury experience (n = 70)

Figure 4.2 indicates the participants' injury experiences.

Figure 4.2 indicates that half (50%, n = 35) of the respondents have sustained an injury during a playing season that caused their season to end early and more than half (68.6%, n = 48) required the use of medication or/and modalities (e.g., pain killers, injections, ultrasound treatments, etc.) to make it possible to continue playing rugby while recovering from an injury. Just less than half (48.6%, n = 34) of the respondents required the use of special safety gear such as strapping, bracing and/or head gear to continue playing rugby. More than half (58.6%, n = 41) of the respondents have hidden an injury or gone against medical advice to continue playing rugby, either before or during a game.

4.7.2 Concussion experience

The following sub-section deals specifically with concussions sustained while playing rugby. According to the NZRH GHQ, concussion symptoms include: "headache, short-term memory loss, dizziness, nausea, short term memory loss, and/or aversion to bright light", but not all symptoms have to be present for a diagnosis to be made.



Chi Square goodness-of-fit p-value of < 0.05 implies a significant difference between the frequency of concussions sustained.

Figure 4.3: Frequency of concussions sustained (n = 70)

Figure 4.3 illustrates the frequency of concussions sustained by respondents.

The majority of respondents have sustained a concussion (68.6%, $n = 48$) with a mean of 2.4 (SD: 1.6, median: 2 and IQR: 1 - 3) concussions per person. Sixteen (22.9%) of the respondents have only sustained one concussion. Approximately 28 (40%) of the have respondents sustained between 2 and 4 concussions while playing rugby. In addition, a small amount of 4 respondents (5.7%) have sustained a higher frequency of 5 to 9 concussions.

Using the raw scores, it was noted that a mean of 1.7 (SD: 1.4, median: 1, IQR: 1 - 2) concussions were not reported to medical staff by the respondents, with an average of 3.3 (SD: 1.9, median: 3, IQR: 2 - 4) total games being missed due to concussions.

Table 4.4 summarises the participants' concussion experiences.

Table 4.4: Concussion experience (n = 70)

Concussion experience	n (%)
Knocked out (loss of consciousness).	48 (68.6)
Short-term memory loss (amnesia)	47 (67.1)
Prolonged symptoms (lasting 4 weeks or more).	47 (67.1)
Returned to play on the same day as the concussion.	47 (67.1)
Returned to play still feeling dizzy or disorientated.	47 (67.1)

n = frequency

Table 4.4 summarises the concussion experience of the respondents who have sustained a concussion while playing rugby. The majority (68.6%, n= 48) of the respondents have experienced loss of consciousness when concussed. Sixty seven percent (n= 47) of the respondents have experienced short term memory loss as well as prolonged symptoms. More than half (67.1%, n= 47) of the respondents admitted to returning to play on the same day as the concussion as well as returning to play whilst still feeling dizzy.

There was a significant difference ($p < 0.001$) amongst the results of other concussion experiences (for respondents who have suffered a concussion) such as experiencing difficulty concentrating for long periods of time (43.5%, n = 30) and difficulty remembering things (31.9%, n = 22). In addition, this was also observed for respondents suffering with unexplained dizzy spells over the last few years (26.1%, n = 18) and regular bouts of headaches (8.8%, n = 6). Only one (1.5%) respondent had been diagnosed with post-concussion syndrome and 13 respondents (18.8%) currently do not know whether they suffer with post-concussion syndrome or not. A frequency of six (9.0%) respondents stated that they were worried about the possible side effects of previous concussions on their current and future health and 14 (20.9%) being only somewhat worried. Twelve (17.9%) of the respondents reported that they themselves as well as anyone living with them, had a few mild concerns about their memory or ability to think and only one (1.4%) individual stated some definite concerns. The majority of the respondents (80.6%, n = 54) had no (none) concerns about their memory or ability to think.

4.8 Section E - Health, lifestyle and well-being

This section summarises aspects concerning the respondent's health, lifestyle and well-being.

4.8.1 Health status

This sub-section summarises the health of the respondents in terms of current and/or past medical conditions (not necessarily diagnosed by a medical practitioner), and rate of current and/or past substance usage.

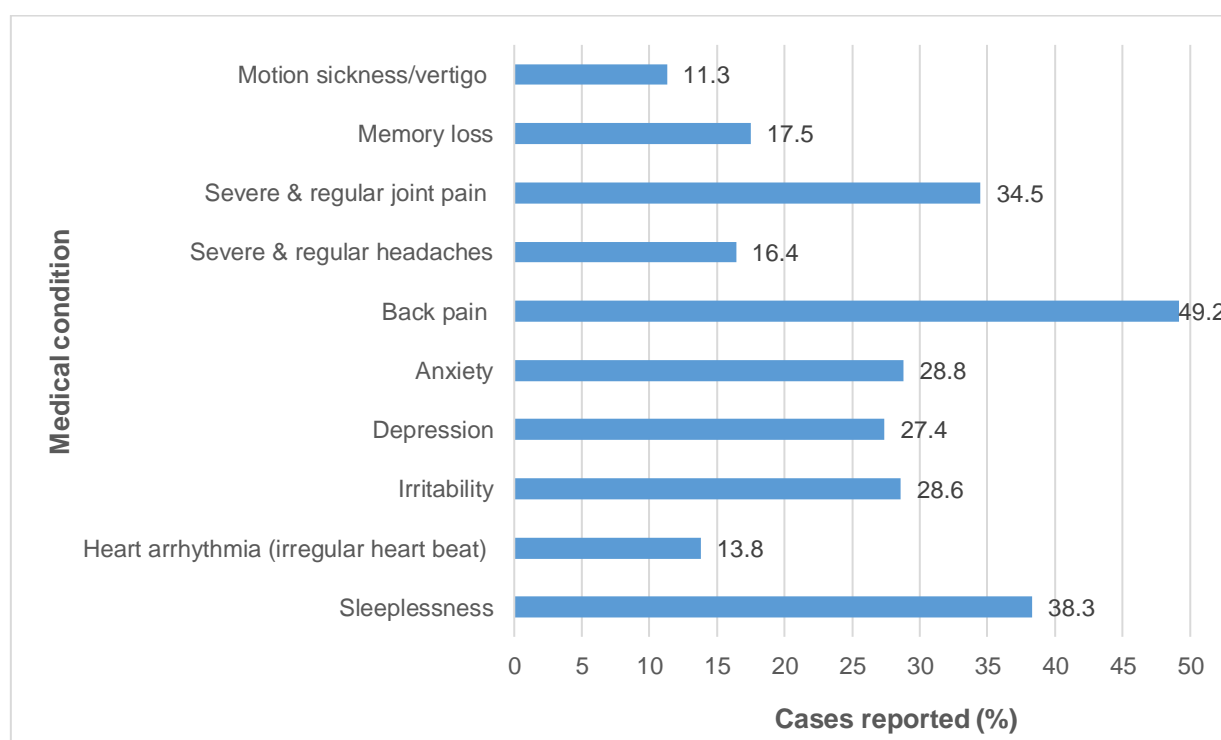


Figure 4.4: Medical conditions (n = 70)

Figure 4.4 indicates the current and/or past medical conditions of the sample.

Between 10% and 35% of the respondents suffered from various medical conditions, with the most common being back pain (49.2%, n = 31) and sleeplessness (38.3%, n = 23).

Table 4.5 summarises the rate of substance usage of the respondents.

Table 4.5: Rate of substance usage (n = 70)

Drug/substance	Never used n (%)	Before a game/sport n (%)	During a game n (%)	After a game n (%)	Used monthly n (%)	Chi Square goodness-of-fit p-value
Alcohol	2 (2.9)	1 (1.6)	0 (0.0)	34 (50.7)	30 (44.8)	< 0.001
Pain killers	19 (29.2)	7 (10.8)	4 (6.1)	18 (27.7)	17 (26.2)	0.005
Cannabis	35 (53.8)	1 (1.6)	1 (1.5)	4 (6.2)	24 (36.9)	< 0.001
Narcotics	53 (91.4)	1 (1.7)	0 (0.0)	1 (1.7)	3 (5.2)	< 0.001
Tranquilisers/sleeping pills	46 (79.3)	0 (0.00)	0 (0.0)	4 (6.9)	8 (13.8)	< 0.001
Hallucinogens	55 (98.2)	0 (0.00)	0 (0.0)	0 (0.0)	1 (1.8)	< 0.001
Inhalants	52 (88.1)	2 (3.4)	1 (1.7)	0 (0.0)	4 (6.8)	< 0.001
Anti-depressants	54 (90.0)	0 (0.0)	0 (0.0)	0 (0.0)	6 (10.0)	< 0.001
Stimulants	46 (76.7)	9 (15.0)	1 (1.7)	1 (1.6)	3 (5.0)	< 0.001
Performance enhancing	44 (71.0)	4 (6.5)	0 (0.0)	2 (3.1)	12 (19.4)	< 0.001

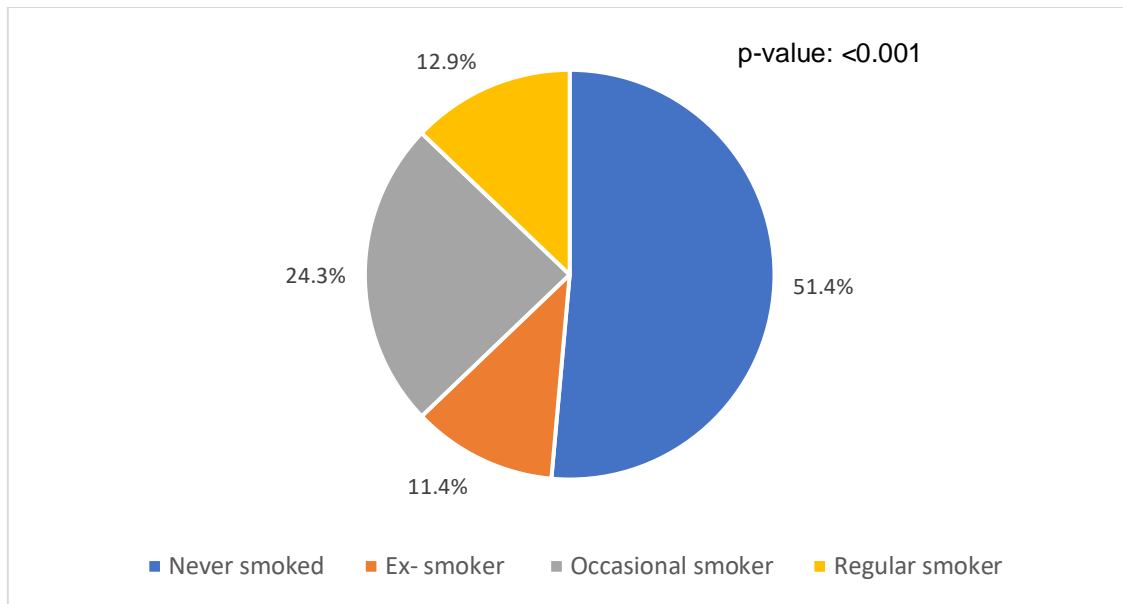
n = frequency

Chi Square goodness-of-fit p-value of < 0.05 implies a significant difference between the rate of usage of the above substances.

It is noted in Table 4.5 that half (50.8%, n = 34) of the respondents consume alcoholic beverage/s after playing a game, as well as 6.9% (n = 4) use tranquilisers or sleeping pills after a game. Pain killers are used by 10.8% (n = 7) before a game and 6.2% (n = 4) while playing a game of rugby. Before a game, 15% (n = 9) of respondents use stimulants. Looking at the use of cannabis and performance enhancing substances on a monthly basis (e.g., substances to build muscle), 36.9% (n = 24) of respondents use cannabis and 19.4% (n = 12) utilise performance enhancing substances. Approximately half (52.3%, n = 34) of the respondents confessed that they have used drugs other than those used for medical reasons.

4.8.2 Smoking status

This sub-section summarises the smoking status of the respondents in terms of smoking categories and the number of cigarettes smoked per week.



Chi Square p-value of < 0.05 implies a significant difference between the smoking status of respondents.

Figure 4.5: Smoking status (n = 70)

Figure 4.5 illustrates the categories that best describe the smoking status of the respondents.

A total of 36 (51.4%) respondents reported to have never smoked before, 17 (24.3%) being an occasional smoker, 9 (12.9%) a regular smoker and a small number of 8 (11.4%) being an ex-smoker. Additionally, amongst the smokers, the mean number of cigarettes smoked within a week was 43 cigarettes (SD 53.8, median: 25 and IQR: 10 – 60).

4.8.3 Psychological well-being

This sub-section deals with how often the respondents have experienced 'good and bad' feelings that are related to overall life enjoyment.

Table 4.6 summarises the psychological well-being of respondents.

Table 4.6: Psychological well-being (n = 70)

	Not at all n (%)	Occasionally n (%)	Sometimes n (%)	Often n (%)	All the time n (%)	Chi square goodness- of-fit p- values
'Good' feelings						
Everything is going right for me	3 (4.3)	10 (14.5)	26 (37.7)	24 (34.8)	6 (8.7)	< 0.001
Satisfied	2 (2.9)	11 (15.9)	22 (31.9)	25 (36.2)	9 (13.1)	< 0.001

My life is on the right track	3 (4.4)	6 (8.7)	19 (27.5)	34 (49.3)	7 (10.1)	< 0.001
Confident	2 (2.8)	9 (12.9)	13 (18.6)	26 (37.1)	20 (28.6)	< 0.001
My future looks good	3 (4.3)	4 (5.7)	14 (20.0)	34 (48.6)	15 (21.4)	< 0.001
Happy	0 (0.0)	2 (2.9)	12 (17.1)	43 (61.4)	13 (18.6)	< 0.001
Things are going my way	4 (5.7)	6 (8.6)	21 (30.0)	33 (47.1)	6 (8.6)	< 0.001
Content	2 (2.9)	13 (18.6)	15 (21.4)	26 (37.1)	14 (20.0)	< 0.001
'Bad' feelings						
I've made a mess of things again	34 (49.3)	19 (27.5)	11 (15.9)	4 (5.8)	1 (1.5)	< 0.001
Miserable	38 (54.3)	11 (15.7)	17 (24.3)	4 (5.7)	0 (0.0)	< 0.001
Nothing is fun any more	45 (64.3)	8 (11.4)	11 (15.7)	5 (7.1)	1 (1.5)	< 0.001
Depressed	39 (56.5)	18 (26.1)	6 (8.7)	5 (7.2)	1 (1.5)	< 0.001
Nothing goes right with me	32 (45.7)	24 (34.3)	10 (14.3)	4 (5.7)	0 (0.0)	< 0.001
Down	20 (28.6)	32 (45.7)	13 (18.6)	5 (7.1)	0(0.0)	< 0.001
Life is hardly worth living	48 (69.6)	13 (18.8)	6 (8.7)	1 (1.4)	1 (1.5)	< 0.001
Upset	19 (27.5)	32 (46.4)	12 (17.4)	6 (8.7)	0 (0.0)	< 0.001

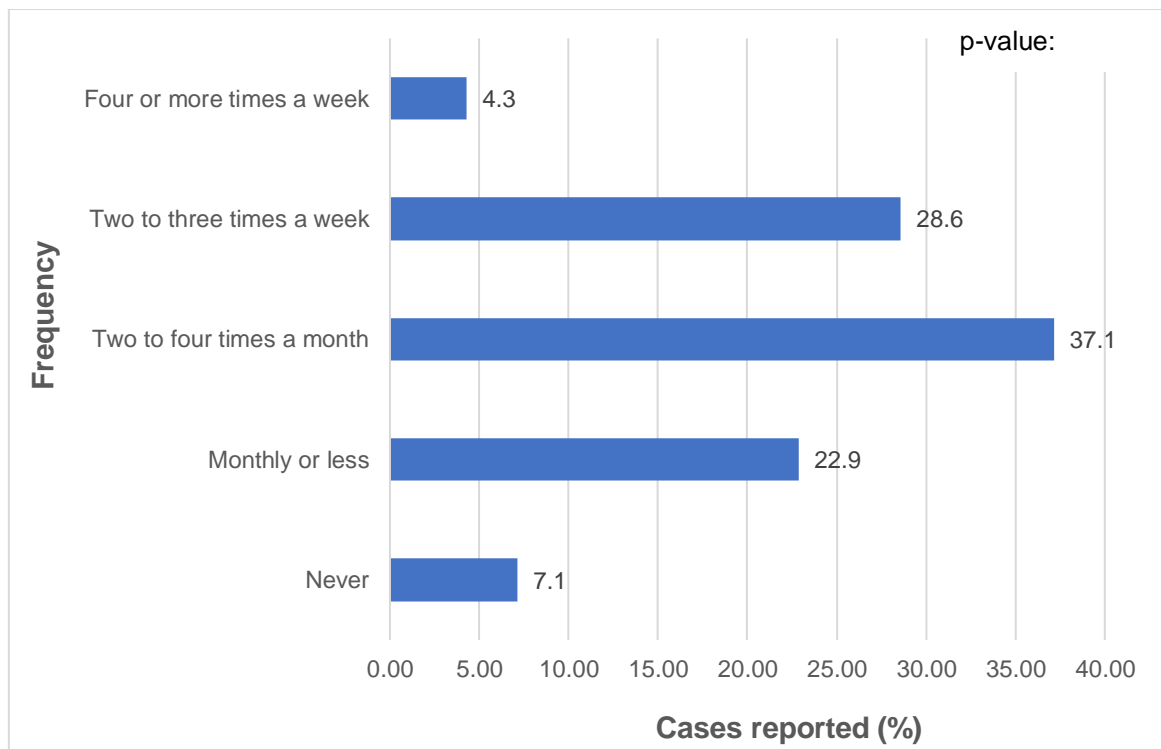
n = frequency

Chi Square p-value of < 0.05 implies a significant difference between the occurrence of 'Good and Bad' feelings.

When assessing Table 4.6, it is noted that feelings with a 'Bad' or negative connotation such as: "I've made a mess of things", "Miserable", "Nothing is fun anymore", "Depressed", "Down", "Life is hardly worth living", and "Upset", tend to be less frequent (not at all or occasionally). 'Good' feelings like "Confident", "My future looks good", and "Happy" occur more frequently (often or all the time).

4.9 Section F - Alcohol Use Disorders Identification Test (AUDIT)

This section summarises the respondents' answers to the AUDIT in terms of frequency of consuming a drink and number of drinks consumed on a typical day when drinking. In the following section a "drink" is equal to one glass of beer, wine or spirits.

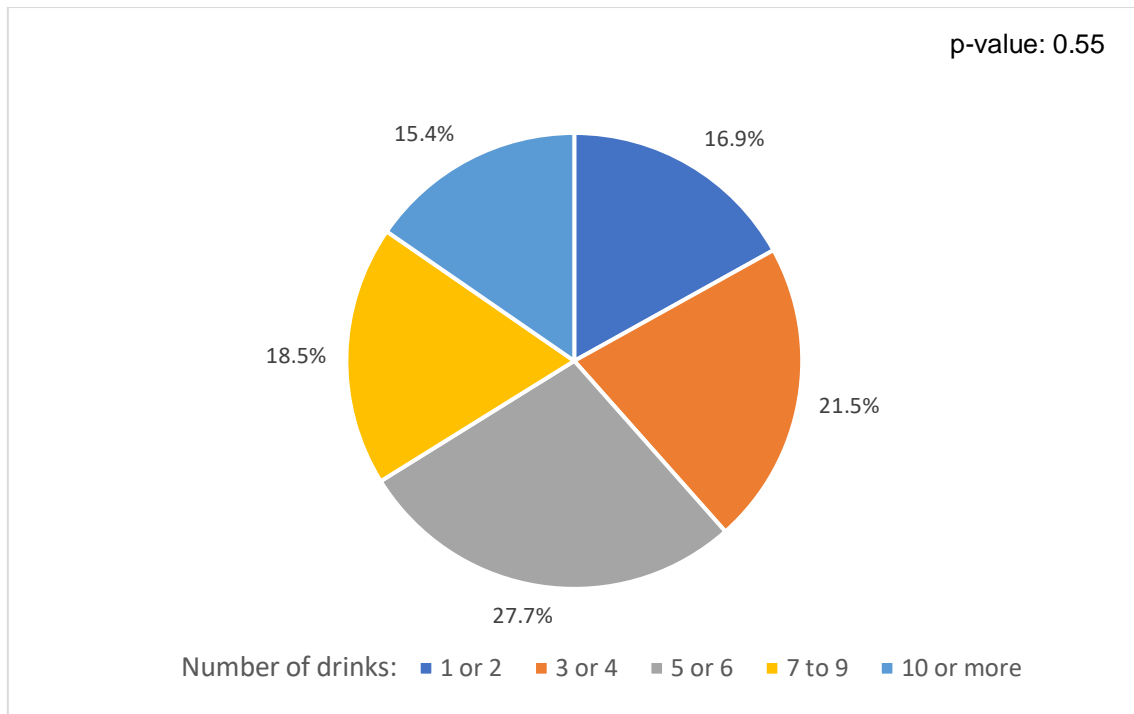


Chi Square p-value of < 0.05 implies a significant difference between the various frequencies of consuming a drink.

Figure 4.6: Frequency of alcohol consumption (n = 70)

Figure 4.6 presents how often the respondents consume an alcoholic drink.

It is noted that the majority (37.1%, n = 26) of respondents consume a drink two to four times a month. Approximately a third (28.6%, n = 20) of the respondents consume a drink two to three times a week and a small number (4.3% n = 3) of respondents consume at a higher drinking rate of four or more times a week.



Chi Square p-value of < 0.05 implies a significant difference between the various numbers of alcohol drinks consumed on a typical day when drinking.

Figure 4.7: Volume of alcohol consumption (n = 70)

Figure 4.7 summarises the number of alcoholic drinks consumed by the respondents (excluding those who do not drink) on a typical day when drinking.

It is noted that the majority (27.7%, $n = 18$) of the respondents consumed 5 or 6 drinks on a day when drinking, with 15.4% ($n = 10$) consuming a larger number of drinks consisting of 10 or more drinks on a typical day when consuming alcohol.

4.10 Section G – CNS Vital Signs Test

This section summarises the standard scores of the CNSVS test in terms of: Composite Memory, Verbal Memory, Visual Memory, Psychomotor Speed, Reaction Time, Complex Attention, Cognitive Flexibility, Processing Speed, Executive Function, Simple Attention, Motor Speed and overall Neurocognitive Index. The CNSVS test was used to determine the cognitive functioning of the respondents. Table 4.7 shows the scoring pattern used for the 12 domains.

Table 4.7: Domain scoring pattern

Category	Scoring
Above average	> 109
Average	90 – 109
Low Average	80 – 89
Low	70 - 79
Very Low	< 70

Table 4.8 summarises the scoring patterns of the respondents for the CNSVS test.

Table 4.8: Neurocognitive functioning domain standard scores (n = 70)

Domain	Mean	SD	Category
Composite Memory	91.1	16.6	Average
Verbal Memory	89.4	20.0	Low Average
Visual Memory	95.2	14.5	Average
Psychomotor Speed	91.2	17.3	Average
Reaction Time	84.2	16.7	Low Average
Complex Attention	78.5	41.1	Low
Cognitive Flexibility	75.5	27.5	Low
Processing Speed	85.9	12.7	Low Average
Executive Function	77.3	27.5	Low
Simple Attention	75.4	103.5	Low
Motor Speed	97.8	18.8	Average
<i>Neurocognitive Index (NCI)</i>	<i>84.1</i>	<i>16.3</i>	<i>Low Average</i>

SD standard deviation

All 12 domain responses ranged between the Low to Average (70 - 109). It is noted that the standard scores for Complex Attention, Cognitive Flexibility, Executive Function and Simple Attention scored in the Low category (70 - 79). The domains: Composite Memory, Visual Memory, Psychomotor Speed and Motor Speed fell under the category of Average (90 - 109) whereas Verbal Memory, Reaction Time and Processing Speed scored in the Low to Average categories (80 – 89). The respondents mean NCI was 84.1 (SD 16.3), therefore representing an overall Low Average NCI.

4.11 Regression analysis of the General Health Rugby Questionnaire

Table 4.9 presents the general linear model univariate analysis, which was run with the NCI score as the dependent variable.

Table 4.9: Regression analysis of between-subject effects with the NCI score as the dependent variable (n = 70)

Independent variables	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Number of years of rugby playing experience	185.38	1	185.38	0.70	0.41	0.02
Number of concussions sustained	108.08	1	108.08	0.41	0.53	0.01
Developed medical conditions whilst playing rugby (yes/no)	508.57	1	508.57	1.92	0.17	0.05
Used drugs for non-medical reasons (yes/no)	376.61	1	376.61	1.42	0.24	0.04
Position played most often (forward/back)	18.96	1	18.96	0.07	0.79	0.00
Body weight (kg)	275.21	1	275.21	1.04	0.32	0.02

Dependent Variable: Neurocognitive Index Score

R Squared = 0.156 (Adjusted R Squared = 0.023)

df = degree of freedom, F = F statistic, Sig. = p-value

The independent variables listed above did not have a significant effect on the respondents NCI ($p > 0.05$). The highlighted partial eta squared values indicate that the variables, “Number of years of rugby playing experience”, “Developed medical conditions whilst playing rugby”, “Used drugs for non-medical reasons” and “Body weight”, did have a small to moderate effect on the respondents’ NCI.

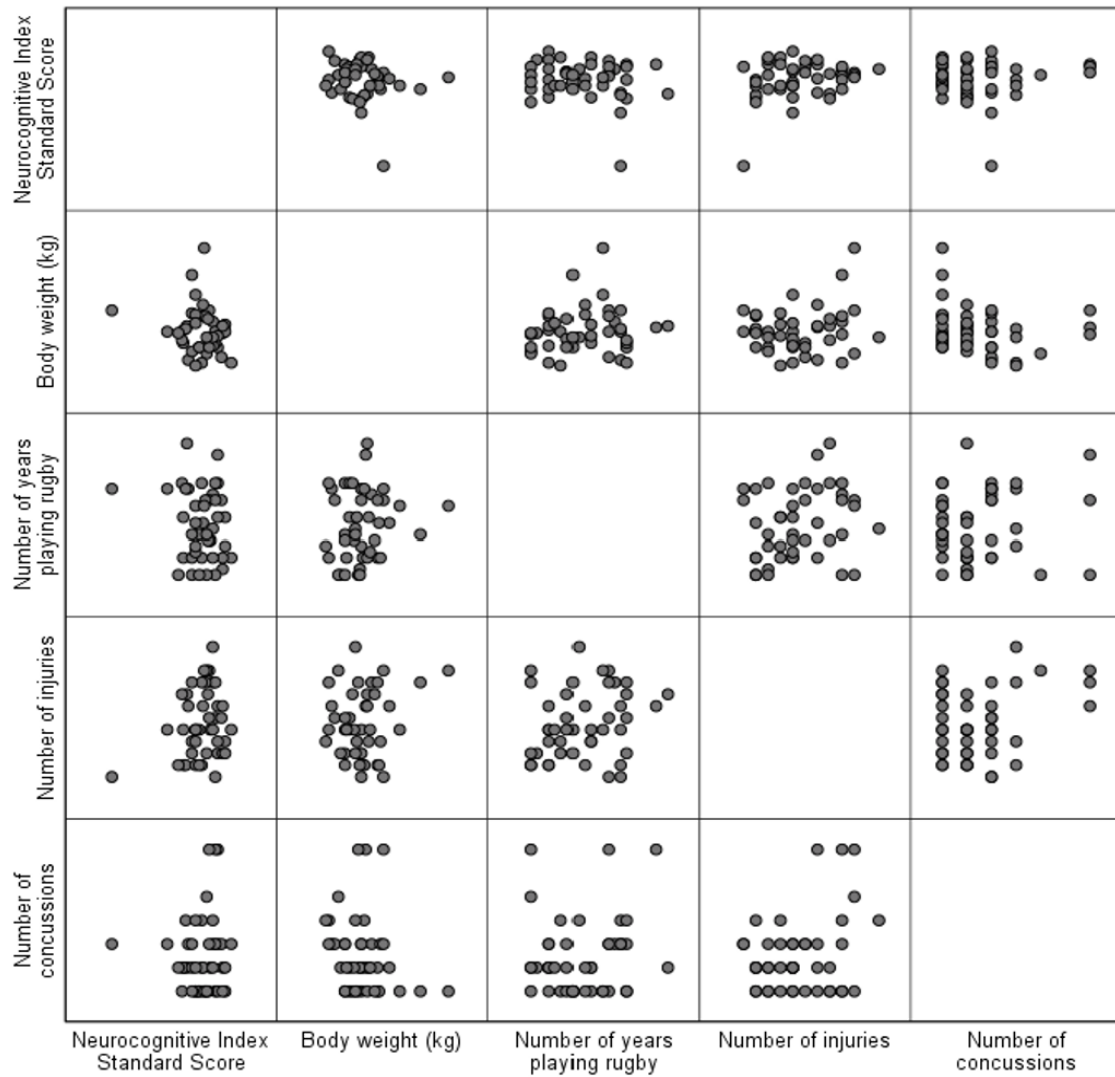


Figure 4.8: Matrix scatter plot graph reflecting the numerical variables therein (n = 70)

As can be seen from Figure 4.8, there is no distinct linear pattern in most of the individual matrices. There are some weak Pearson correlation coefficients: The correlation coefficient between “Number of years of rugby playing experience” and “Neurocognitive index score” is -0.24 ($p = 0.05$). This indicates an inverse relationship, therefore an increase in one unit of duration of playing rugby results in a decrease of 0.6 in the NCI score. The other is between “Number of injuries” (specifically non-concussive injuries such as ankle ligament sprain, hamstring tear and shoulder dislocation) and “Number of concussions” ($r = 0.29$, $p = 0.05$). This is a directly proportional relationship, implying an increase in the number of concussions would tend to lead to an increase in the number of injuries, and vice versa.

Table 4.10 presents the univariate analysis of variance, which was run with the number of concussions sustained by the respondents as the dependent variable.

Table 4.10: Regression analysis of between-subject effects with the number of concussions sustained by the respondents as the dependent variable (n = 70)

Independent variables	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Position played most often (forward/back)	0.40	1	0.40	0.16	0.69	0.00
Body weight (kg)	3.19	1	3.19	1.25	0.27	0.03

Dependent Variable: Number of concussions sustained

R Squared = 0.030 (Adjusted R Squared = -0.015)

df = degree of freedom, F = F statistic, Sig. = p-value

As mentioned above, there are no significant associations, but body weight does have a small effect on the dependent variable: “Number of concussions sustained”. The Spearman’s coefficient between these two variables is however not significant ($r = -0.24$, $p = 0.11$) and these results should be interpreted with caution. This is reflected in Figure 4.9.

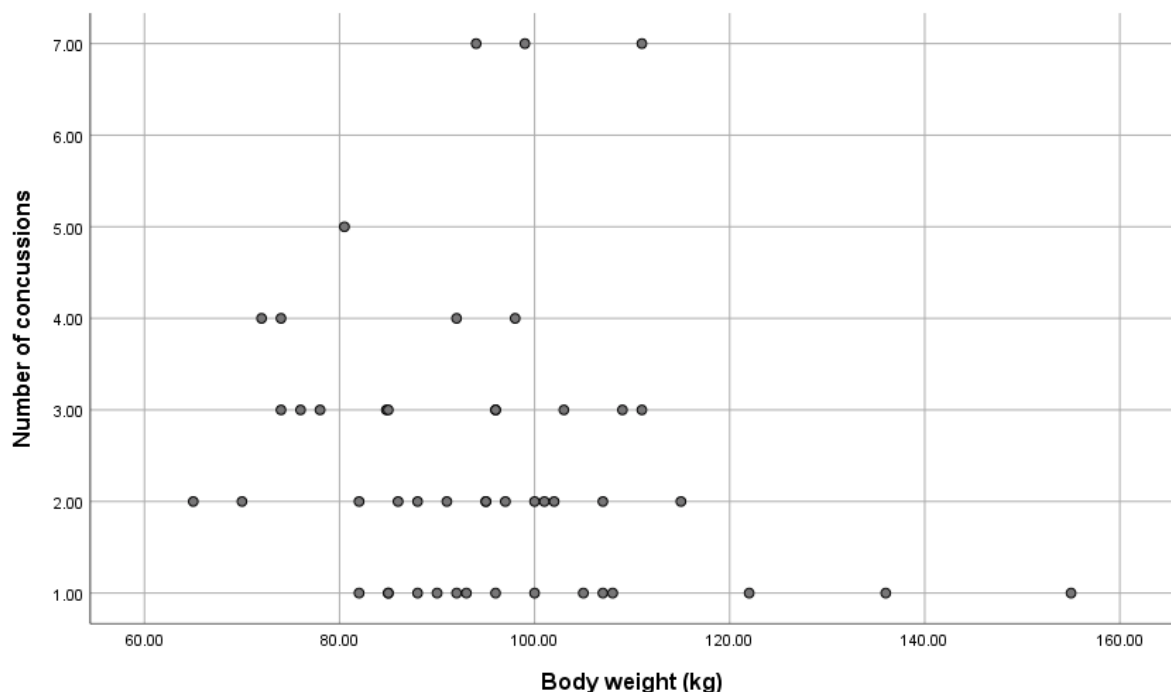


Figure 4.9: Scatter plot graph reflecting the relationship between body weight and the number of concussions sustained by the respondents (n = 70)

Most concussions that were sustained occurred within the 80 kg to 120 kg bodyweight range. However, this is not surprising as 80% of the respondents have bodyweights in this range.

4.11.1 Multiple linear regression of the General Health Rugby Questionnaire

Linear regression predicts the value of a variable (dependent/outcome variable) based on the value of another variable (independent/predictor variable). Multiple linear regression is a basic and frequently used type of predictive analysis. It offers statisticians three key uses for regression analysis, which are to determine the strength of predictors, to forecast an effect, and to forecast a trend in the data.

According to the model summary there is a weak correlation between the following independent variables; “Number of concussions sustained”, “Number of years of rugby playing experience”, and “Having sustained a concussion while playing (or practising) rugby”, and the respondents NCI score ($r = 0.25$). However, the analysis of variance (ANOVA) output for the investigation reveals that the independent variables listed above are not significant determinants for the respondents NCI score ($p = 0.4$). Therefore, there is no significant relationship between the respondents NCI score and whether they have sustained a concussion before while playing rugby, how many concussions they have sustained, or the number of years they have played rugby for. Therefore, the regression results should be interpreted with a large degree of caution.

Table 4.11 represents the unstandardised and standardised coefficients from the regression model.

Table 4.11: NCI regression model coefficients (n = 70)

Independent variables	Unstandardised Coefficients		Standardised Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
Number of years of rugby playing experience.	-0.64	0.39	-0.24	-1.64	0.11	0.99	1.02
Sustained any concussions while playing (or practising) rugby (yes/no)	-4.56	16.43	-0.04	-0.28	0.78	0.98	1.02

Number of concussions sustained.	0.66	1.51	0.07	0.44	0.67	0.97	1.03
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Dependent Variable: Neurocognitive Index Standard Score

B = B coefficient, STD. = Standardised, t = t statistic, Sig. = p-value, VIF = variance inflation factor

Variance inflation factor (VIF) is a measure of the amount of multicollinearity in a set of multiple regression variables. Mathematically, the VIF for a regression model variable is equal to the ratio of the overall model variance to the variance of a model that includes only that single independent variable. This ratio is calculated for each independent variable. A high VIF indicates that the associated independent variable is highly collinear with the other variables in the model. The VIF values in these results are low and meet the criteria of being < 4 .

None of the p-values above are significant ($p > 0.05$). This implies that the coefficients of the independent variables are not that different from zero.

4.11.2 Logistic regression relating to the respondents sustaining a concussion and the number of injuries the respondents have experienced

A logistic regression was conducted to determine the relationship between the number of injuries the respondents have experienced (independent) and whether the respondents have sustained a concussion (binary dependent, yes/no). The regression was not adjusted for any other factors as there were no significant chi square results.

Table 4.12 presents the output of the logistic regression model.

Table 4.12: Logistic regression of whether the respondents have sustained a concussion whilst playing/practising rugby and the number of injuries they have sustained (n = 70)

Variables in the Equation								
Independent variable	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
Total number of injuries	0.27	0.12	4.70	1	0.03	1.31	1.03	1.66

Dependent variable: Having sustained a concussion

B = Coefficient for the constant/intercept, S.E. = Standard error, Wald = Wald chi-square test, df = degree of freedom, Sig. = p-value, Exp(B) = Exponentiation of the B coefficient, C I = 95% confidence interval

There is a significant relationship between the number of injuries (specifically non-concussive injuries such as ankle ligament sprain, hamstring tear and shoulder dislocation) and whether the respondent has sustained a concussion whilst playing/practising rugby. The odds ratio (B) indicates that a player is 1.31 times more likely to have had a concussion having had a higher number of injuries compared to a lower number of injuries.

4.12 Univariate analysis of variance

Table 4.13 presents the General Linear Model univariate analysis, which was run with the neurocognitive domain scores as the dependent variable.

Table 4.13: Univariate analysis of between-subject effects relating to the number of concussions the respondents have sustained with their neurocognitive domain scores (n = 70)

Dependent variables	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Effect
Composite Memory	905.12 ^a	5	181.02	0.67	0.65	0.07	Medium
Verbal Memory	1541.171 ^b	5	308.23	0.80	0.56	0.09	Medium
Visual Memory	541.54 ^c	5	108.31	0.51	0.77	0.06	Medium
Psychomotor Speed	975.40 ^d	5	195.08	1.16	0.35	0.12	Large
Reaction Time	1463.94 ^e	5	292.79	1.19	0.33	0.12	Large
Complex Attention	7093.03 ^f	5	1418.61	0.68	0.64	0.08	Medium
Cognitive Flexibility	1759.53 ^g	5	351.91	0.42	0.83	0.05	Medium
Processing Speed	618.80 ^h	5	123.76	0.70	0.63	0.08	Medium
Executive Function	2185.22 ⁱ	5	437.04	0.52	0.76	0.06	Medium
Simple Attention	51967.57 ^j	5	10393.51	0.70	0.63	0.08	Medium
Motor Speed	1022.41 ^k	5	204.48	1.41	0.24	0.14	Large

Independent variable: Number of concussions

df = degree of freedom, F = F statistic, Sig. = p-value

Even though the p-values are not significant, there are medium to large effects for most of the dependent variables. That is, the neurocognitive domain scores do depend on the number of concussions the respondent sustains, therefore lower NCI score ratings do tend to yield more concussions than higher NCI score ratings.

4.13 Summary

A response rate of 87.5% was achieved. Most of the respondents have played rugby for 10 to 19 years. There was a significant difference between the number of respondents that had sustained a concussion and those who had not, with majority of the respondents stating that they had sustained at least one concussion. The median number of concussions experienced by the respondents was two per person. Chapter 5 expands on the consequence of the study's results in the context of the literature. This will allow accurate comparison with regard to cognitive functioning of rugby players, between the literature and this study, particularly highlighting the associations with duration of exposure to the sport and a history of concussion.

CHAPTER 5: DISCUSSION

5.1 Introduction

This chapter will provide a discussion of the results presented in Chapter 4 and compare these results to similar studies conducted on rugby players which have been gathered from both local and international literature in order to gain a better understanding of how cognitive function among first division KwaZulu-Natal Rugby Union players is associated with duration of exposure to the sport and a history of concussion.

5.2 Cognitive function

5.2.1 Rugby playing experience / Age and cognitive function

As the players age, it is possible they would obtain more rugby playing experience and therefore we grouped rugby playing experience and age together in this discussion section of 5.3.1.

The majority (53.6%, $n = 37$) of respondents have played rugby for 10 to 19 years and 26.1% ($n = 18$) of the respondents have played rugby for 20 to 29 years (Table 4.3). There were only two respondents (2.9%, $n = 2$) that have played rugby for over 30 years (Table 4.3).

The results of this study showed that the number of years of rugby playing experience did have a small to moderate effect on the respondents NCI score (Figure 4.9). The correlation coefficient between these two variables was -0.24 ($p = 0.05$), which indicates an inverse relationship. On average, an increase in one unit of rugby playing experience (one year) resulted in a decrease of 0.6 in the NCI score. This finding, where an increase in age/rugby playing experience causes a decrease in NCI, was expected since authors such as Gajewski and Falkenstein (2016) and Feng *et al.* (2017) have elaborated on how healthy ageing, within the general population, is associated with a decline in sensory, motor and cognitive functions, specifically executive and memory functions. This finding is

also supported by the reliability and validity study on the CNSVS test battery, which reported that peak cognitive performance, specifically composite memory (verbal and visual memory) and psychomotor speed (finger tapping test and symbol digit coding) is achieved between 20 and 30 years of age, and declines gradually thereafter (Gualtieri and Johnson 2006). Therefore, with increasing age it is expected that cognitive function slowly deteriorates.

In the current study, and according to the 'Brief Interpretation Guide' (Appendix D) four neurocognitive domains (complex attention, cognitive flexibility, executive function and simple attention) fell under the low category (70 – 79), three domains (verbal memory, reaction time and processing speed) fell under the low average category, and the final four domains (composite memory, visual memory, psychomotor speed and motor speed) fell under the average category (90 – 109) (Table 4.9).

However, in the New Zealand study (Hume *et al.* 2017) all 11 neurocognitive domains of the community level rugby players fell in the average (90 – 109) category. Therefore, the NCI scores of the respondents from the current study scored less than the Hume *et al.*, respondents, despite the Hume *et al.*, study being in much older persons (aged between 23 and 72) as they were retired athletes. Hume *et al.* (2017) study also used the CNSVS battery test to measure NCI scores and recorded age as a continuous variable, but grouped the number of concussions in two groups: no concussion and one or more concussions. Given the negative relationship between age and NCI described above, and that the current study's athletes were almost half the age (19 to 45 years of age), on average, of the Hume *et al.* study, one would have expected the current cohort to have superior NCI scores.

A possible explanation for this difference in domain scores between the current study and the New Zealand study (Hume *et al.* 2017) may be due to South Africa having a high Gini coefficient (0.63) (Vanderschuren, Cameron and Newlands 2021). According to the Gini coefficient, as well as other inequality measurements, South Africa is ranked as one of the most unequal countries in the world (Maluleke 2019). Therefore, the overall quality of life and quality of education in New Zealand may be greater than in South Africa. This inequality could result in South African

rugby players receiving sub-optimal healthcare management, which may explain the higher NCI findings reported by Hume *et al.*, for the former New Zealand community level group.

In the Gualtieri and Johnson (2006) study the exact same CNSVS test battery as in this study was used to measure NCI scores. When comparing this study's NCI mean scores to the approximate age matched (20 to 40 years of age) normative data for CNSVS, which Gualtieri and Johnson (2006: 634) reported, this study's mean psychomotor speed (91.2) and reaction time (84.2) fell below the CNSVS normative data. Gualtieri and Johnson's (2006) study and this current study differs in regards to the cohort used; Gualtieri and Johnson (2006) used 1069 normal volunteers (both male and female) that ranged in age between 7 and 90 and were in good health and did not suffer with neurological disorders or head injuries in the past. This study used first division/amateur male rugby players that have played rugby for a minimum of a year and ranged between 19 and 45 years of age. In this study the cohort's age was a continuous variable with a mean age of 28, whereas in the Gualtieri and Johnson's (2006) study they examined age as a grouped variable (<10, 10–14, 15–19, 20–29, 30–39).

Moreover, the CNSVS scores in a study that observed the association between concussion history, cognitive functioning, general health, and psychological health in a sample of active U.S. soldiers, scored higher than the current study's (Dretsch, Silverberg and Iverson 2015). Dretsch, Silverberg and Iverson (2015) cohort had a mean age of 26 years and a mean number of two concussions each, which is similar to the results in the current study (28 years of age and 2.4 concussions). Of the seven neurocognitive domains tested in the Dretsch, Silverberg and Iverson (2015) study, four of the domains (reaction time, cognitive flexibility, processing speed, executive function and verbal memory) fell in the above average category and complex attention fell under the average category, which is much higher in category scoring compared to the current study where these five specific domains scored in the low/low average categories. The current study's NCI scores for these five domains scored less than Dretsch, Silverberg and Iverson's (2015) study despite the ages of respondents and the number of concussions sustained by respondents in both studies being similar. A main

reason for the differing results between Dretsch, Silverberg and Iverson's (2015) study and this study, could be due to Dretsch, Silverberg and Iverson (2015) using both male and female active-duty U.S. soldiers preparing for deployment as respondents, compared to only male first division/amateur KwaZulu-Natal rugby union players being used in this study.

5.2.2 Concussion history and cognitive function

This study revealed that the majority (68.6%, $n = 48$) of the players have sustained at least one concussion (Figure 4.3), with 2.4 ± 1.6 being the average number of concussions reported per player, which is similar to the study conducted by Hume *et al.* (2017) study which found an average of 2.9 ± 2.2 concussions for former male New Zealand community rugby players, aged 23 to 72 years. Given that the athletes from the Hume *et al.* (2017) study were former players and of an older age group compared to the current study's age group (19 to 45), one would have expected the current cohort to have a lower mean concussion rate as they have not experienced as long a rugby playing career as the Hume *et al.* (2017) cohort has.

The current study did not report a significant relationship between the number of concussions and respondent's NCI score ($p > 0.05$) (Table 4.10), but there were medium to large effects for the relationship between the number of concussions the respondents sustained and most of the neurocognitive domain scores (Table 4.16). Even though the p-values were not significant, the medium to large effects do suggest that the neurocognitive domain scores have an indirect relationship with the number of concussions the respondents sustained. Therefore, more concussions tend to yield lower NCI score ratings than higher NCI score ratings. This study's finding was similar to Hume *et al.* (2017) and McCrory *et al.* (2018) studies but different to McMillan *et al.* (2017) and Dretsch, Silverberg and Iverson (2015)

Specifically, Hume *et al.* (2017) found a relationship between the player groups (retired elite and community level rugby players) who have experienced one or more concussions and cognitive functioning specifically in cognitive flexibility (96 ± 12.7), complex attention (103 ± 11.4), and executive function (96 ± 41.1),

with regards to the player group who had no concussion history. This relationship reported by Hume *et al.* (2017) was similar to this study as the respondents' scores from the current study for cognitive flexibility (75.5 +/- 27.5), complex attention (78.5 +/- 41.1) and executive function (77.3 +/- 27.5) were even less compared to the community level players scores in Hume *et al.* study. Therefore, according to the current study and the Hume *et al.* study, exposure to one or more SRC may lead to small to moderate deficits in cognitive functioning.

This finding is also supported by Zoccola *et al.* (2020) and McCrory *et al.* (2018), who have elaborated that cognitive vulnerability can occur in rugby players compared with controls, and that SRC can be related with changes in neuroanatomy and neurocognitive function, which correlates with performance in neurocognitive testing. Gardner, Shores and Batchelor (2010) reported similar results to this study as well. That study reported that adult male rugby players reporting three or more concussions demonstrated significantly reduced visual motor speed scores and processing speed scores, compared with athletes who reported zero sport concussions.

In contrast to the above studies, McMillan *et al.* (2017) and Dretsch, Silverberg and Iverson (2015) reported no significant associations between number of concussions and performance on neurocognitive tests. McMillan *et al.* (2017) reported that the rugby players performance was poorer in verbal learning ($p = 0.022$) and fine co-ordination of the dominant hand ($p = 0.038$) compared to the control group, but not significantly different on other cognitive tests ($p > 0.05$).

A possible explanation for the difference in results between the McMillan *et al.* (2017) study and the current study, may be that they used different tools to measure the respondents' cognitive functioning. McMillan *et al.* (2017) used multiple cognitive tests and health questionnaires including: The Montreal Cognitive Assessment screening test of general cognitive function, Symbol Digit Test (information processing speed); Trail Making Test (executive function); Rey Auditory Verbal Learning Test (memory and learning); Sustained Attention to Response Task (sustained attention); Judgement of Line Orientation Test (visual perception), Lafayette Grooved Pegboard (fine hand coordination), The Hospital Anxiety and Depression Scale, Rivermead Post Concussion Symptoms

Questionnaire, Short Form Health Survey, Glasgow Outcome Scale-Extended and the Alcohol Use Disorders Identification Test. The current study made use of one computerised neurocognitive screening battery (CNSVS) to evaluate complex attention, reaction time, processing speed, cognitive flexibility, psychomotor speed, executive function, simple attention, motor speed and memory, as well as the General Rugby Health questionnaire. In the McMillan *et al.* (2017) study the number of concussions sustained by the rugby players were grouped into three levels: no repeat concussions (0–1), moderate repeat concussion (2–9) and high repeat concussion (10 or more), which is different to the current study where the number of concussions was analysed as a continuous variable.

Dretsch, Silverberg and Iverson (2015) reported an association between post-concussive symptoms and a history of three or more concussions. There were no significant differences between the four concussion groups on any of the neurocognitive measures ($p > 0.006$) in his study. Individuals with three or more prior concussions were associated with more current post-concussive symptoms, however, this relationship may be complicated by other factors, such as longer deployment periods and a higher level of traumatic stress. One of the main explanations for the differing results between Dretsch, Silverberg and Iverson (2015) study and this study could be the target population. This study used 70 male first division KwaZulu-Natal rugby union players, whereas the Dretsch, Silverberg and Iverson study used 458 active-duty soldiers (male 92.9% and female 6%) as respondents. Another explanation could be the statistical analysis used. To explore the impact of cumulative concussions, Dretsch, Silverberg and Iverson categorised participants into one of four groups based on the number of concussions they reported having over their lifetime. The four groups included: zero, one, two, and three or more prior concussion, compared to this study which ran the number of concussions as a continuous outcome. In addition, there were similarities between these two studies. The mean ages of both studies samples were similar; the mean age for Dretsch, Silverberg and Iverson study was 26 years and the current study's mean age was 28 years. The CNSVS test battery was also used in Dretsch, Silverberg and Iverson study but only assessed complex attention, reaction time, processing speed, cognitive flexibility, and memory, but did not include executive function, simple attention, motor speed and

psychomotor speed. However, the health questionnaires included in Dretsch, Silverberg and Iverson study were different to the current study and included the Neurobehavioral Symptom Inventory, PTSD Checklist-Military Version, Zung Depression and Anxiety Scales, Perceived Stress Scale, Pittsburgh Sleep Quality Index, Epworth Sleepiness Scale, and the Alcohol Use and Dependency Identification Test.

Therefore, it is possible that if the exact testing tools and statistical analyses were used in this current study as McMillan *et al.* (2017) and Dretsch, Silverberg and Iverson used in their studies, similar relationships would have been reported between the number of concussions and cognitive function for the current cohort.

5.2.3 Rugby playing position / Body weight and cognitive function

More than half of the respondents playing position was as a forward player (60%, $n = 42$), and 40% a backline player (Table 4.3). This ratio of the players positions is expected, since a rugby team which consists of 15 players, has eight forwards and seven backline players. These results indicate that this cohort was representative. This study reported a weak correlation between playing position (forwards/back) and the respondents NCI score ($r = 0.25$), therefore no significant effect was found (Table 4.10). To our knowledge there is limited published literature that has investigated whether rugby playing positions has an effect on the rugby players cognitive functioning. However, a study performed by Shuttleworth-Edwards and Radloff (2008) reported low-medium to medium effect sizes for poorer performance for the forwards versus backs on Digit Symbol Substitution (DSS). According to Shuttleworth-Edwards and Radloff (2008), the poorer performance by the forwards on DSS was strongly attributable to the forwards being more exposed to contact play whilst practicing and/or playing a match. However, we cannot compare our study's results to Shuttleworth-Edwards and Radloff's (2008) results, the current study did not test DSS, therefore there is no data to compare Shuttleworth-Edwards and Radloff's (2008) data to. There is no other literature, to our knowledge, that is readily available to us to compare our data to.

This study revealed no significant relationship ($p > 0.05$) between the respondents' playing position (forward/back) and the number of concussions they have sustained (Table 4.11). There was also no statistically significant relationship reported in this study ($p > 0.05$) between the respondent's body weight and the respondents NCI.

However, the results of Baccouche *et al.* (2014) study indicated a negative relationship between BMI and cognitive function. A high BMI (weight/height squared ≥ 25) was related to reduced cognitive performance, but only in specific areas of functioning such as memory. The results of the Baccouche *et al.* (2014) study indicate that BMI is related to poor cognitive function but the exact mechanisms for this association are unclear. The current study did not make use of the respondents BMI and only recorded the respondents' weight, which provides a possible explanation as to why the results differ.

5.3 Concussion history

5.3.1 Rugby playing experience / Age and concussion history

There was no significant relationship between the number of years of rugby playing experience and the number of concussions sustained by the respondents (Figure 4.9). This finding is supported by an article conducted by Baker *et al.* (2013) who reported that the amount of seasons played as well as level of participation (club or academy) did not predict any rise in the number of concussions reported by the rugby players in Ireland.

With regard to the mean number of concussions sustained in this current study by the players between the ages 19 and 45 2.4, concussions were reported per player (Figure 4.3). Baker *et al.* (2013) reported similarities to this current study regarding the mean number of concussions rugby players sustain. In that study a mean number of 2.25 concussions were reported for rugby union players in Ireland who were under the 20 years age category, which is similar to the finding that Hume *et al.* (2017) reported. Hume *et al.* (2017) reported a mean number of 2.9 concussions for former New Zealand community level rugby union players between the ages of 29 and 72. All these results suggest that age does not play a significant role in concussion risk amongst rugby players.

This current study agreed with the systematic review conducted by Abraham *et al.* (2013), that age did not play a significant role in the respondents' (rugby players) concussion risk. However, the AMSSM position statement reported that youth athletes are more susceptible to concussions accompanied by a catastrophic injury related to the physiological differences between younger and older brains (Harmon *et al.* 2013: 4). A study conducted by Tsushima *et al.* (2019) reported the relative risk for a concussion amongst athletes of 12 different sports was nearly two times greater in 18-year-olds than in 13-year-old athletes. A reason for the differing results could be due to the fact that this study did not use youth participants (<19-year-olds) and that the participants used in Harmon *et al.* (2013) and Tsushima *et al.* (2019) studies were athletes from various sports and not specifically rugby players.

5.3.2 Rugby playing position / Body weight and concussion history

Body weight had a small effect on the frequency of concussions that respondents sustained, however the Pearson coefficient between these two variables was not significant ($p = 0.33$), therefore no significant relationship between weight and concussion risk was found (Table 4.11).

In contrast to this study, Schneider *et al.* (2013) reported that the players in the lowest body weight quartile had an increased risk of concussion, which may be due to players using their weight to their advantage, resulting in heavier players causing concussions in their lighter opponents. The lack of a strong relationship in the present study may be explained by the fact that the Schneider *et al.* (2013) study was conducted on junior ice hockey players, while the present study was on adult rugby players.

This study revealed no significant relationship ($p > 0.05$) between the respondents playing position (forward/back) and the number of concussions they have sustained (Table 4.11). This finding is similar to those of Abraham *et al.* (2013), Baker *et al.* (2013) and Fuller, Tylor and Raftery (2015) in terms of the influence playing position has on concussion risk. Abraham *et al.* (2013), Baker *et al.* (2013) and Fuller, Tylor and Raftery (2015) reported that rugby playing position (forward/back) has no effect on concussion risk. However, Kearney and See

(2017) presented results different to this study. Kearney and See (2017) reported that forward players were more at risk of concussions in general, as the forward players suffered with the majority (84.24%, $n = 65$) of the total reported concussions ($n = 77$). However, Kearney and See's study used younger rugby players (11 to 17-year olds) as their participants as well as 17 female participants, compared to this study. The current study used respondents between the ages of 19 and 45, and only male respondents, which could explain the reason why there was a difference in results reported. According to the AMSSM consensus statement the most common mechanism of a concussion is player-to-player contact therefore positions involved in frequent collision impacts, such as scrummaging, tackling, mauling and breakdown rucking which forward players are more frequently involved in compared to backline players, sustain more concussions (Harmon *et al.* 2013: 4). In contrast, Fraas *et al.* (2014) reported that the relative proportion of concussions was higher for backs than forwards; however, the severity of injury was greater for forwards. Scrum-halves and flankers accounted for the majority of concussions reported in the Fraas *et al.* (2014) study. A reason for the different results reported by Fraas *et al.* (2014) compared to this study's results could be due to the differing level of competition the participants were involved in. In the current study, first division club level rugby players were used, whereas in the study conducted by Fraas *et al.* (2014) elite Irish rugby union players were used as participants.

5.3.3 Other injury history and concussion history

The 70 respondents reported a mean of 5.1 injuries per person whilst playing rugby. The results of this study showed hamstring or quadriceps tears (37.1%, $n = 26$) to be the most common injury type, with shoulder dislocations and ankle ligament tears (35.7%, $n = 25$) the second most common (Figure 4.1.). This study showed similarities to King *et al.* (2016) and Brooks *et al.* (2005) who reported that injury to the lower limb was the most common injury recorded.

This study revealed a directly proportional relationship between the number of concussions and the number of injuries (non-concussive injuries) the respondents sustained (Table 4.9), implying an increase in the number of concussions would tend to lead to an increase in the number of injuries, and vice versa. The odds

ratio in this study indicated that a player is 1.3 times more likely to have had a concussion having had a higher number of injuries compared to a lower number of injuries (Table 4.15). This study reported similarities to Cross *et al.* (2016) in the risk of injury after a concussion. Cross *et al.* (2016) reported that following a concussion, players were 1.6 times more likely to suffer a match injury of any type than players who had not sustained a concussion. A study conducted by Houston *et al.* (2018:1355) also revealed that athletes who reported multiple concussions had the greatest risk of ankle sprain or knee injury history compared to athletes with no previous concussions.

5.4 Summary

This study revealed the inverse relationship between cognitive functioning and duration of exposure to rugby ($p = 0.05$), as well as the medium to large size effect association between cognitive functioning and a history of concussion ($p > 0.05$), amongst first division KwaZulu-Natal Rugby Union. Cognitive function has been assessed in South Africa amongst Premium League rugby players (Zaccola *et al.* 2020), but not using the same measurement tool (CNSVS) which was used in the New Zealand rugby cohort (Hume *et al.* 2017). Consequently, there is a general lack of information from previous studies relating to the correlations of cognitive functioning, and whether or not the number of years of rugby playing experience as well as the number of concussions that players sustain whilst playing/practising rugby has an effect on the players CNS Vital Signs NCI scores. Therefore, this study has provided valuable information which can be added to the literature, such as the finding ($p = 0.05$) that revealed the number of years of rugby playing experience did have a small to moderate effect on the respondents NCI score. Despite a history of concussion/s not being associated with NCI scores ($p > 0.05$), an increased number of concussions had medium to large effect size associations with poorer NCI domain scores. Similar relationships were found in older, retired rugby players in New Zealand, but not in similarly aged active-duty military persons. It was also noted that the current study's NCI overall performance was worse than older, retired New Zealand rugby players, as well as age matched active-duty U.S. soldiers.

This study shows some evidence of a negative association between playing amateur rugby or sustaining concussions whilst playing/practicing rugby and cognitive functioning. Therefore, this study can help the rugby community become more aware of the possible risks if players do sustain one or multiple SRCs, and can further help players gain access to medical assistance and support including prevention, management and treatment if a concussion or neurocognitive decline is suspected.

CHAPTER 6: CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter draws conclusions from the results and discussion of the study as to how the duration of exposure to rugby and a history of concussions whilst playing/practising rugby affects first division/amateur KwaZulu-Natal Rugby Union players cognitive functioning. This chapter summarises key findings, the strengths of the study, as well as the limitations of the study. Furthermore, recommendations for future studies are outlined, with an emphasis towards achieving a greater understanding of neurological health in rugby players.

6.2 Key findings

- The majority of respondents played rugby for 10 to 19 years (53.6%).
- Respondents experienced an average of 5.1 injuries per person whilst playing/practising rugby.
- The most common injury sustained by the respondents was hamstring or quadricep tears (37.1%). Shoulder dislocations and ankle ligament tears were the second most common injury (35.7%).
- 68.6% of respondents had sustained at least one concussion in their career whilst playing/practising rugby.
- A mean number of 2.4 concussions per player was reported.
- Domain scores ranged between the Low to Average categories with the standard scores for Complex Attention, Cognitive Flexibility, Executive Function and Simple Attention falling under the Low category.
- The respondents mean NCI score fell under the Low Average category.
- Small to moderate effect sizes was observed with the number of years of playing rugby and NCI score ($p = 0.05$) (Figure 4.9), where an increase in one year of playing rugby resulted in a decrease of 0.6 in the NCI score of the respondents.

- An increased number of concussions had medium to large effect size associations with poorer NCI domain scores ($p > 0.05$).
- An association was found between the number of injuries (non-concussive injuries) and the number of concussions the respondents had sustained i.e., an increase in the number of concussions tended to lead to an increase in the number of injuries the respondents experienced.

6.3 Strengths of the study

- To the researcher's knowledge, this is the first rugby union study in South Africa to determine the association between cognitive functioning and duration of exposure to rugby as well as a history of concussion, using the CNS Vital Signs test battery, in first division male rugby union players.
- This study was a sufficiently powered study using a reliable/valid cognitive score in a representative sample of amateur rugby players within a province of South Africa.
- The CNSVS test battery was donated to the researcher for the use in this study and is widely used by neuropsychologists and known to be reliable and valid.
- The New Zealand Rugby Health General Health Questionnaire (NZRH GHQ) was donated to this study by Professor Patria Hume. This NZRH GHQ is being used globally by the Research Codes Rugby Group (RCRG) members. Both the CNSVS test battery and NZRH GHQ were used in a comparable cohort in New Zealand and thus allowed direct comparison between the two cohorts.

6.4 Limitations

- This study only included male rugby union respondents between the ages of 19 and 45.
- Respondents had to play at least one year/season of rugby to participate in this study.
- Respondents were required to complete the questionnaire and CNSVS test battery in their own time via a laptop or computer. This may have led to a

decreased participation rate since there was no designated time period to complete it.

- The questionnaire was administered during the playing season and respondents were asked to recall information about their past rugby experience. It is possible that respondents may have made errors or forgotten information over the duration of their past playing seasons.
- Injuries and concussions were self-reported. This may have caused over or under reporting of concussions which was a main independent variable in this study.
- This study was a cross-sectional study and did not have a matched non-contact sport group for comparison.

6.5 Recommendations

- A more diverse population size should be included in future studies regarding the associations between cognitive functioning and duration of exposure to rugby union, as well as a history of concussion amongst first division KwaZulu-Natal rugby union players. This could include a national study that includes all the provinces in South Africa, thus ensuring a greater understanding of cognitive functioning amongst rugby players. This could provide more accurate and externally valid results with a sample that is more representative of South Africa.
- Future studies should include all ages of both male and female rugby players to see if other associations can be identified and to draw comparisons between genders, as well as to enlarge the population size. However, there is a limited population of female amateur rugby union players in South Africa which would make gaining this data challenging.
- More attention could be paid in future studies regarding the knowledge that the rugby players have of cognitive functioning and concussion, and the role healthcare professionals play in rugby injuries, and what treatment protocol was most effective for their injuries.
- Regular cognitive testing could be introduced at the start of each season to check cognitive function status.

- A 'Concussion Passport' should be given to each player at the start of their first playing season. This 'passport' should be used by medical staff to log how many concussions a player has sustained, so that monitoring of players can take place.

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Appendixes

Appendix A: Letter of Information (research participant)



LETTER OF INFORMATION

Title of the Research Study:

Cognitive Function among First Division Kwazulu-Natal Rugby Union Players and its associations with duration of exposure to the sport and a history of concussion.

Principal Investigator/s/researcher:

Emily Skelding, current 5th year Chiropractic student.

Co-Investigator/s/supervisor/s:

Prof JD Pillay- PhD (Physiology)
Dr JC Brown- PhD (Ex science)
Prof P Hume- PhD (Biomechanics)

Brief Introduction and Purpose of the Study:

This study will involve 70 rugby players, approximately 18 players from each of the following rugby clubs: Westville Old Boys, Jaguars, UKZN Durban and Hillcrest Villagers. The purpose of which is to determine the cognitive functioning of the rugby players and the impact concussions have on their cognitive abilities through a questionnaire and Central Nervous System (CNS) Vital signs battery test.

Outline of the Procedures:

In order to participate in this study, you must have played a minimum duration of one year in the First Division Kwazulu-Natal Rugby Union. You will not be able to participate if you have experienced a concussion from another incident or sport. You will be required to complete a self-report rugby general health questionnaire which will take place at your specific rugby club prior to practice or on a separate scheduled day and time. You will be asked questions regarding engagement in sport, sport-related injury, The Alcohol Use Disorders Identification Test (AUDIT) and concussion history, and demographic information. This questionnaire will be confidential and after completion you will be

required to hand it to the researcher and will be stored in a separate ballot box. The questionnaire should not take more than thirty minutes and if you have any questions please contact the researcher to address any queries. After completing the questionnaire, you will be required to complete the CNS vital signs battery test that will be completed on a laptop and shouldn't take more than thirty minutes. It will include seven tests assessing functioning across different cognitive domains, including verbal, visual and composite memory, psychomotor and information processing speed, reaction time, executive functioning, motor speed, cognitive flexibility, simple and complex attention. Therefore, in total the required time needed by the researcher from you will be approximately one hour. The results of the test will be saved in a password protected file on a USB. Only the researcher, supervisors and psychologist will have access to the questionnaire and the test results. Respondents results will be emailed to them if required, with the researcher's contact details, so if the participant wants to discuss or query the results a meeting can be made. The qualified psychologist will evaluate every participant's results and if he/she reasons that the participant needs treatment a meeting will be held with the participant, researcher and psychologist to discuss the situation.

Risks or Discomforts to the Participant:

The Alcohol Use Disorders Identification Test (AUDIT) will be used in the questionnaire, therefore if you suffer with alcoholism or alcoholic related disorders it may make you feel anxious or uncomfortable. The CNS battery test may also appear as stressful as it will give you a feeling of a "test situation" which may come across as anxiety producing to some individuals. If neurocognitive deficits are found, a diminished self-esteem may be felt or cause you to experience embarrassment or regret.

Benefits:

The results of this study will benefit you as you will receive neurocognitive data such as verbal, visual and composite memory, processing speed, reaction time and motor speed results. The CNS battery test will give you an overall indication of your neurocognitive functioning. The questionnaire results will reveal whether you meet the WHO (World Health Organization) AUDIT that assesses alcohol consumption, drinking behaviours, and alcohol-related problems. This information will give you insight into your health and can help you make appropriate changes. Results of the study will be made available in the form of a dissertation at the Durban University of Technology library.

Reason/s why the Participant May Be Withdrawn from the Study:

If you have experienced concussions from other incidents other than rugby. If you cannot perform the CNS battery test. You are free to withdraw from the study at any stage. There will be no adverse consequences for you, should you choose to withdraw from the study.

Remuneration:

Participation in this study will be entirely voluntary and without remuneration. You are free to withdraw from the research at any time.

Costs of the Study:

There is no cost to you or your family for you participating in this research.

Confidentiality:

All research data will be submitted to the Chiropractic program for storage and disposal. After 5 years the data will be shredded. Questionnaires will be kept in a locked cupboard and kept safe during the research procedure.

Research-related Injury:

Research-related injuries should not occur.

Persons to Contact in the Event of Any Problems or Queries:

Please contact the research student, Emily Skelding (072 051 3033), my supervisor, Prof. JD Pillay (031 373 2398), my co-supervisor, Dr.JC Brown (0820935926), or the Institutional Research Ethics Administrator on 031 373 2375. Complaints can be reported to the DVC: Research, Innovation and Engagement Prof S Moyo on 031 373 2577 or moyos@dut.ac.za.

Appendix B: Recruitment flyer



DEPARTMENT OF
CHIROPRACTIC
AND SOMATOLOGY

- ✓ Are you a rugby player?
- ✓ Ever been concussed due to rugby?

The Global Rugby General Health Research Programme (GRGHRP) and Durban University of Technology (DUT- Chiropractic Department) are conducting a project on the short and long term effects of rugby on rugby players.

Get involved if you are:

- A 1st division rugby union player between 19-45 years of age.
- A retired 1st division rugby union player between 19-45 years of age.

FREE head assessment!

Each participant will be tested using the CNS Vital Signs battery test to measure players cognitive functioning. Results will be assessed by a qualified psychologist and will be made available to participants.

For more information:

Contact: **Emily Skelding** at 072 051 3033

Email: emilyskelding1@gmail.com

Appendix C: General Health Rugby Questionnaire

General Health Rugby Questionnaire

Section 1: Demographics

Please enter your date of birth

Please select the rugby club you play for:

Westville Old Boys (W.O.B)
Hillcrest Villagers
University of KwaZulu-Natal (UKZN)
Durban University of Technology (DUT)

What is your age? _____

What is your height (cm)? _____

What is your body weight (kg)? _____

What is your ethnic origin? (Please tick all that apply)

Caucasian
Asian
Black African
Indian
Coloured
Mixed Race
Other _____

How many years of rugby playing experience do you have? _____

Section 2: Other General Details

In this section we want to get some general information about your life and your living situation.
The next questions are about your schooling:

1. What is your highest secondary school qualification?

- a. No formal school qualification
- b. Bachelor's Pass
- c. National Senior Certificate (NSC)

2. Please Tick any trade, academic or professional qualifications you have obtained since leaving secondary school.

- a. Trade Certificate
- b. Advanced Trade Certificate
- c. Diploma
- d. Bachelor's degree

- e. Post-Graduate diploma
- f. Post-Graduate Degree
- g. Professional qualification (e.g. law, medical, accountancy)

Please specify:

The following questions are about your home situation.

3. Are you currently

- a. Single
- b. Married or living with a partner
- c. Separated or divorced
- d. Widowed

4. Have you ever been:

- a. divorced
- b. separated
- c. widowed

5. Who else lives with you? (Please tick all that apply)

- a. I live on my own.
- b. Spouse/partner
- c. Parents (including in-laws)
- d. Other relatives (including children)
- e. Non-relatives/ other friends

6. How many children do you have? None OR number of children ____

8. Do you have any health problems associated to rugby participation that impact your ability to work?

Yes No N/A

If yes, please describe _____

10. Have you ever been in a serious motor vehicle accident?

Yes No

If yes, please give the month and year.....

Did you experience whip lash? Yes No

Did you experience a head injury? Yes No

Section 3: Rugby Experience

In this section we want to find out about your experience as an athlete.

1. What is your major sport?

Rugby Union
Other (specify)

The following questions relate to your major sport:

2. At what age did you first play rugby?

Less than 6 years
6-7 years
8-9 years
10-11 years

12-13 years
14-15 years
16-17 years
18-19 years
20 years or older

3. What is the highest level of competition you have competed at?

Club level (Premium, 1st division 2nd division etc)
Regional (KZN)
National (RSA)

4. How many years did you compete at each level?

Club level _____
Regional _____
National _____

5. What is your average playing body weight? _____

6. What level of sport did you play in your last season (tick all that apply)?

National
Regional
Premier league club level
1st division club level
3rd division club level
Other: _____

8. What position do you play most often in rugby?

Rugby League
1. L. head prop
2. T. head prop
3. Hooker
4. Lock
5. Openside flanker
6. Blindside flanker
7. No. 8
8. Scrum-half
9. Fly-half
10. Inside centre
11. Outside centre
12. Wing
13. Full-back

Section 4: Lower limb tasks

In this section we ask you to rate your ability to do the following activities in the **past 24 hours** by selecting the number below the appropriate response. If you did not have the opportunity to perform an activity in the **past 24 hours**, please make your *best estimate* on which response would be the most accurate.

Please also rate how important each task is to you in your daily life according to the following scale:

- 1. = Not important**
- 2. = Mildly important**
- 3. = Moderately important**
- 4. = Very important**

1. Please rate your active daily living

	NO DIFFICULTY	MILD IMPORTANCE DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE	OF TASK
1. Walk for 10 minutes	4	3	2	1	0	1 2 3 4
2. Walk up or down 10 steps (1 flight)	4	3	2	1	0	1 2 3 4
3. Stand for 10 minutes	4	3	2	1	0	1 2 3 4
4. Stand for a typical work day	4	3	2	1	0	1 2 3 4
5. Get on and off a bus	4	3	2	1	0	1 2 3 4
6. Get up from a lounge chair	4	3	2	1	0	1 2 3 4
7. Push or pull a heavy trolley	4	3	2	1	0	1 2 3 4
8. Get in and out of a car	4	3	2	1	0	1 2 3 4
9. Get out of bed in the morning	4	3	2	1	0	1 2 3 4
10. Walk across a slope	4	3	2	1	0	1 2 3 4

2. Please rate your recreational activities

	NO DIFFICULTY	MILD IMPORTANCE DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE	OF TASK
1. Jog for 10 minutes	4	3	2	1	0	1 2 3 4
2. Pivot or twist quickly while walking	4	3	2	1	0	1 2 3 4
3. Jump for distance	4	3	2	1	0	1 2 3 4
4. Run fast/sprint	4	3	2	1	0	1 2 3 4
5. Stop and start moving quickly	4	3	2	1	0	1 2 3 4
6. Jump upwards and land	4	3	2	1	0	1 2 3 4
7. Kick a ball hard	4	3	2	1	0	1 2 3 4
8. Pivot or twist quickly while running	4	3	2	1	0	1 2 3 4
9. Kneel on both knees for 5 minutes	4	3	2	1	0	1 2 3 4
10. Squat to the ground/floor	4	3	2	1	0	1 2 3 4

Section 5: Injury and Concussion Experience

This section asks about your experience with injuries that have affected your sport performance or continue to affect your health. For the purposes of this question, an injury is defined as a physical problem that caused you to miss:

- At least one rugby game OR
- At least two rugby team practices or scheduled training sessions OR
- Required assessment and/or treatment by a health professional (doctor, dentist, physiotherapist/chiropractor, nurse etc).

1. Did you develop any medical conditions whilst playing your sport? Yes No N/A

If Yes please state what they were and when if you can.

2. In your rugby career, did you ever sustain any of these injuries?

	# total injuries	# total surgeries	Avg. # days lost for each injury	Did the injury end your rugby season/s?	Are you still affected by the injury?
Eye injury				Yes No	Yes No
Neck burner/numbness				Yes No	Yes No
Neck fracture/spinal cord injury				Yes No	Yes No

Disc rupture/herniation				Yes No	Yes No
Shoulder dislocation				Yes No	Yes No
Biceps/triceps tear				Yes No	Yes No
Elbow dislocation/separation				Yes No	Yes No
Arm/wrist/hand fracture				Yes No	Yes No
Hip dislocation/fracture				Yes No	Yes No
Thigh/leg fracture				Yes No	Yes No
Hamstring/Quad tear				Yes No	Yes No
Knee/Patellar dislocation				Yes No	Yes No
MCL tear				Yes No	Yes No
LCL tear				Yes No	Yes No
ACL tear				Yes No	Yes No
PCL tear				Yes No	Yes No
Meniscus tear				Yes No	Yes No
Calf/achilles tendon tear				Yes No	Yes No
Ankle ligament tear				Yes No	Yes No
Ankle/foot fracture				Yes No	Yes No

N/A.....

3. Main sport related Injury

The following is a list of injuries sometimes experienced by rugby players. Please tick any of these injuries that you have experienced **as a result of your main sport participation** that meet the above injury definition. (Please tick all that apply).

- a. No injury due to main sport participation
- b. Cut/laceration to the face
- c. Neck strain or sprain
- d. Shoulder strain or bruising
- e. Shoulder dislocation
- f. Collarbone broken/fractured
- g. Upper or lower back pain
- h. Ribs broken/fractured or bruised
- i. Thumb sprain
- j. Thigh strain or bruising
- k. Hamstring or calf strain or tear
- l. Knee ligament injury
- m. Achilles tendonitis

N/A.....

4. Did you have any chronic (long term) injuries or conditions that required you to use special safety gear (e.g. strapping, thermoskin, brace, head gear) when playing rugby?

If Yes, please describe:

5. Did you ever have an injury during a playing season that caused you to end your season early?

Yes No N/A

If Yes, please specify _____

6. Have you ever used anything (e.g. pain killers, injections, ultrasound treatments, etc.) to make it possible for you to play rugby while recovering from an injury?

Yes No N/A

If Yes, please specify _____

7. Have you ever hidden an injury or gone against medical advice so you could continue playing either before or during a game? Yes No N/A

8. Did you ever have any difficulties obtaining medical advice for your sporting injuries? Yes No
N/A

9. Has a physician or health professional ever told you that you suffer from osteoarthritis/ degenerative arthritis? Please check all body parts that this diagnosis has been made for:

- a) Neck
- b) Left Shoulder
- c) Right Shoulder
- d) Mid Back
- e) Left Elbow
- f) Right Elbow
- g) Lower Back
- h) Left wrist/Hand/Fingers
- i) Right wrist/hand/fingers
- j) Left Hip
- k) Right hip
- l) Left knee
- m) Right knee
- n) Left Ankle
- o) Right Ankle
- p) Left foot/toes
- q) Right foot/toes

The following questions deal specifically with concussions you may have sustained while playing rugby. Concussion symptoms include headache, dizziness, nausea, short term memory loss, and/or aversion to bright light, but not all symptoms have to be present for diagnosis. At its worst, concussion can bring loss of consciousness.

10. Did you sustain any concussions while playing (or practising) rugby?

Yes No N/A (move to Q11)

If Yes how many? 1 2 3-4 5-9 10-19 20+ Don't know but more than 3

10a. Number of times you were evaluated by a physician or other health professional

0 1 2 3-4 5-9 10-19 20+ Don't know but more than 3

10b. Number of times that you were 'knocked out' (unconscious for a period of time)

0 1 2 3-4 5-9 10-19 20+ Don't know but more than 3

10c. Number of times you had short-term memory loss

0 1 2 3-4 5-9 10-19 20+ Don't know but more than 3

10d. Number of times that you had prolonged symptoms (lasting 4 weeks or more)

0 1 2 3-4 5-9 10-19 20+ Don't know but more than 3

10e. Number of times you returned to competition immediately (same day) following concussion

0 1 2 3-4 5-9 10-19 20+ Don't know but more than 3

10f. Number of times you returned to play (same game/session) after concussion

0 1 2 3-4 5-9 10-19 20+ Don't know but more than 3

10g. Number of times you returned still feeling dizzy or disoriented

0 1 2 3-4 5-9 10-19 20+ Don't know but more than 3

10h. Number of times you never reported your concussion to medical staff

0 (always reported) 1 2 3-4 5-9 10-19 20+ Don't know but more than 3

10i. How many total games did you miss due to any concussions?

0 1 2 3-4 5-9 10-19 20+ Don't know but more than 3

10j. Did you ever suffer a mini stroke or stroke after a concussion?

Yes No

10k. Do you, or anyone who lives with you, have any concerns about your memory or ability to think?

None A few mild concerns some definite concerns major concerns

10l. Do you currently find it difficult to concentrate for long periods of time?

Yes No

10m. Do you currently find it difficult to remember things?

Yes No

10n. Over the last few years have you suffered any unexplained dizzy spells (e.g. not due to diet)?

Yes No

10o. Have you ever been diagnosed with 'post concussion syndrome'?

Yes No Don't know

10p. Do you currently suffer from post-concussion syndrome?

Yes No Don't know

10q. Do you experience regular (at least once/week) bouts of headaches?

Yes No

If yes, how many years have you suffered this?

less than 1 year; 1-2 years; 3-4 years; 5 years or more

10r. Are you worried about the possible effect of previous concussions on your current and future health?

Yes Somewhat No

11. Do you have any other comments regarding concussion experiences?

Section 6: Health, Lifestyle and Well-Being

This section asks about you and your health, well-being and factors related to your current lifestyle.

1. How would you rate your overall health?

- a) Poor
- b) Not too good
- c) Good
- d) Very good

2. Do you currently take or have you in the past taken medication for:

	Currently		Previously	
a) Type 2 Diabetes	Y	N	Y	N
b) Cardiovascular disease	Y	N	Y	N
c) High Blood Pressure	Y	N	Y	N
d) Osteoarthritis	Y	N	Y	N
e) Depression	Y	N	Y	N
f) Anxiety	Y	N	Y	N
g) Regular headaches/migraines	Y	N	Y	N
h) Stroke	Y	N	Y	N
i) Motion sickness/Vertigo	Y	N	Y	N

3. Do you suffer from or have you in the past:

	Currently		Previously	
a) Sleeplessness	Y	N	Y	N
b) Heart arrhythmia (irregular heart beat)	Y	N	Y	N
c) Irritability	Y	N	Y	N
d) Depression	Y	N	Y	N
e) Anxiety	Y	N	Y	N
f) Back pain	Y	N	Y	N
g) Severe & regular headaches	Y	N	Y	N
h) Severe & regular joint pain (Please specify joint):	Y	N	Y	N
i) Memory loss	Y	N	Y	N
j) Motion sickness/vertigo	Y	N	Y	N

4. Have you ever suffered from:

- a) Stroke (including TIA)
(please specify age): Y N
- b) Heart attack
(please specify age): Y N

5. In the last 12 months, have you had any worries about your health? Yes No

If YES, please describe: _____

6. In the last 12 months, did you spend any time in hospital? Yes No

7. Please list any medication(s) you have been taking over the last four weeks _____

8. In the last four weeks, have you had any difficulty with the following:

	None	Rarely	Sometimes	Often	Always
Difficulty falling asleep					
Waking in the night and taking a long time to get back to sleep					
Waking a long time before you have to					
Needing a lot more sleep than you used to					

9. Which of the following categories best describes your smoking:

- a) Never smoked (go to Question 12)
- b) Ex- smoker (go to Question 12)
- c) Occasional smoker
- d) Regular smoker

10. How many cigarettes have you smoked in the last week? ____ cigarettes

11. Do you usually smoke about this number of cigarettes per week?

- a. Yes
- b. No, usually smoke less
- c. No, usually smoke more

12. Have you ever used drugs other than those used for medical reasons? Yes No

13. How often have you used any of the following? Please tick all answers that apply.

Never used

Frequency/month

before a game/sport during a game/sport after a game/sport

Alcohol
Pain killers
Cannabis
Narcotics
Tranquilizers/sleeping pills
Hallucinogens
Inhalants
Anti-depressants
Stimulants
Performance enhancing (eg muscle building)

14. Have you ever experienced withdrawal symptoms (felt sick) when you stopped taking any of the above?

Yes No n/a

15. Have you had medical problems as a result of your drug use (e.g. memory loss, hepatitis, convulsions, bleeding, etc.)?

Yes No N/A

If yes, please state _____

16. Have you ever gone to anyone for help with a drug problem? Yes No

17. Have you ever been in hospital for medical problems related to your drug use? Yes No

This is a question on the occurrence of good and bad feelings that are related to overall life enjoyment. For each feeling listed, tick the ONE that best shows how often you have had that feeling over the past four weeks.

18. Over the past four weeks I have felt:

	Not at all	Occasionally	Sometimes	Often	All
the time					
Everything is going right for me					
I've made a mess of things again					
Satisfied					
Miserable					
My life is on the right track					
Nothing is very much fun any more					
Confident					
Depressed					
My future looks good					
Nothing goes right with me					
Happy					
Down					
Things are going my way					
Life is hardly worth living					
Content					
Upset					

19. Over the last four weeks, have you _____

- Been able to concentrate on whatever you're doing?
 - a. Better than usual
 - b. Same as usual
 - c. Less than usual
 - d. Much less than usual
- Lost sleep over worry?
 - a. Not at all
 - b. No more than usual
 - c. Rather more than usual
 - d. Much more than usual
- Felt capable of making decisions about things?
 - a. More so than usual
 - b. Same as usual
 - c. Less so than usual
 - d. Much less capable
- Felt constantly under strain?
 - a. Not at all
 - b. No more than usual
 - c. Rather more than usual
 - d. Much more than usual
- Felt that you couldn't overcome your difficulties?
 - a. Not at all

- b. No more than usual
 - c. Rather more than usual
 - d. Much more than usual
- Been able to face up to your problems?
 - a. More so than usual
 - b. Same as usual
 - c. Less so than usual
 - d. Much less able
- Been feeling unhappy and depressed?
 - a. Not at all
 - b. No more than usual
 - c. Rather more than usual
 - d. Much more than usual
- Been losing confidence in yourself?
 - a. Not at all
 - b. No more than usual
 - c. Rather more than usual
 - d. Much more than usual
- Been thinking of yourself as a worthless person?
 - a. Not at all
 - b. No more than usual
 - c. Rather more than usual
 - d. Much more than usual
- Felt that you are playing a useful part in things?
 - a. More so than usual
 - b. Same as usual
 - c. Less useful than usual
 - d. Much less useful
- Been able to enjoy your normal day-to-day activities?
 - a. More so than usual
 - b. Same as usual
 - c. Less so than usual
 - d. Much less than usual
- Been feeling reasonably happy, all things considered?
 - a. More so than usual
 - b. Same as usual
 - c. Less so than usual
 - d. Much less than usual

This section asks about your involvement and attachment to family and friends.
Please tick the box above the number on the scale that best represents your feelings:

20. What number best indicates your attachment and involvement with your family?

0	1	2	3	4	5
None				Very Much	

21. What number best indicates your attachment and involvement with your friends?

0	1	2	3	4	5
None				Very Much	

22. What number best indicates your attachment and involvement with your work/university/school?

0	1	2	3	4	5
None				Very Much	

23. What number best indicates your attachment and involvement with your rugby club, team, coaches and other players?

0	1	2	3	4	5
None				Very Much	

**24. What would you do if you had a problem that was upsetting or bothering you?
Would you generally:**

- Try not to talk about it
- Try to talk to someone about it

25. Who would you talk to if you did have a problem or feel upset about something?

(Please tick all that apply.)

- a. Wife/husband/partner
- b. Girl/boyfriend
- c. Mother/mother figure
- d. Father/father figure
- e. Brother
- f. Sister
- g. Teammate
- h. Coach
- i. Other friends
- j. Other: _____
- k. Wouldn't talk to anyone

26. Everyone feels angry or furious from time to time, but people differ in the ways that they react when they get like this. Please read each statement below, then tick the box to the right of the statement that indicates how often you generally react or behave in the manner described. There are no right or wrong answers. Please tick only ONE answer for each statement.

When angry/furious...	almost never	sometimes	often	almost always
1. I lose my temper	1	2	3	4
2. I get angry	1	2	3	4
3. I get very angry	1	2	3	4
4. I am angry	1	2	3	4
5. I am very angry	1	2	3	4
6. I am angry	1	2	3	4
7. I am very angry	1	2	3	4
8. I am angry	1	2	3	4
9. I am very angry	1	2	3	4
10. I am angry	1	2	3	4
11. I am very angry	1	2	3	4
12. I am angry	1	2	3	4
13. I am very angry	1	2	3	4
14. I am angry	1	2	3	4
15. I am very angry	1	2	3	4
16. I am angry	1	2	3	4
17. I am very angry	1	2	3	4
18. I am angry	1	2	3	4
19. I am very angry	1	2	3	4
20. I am angry	1	2	3	4
21. I am very angry	1	2	3	4
22. I am angry	1	2	3	4
23. I am very angry	1	2	3	4
24. I am angry	1	2	3	4
25. I am very angry	1	2	3	4
26. I am angry	1	2	3	4
27. I am very angry	1	2	3	4
28. I am angry	1	2	3	4
29. I am very angry	1	2	3	4
30. I am angry	1	2	3	4
31. I am very angry	1	2	3	4
32. I am angry	1	2	3	4
33. I am very angry	1	2	3	4
34. I am angry	1	2	3	4
35. I am very angry	1	2	3	4
36. I am angry	1	2	3	4
37. I am very angry	1	2	3	4
38. I am angry	1	2	3	4
39. I am very angry	1	2	3	4
40. I am angry	1	2	3	4
41. I am very angry	1	2	3	4
42. I am angry	1	2	3	4
43. I am very angry	1	2	3	4
44. I am angry	1	2	3	4
45. I am very angry	1	2	3	4
46. I am angry	1	2	3	4
47. I am very angry	1	2	3	4
48. I am angry	1	2	3	4
49. I am very angry	1	2	3	4
50. I am angry	1	2	3	4
51. I am very angry	1	2	3	4
52. I am angry	1	2	3	4
53. I am very angry	1	2	3	4
54. I am angry	1	2	3	4
55. I am very angry	1	2	3	4
56. I am angry	1	2	3	4
57. I am very angry	1	2	3	4
58. I am angry	1	2	3	4
59. I am very angry	1	2	3	4
60. I am angry	1	2	3	4
61. I am very angry	1	2	3	4
62. I am angry	1	2	3	4
63. I am very angry	1	2	3	4
64. I am angry	1	2	3	4
65. I am very angry	1	2	3	4
66. I am angry	1	2	3	4
67. I am very angry	1	2	3	4
68. I am angry	1	2	3	4
69. I am very angry	1	2	3	4
70. I am angry	1	2	3	4
71. I am very angry	1	2	3	4
72. I am angry	1	2	3	4
73. I am very angry	1	2	3	4
74. I am angry	1	2	3	4
75. I am very angry	1	2	3	4
76. I am angry	1	2	3	4
77. I am very angry	1	2	3	4
78. I am angry	1	2	3	4
79. I am very angry	1	2	3	4
80. I am angry	1	2	3	4
81. I am very angry	1	2	3	4
82. I am angry	1	2	3	4
83. I am very angry	1	2	3	4
84. I am angry	1	2	3	4
85. I am very angry	1	2	3	4

- I express my anger
- I keep things in
- I pout or sulk
- I withdraw from people
- I make sarcastic remarks to others
- I do things like slam doors
- I boil inside but don't show it
- I argue with others
- I tend to harbour grudges that I don't tell anyone about
- I strike out at whatever infuriates me
- I am secretly quite critical of others
- I am angrier than I am willing to admit I say nasty things
- I'm irritated a great deal more than people are aware of
- I lose my temper

27. In the last four weeks, have you experienced any events in your working, sporting, social or family life that caused you to feel stressed? Yes No

- a. If YES, please list the events you have experienced in the last four weeks.

28. Overall, how stressful have the past four weeks been for you?

Not at all A little somewhat a lot

Section 7: AUDIT test

In the following questions a “drink” is equal to one glass of beer, wine or spirits. Please **tick only** one answer for each question. Remember, your answers are totally confidential.

1. How often do you have a drink containing alcohol?

- a. Never
- b. Monthly or less
- c. Two to four times a month
- d. Two to three times a week
- e. Four or more times a week

2. How many drinks containing alcohol do you have on a typical day when you are drinking?

- a. 1 or 2
- b. 3 or 4
- c. 5 or 6
- d. 7 to 9
- e. 10 or more

3. How often do you have six or more drinks on one occasion?

- a. Never
- b. Less than monthly
- c. Monthly
- d. Weekly
- e. Daily or almost daily

4. How often during the last 12 months have you found that you were not able to stop drinking once you had started?

- a. Never
- b. Less than monthly
- c. Monthly
- d. Weekly
- e. Daily or almost daily

5. How often during the last 12 months have you needed a first drink in the morning to get yourself going after a heavy drinking session?

- a. Never
- b. Less than monthly
- c. Monthly
- d. Weekly
- e. Daily or almost daily

6. How often during the last 12 months have you had a feeling of guilt or remorse after drinking?

- a. Never
- b. Less than monthly
- c. Monthly
- d. Weekly
- e. Daily or almost daily

7. How often during the last 12 months have you been unable to remember what happened the night before because you had been drinking?

- a. Never
- b. Less than monthly
- c. Monthly
- d. Weekly
- e. Daily or almost daily

8. Have you or someone else been injured as a result of your drinking?

- a. No
- b. Yes, but not in the last 12 months
- c. Yes, during the last 12 months

9. Has a relative or friend or a doctor or other health worker, been concerned about your drinking or suggested you cut down?

- a. No
- b. Yes, but not in the last 12 months
- c. Yes, during the last 12 months

***Thank You for completing the
GHQ! Your response is very important to us.***

Thank You!

Appendix D: CNS Vital Signs Brief Interpretation Guide
(see <http://www.cnsvitalsigns.com>)



CNS Vital Signs Interpretation Guide

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Contents

Interpretation Guide: Why & How	3
CNS Vital Signs Report	4
Evaluate Effort - Test Validity Indicator	5
Evaluate Severity – Impairment Status	7
Evaluate Pattern – Personalized Medicine	9
CNS Vital Signs Normed Neurocognitive Tests	12
CNS Vital Signs Clinical Domain Description	13
Formulas for Calculating the Neurocognitive Domain Scores	14
Neurocognitive Tests and Domain Scoring Process	15

One Key Difference – Measuring Millisecond Precise Cognitive Speed... ^{**} CNS Vital Signs is sensitive in detecting cognitive impairment ...uses computerized forms of traditional tests such as Symbol Digit Modalities and Stroop ...are easy to use, require significantly less time to administer, produce instant scoring and can incorporate alternate forms, necessary to minimize learning effect on follow-up. *...also the capacity to accurately-automatically quantify "speed factor" via multiple parameters such as reaction time, psychomotor speed, and processing speed, increasing their sensitivity in detecting even subtle changes in information processing speed.* ^{**}

^{**} Cognitive Impairment in Relapsing Remitting and Secondary Progressive Multiple Sclerosis Patients: Efficacy of a Computerized Cognitive Screening Battery (RNN Neurology, 2014 Mar 12)

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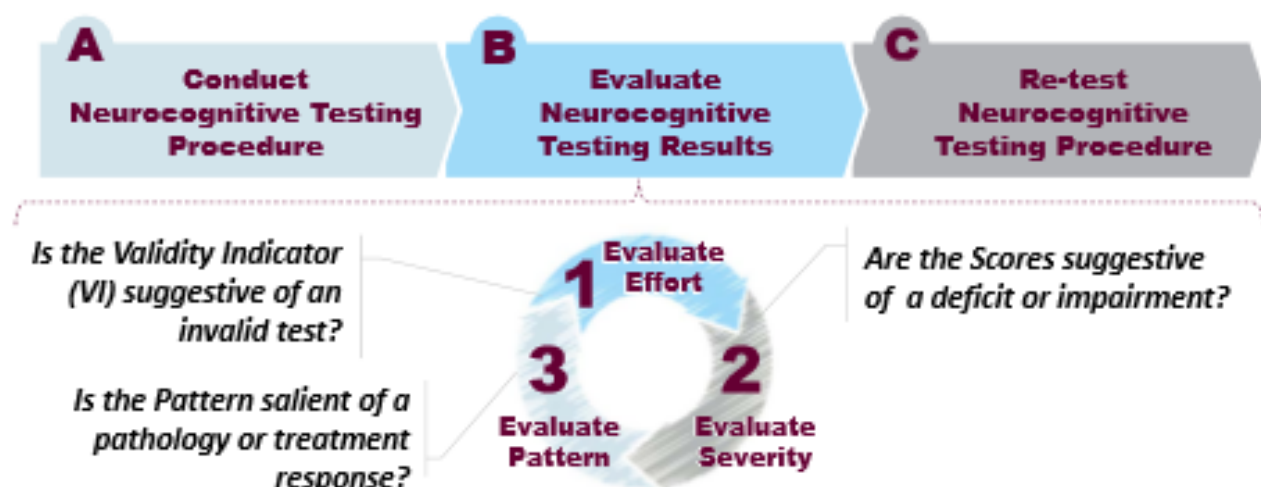
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Interpretation Guide

Why CNS Vital Signs Testing Platform?

CNS Vital Signs computerized neuropsychological / neurocognitive tests enables a non-invasive, customizable clinical procedure to efficiently and objectively assess a broad-spectrum of brain function domain performances under challenge (cognition stress test) and the millisecond precise measurement of important cognitive functions. The testing platform also contains 60+ well recognized, evidence-based rating instruments to help identify clinical symptoms, behaviors, and comorbidities salient to the evaluation and ongoing management of many neurological, psychiatric and other clinical conditions. Serial evaluation of neurocognition can help patients and caregivers navigate problems related to daily living, school or vocational work.



HOW?

A: After medical necessity for neurocognitive testing has been determined practices use CNS VS assessment platform for the evaluation, management and treatment in patient care. It is important to conduct a valid assessment and clinics can refer to and use the Test Administration Guide for optimal results. Testing strategy should be determined using the ten neurocognitive tests and/or the sixty plus evidenced-based rating instruments. For initial baseline evaluations or in complex presentations, a customizable broad-spectrum battery is always an appropriate consideration or starting point.

B: Review the immediately auto-scored report to **1** validate testing effort, **2** evaluate the Domain Dashboard to quickly assess the level of impairment or grade the level of severity based on age matched norms ages 8-89, and **3** Evaluate the Cognitive Domains to help rule-in, rule-out, confirm certain clinical conditions or evaluate treatment results. Feedback to the patient on the testing results may be presented at the clinical encounter or at a subsequent patient visit.

C: If invalid test results were noted then consider re-testing the patient to confirm clinical results. If the test results were valid, then, as part a continuum of care, reschedule testing to track disease progression and measure ongoing status or outcomes.

NOTE: The **Validity Indicator** denotes a guideline for representing the possibility of an invalid test or domain score. "No" means a clinician should evaluate whether the test subject understood the test, put forth their best effort, or has a clinical condition requiring further evaluation.

All assessment results should be considered with other relevant clinical information such as history, physical examination, other psychological or neuropsychological tests, lab results, imaging studies, etc., in accordance with good clinical practice standards. CNS Vital Signs is not a diagnostic. Diagnosis is a clinical exercise that relies on data from many different sources.

CNS Vital Signs Test Report Example ...Current Cognitive Status View

...is auto-scored from computerized versions of VENERABLE NEUROPSYCHOLOGICAL TESTS. The results measures the **MILLISECOND PRECISE SPEED** and **ACCURACY** of a patient's response. **TOTAL TESTING TIME** depends on the number of tests and rating instruments selected.

CNS Vital Signs Clinical Report					Test Date: July 23 2013 10:48:38				
Subject Reference ID: Case Study Example					Administrator: Technician				
Age: 27					Language: English (United States)				
Total Test Time: 29:40 (min:secs)					Version 3,2,0,34				
Patient Profiles	Percentile Range				> 74	75 - 74	6 - 24	2 - 6	< 2
	Standard Score Range				> 100	90 - 100	80 - 90	70 - 79	< 70
Domain Scores	Subject Score	Standard Score	Percentile	VI**	Above	Average	Low Average	Low	Very Low
Neurocognitive Index (NCI)	86	85	16	Yes			*		
Composite Memory	103	103	58	Yes		*			
Verbal Memory	51	51	32	Yes		*			
Visual Memory	51	110	75	Yes	*				
Psychomotor Speed	174	93	32	Yes		*	2		
Reaction Time*	555	107	48	Yes		*			
Complex Attention*	21	54	1	Yes					*
Cognitive Flexibility	20	61	1	Yes					*
Processing Speed	48	79	8	Yes				*	
Executive Function	34	75	5	Yes				*	
Simple Attention	40	108	70	Yes		*			
Motor Speed	124	105	63	Yes		*			

Domain Thresholds: Above average domain scores indicate a standard score (SS) greater than 100 or a Percentile (P) greater than 74, indicating a high functioning test subject. Average is a SS 90-100 or P 25-74, indicating normal function. Low Average is a SS 80-90 or P 16-24 indicating a slight deficit or impairment. Below Average is a SS 70-79 or P 1-15, indicating a moderate level of deficit or impairment. Very Low is a SS 60-69 or P 1-15, indicating a severe deficit or impairment. Reaction times are in milliseconds. An * denotes a raw score calculation generated from data values of the individual subjects.

VI - Validity Indicator:** Denotes a guideline for representing the possibility of an individual not having done their best effort, or has a clinical concern.

Verbal Memory Test (VMT)	Score	Standard	Percentile	Verbal Memory Test (VMT) is a test of verbal memory. It measures the ability to learn and recall words.
Correct Hits - Immediate	13	102	50	
Correct Passes - Immediate	14	95	37	
Correct Hits - Delay	9	85	16	
Correct Passes - Delay	15	105	73	

Visual Memory Test (VMT)	Score	Standard	Percentile	Visual Memory Test (VMT) is a test of visual memory. It measures the ability to learn and recall figures.
Correct Hits - Immediate	13	107	60	
Correct Passes - Immediate	14	117	87	
Correct Hits - Delay	13	111	77	
Correct Passes - Delay	11	93	32	

Finger Tapping Test (FTT)	Score	Standard	Percentile	The FTT is a test of motor speed. It measures the number of taps a subject can make with their fingers.
Right Taps Average	66	104	61	
Left Taps Average	60	105	63	

Symbol Digit Coding (SDC)	Score	Standard	Percentile	The SDC is a test of psychomotor function. It measures the number of symbols a subject can code correctly.
Correct Responses	50	80	9	
Errors*	2	92	30	

Stroop Test (ST)	Score	Standard	Percentile	The ST is a test of cognitive flexibility. It measures the number of correct responses a subject can give.
Simple Reaction Time*	214	108	70	
Complex Reaction Time Correct*	542	100	50	
Stroop Reaction Time Correct*	558	112	74	
Stroop Commission Errors*	8	5	1	

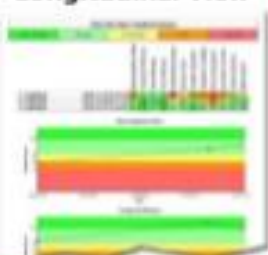
Shifting Attention Test (SAT)	Score	Standard	Percentile	The SAT is a test of cognitive flexibility. It measures the number of correct responses a subject can give.
Correct Responses	47	82	13	
Errors*	13	79	9	
Correct Reaction Time*	1003	67	43	

Continuous Performance Test (CPT)	Score	Standard	Percentile	The CPT is a test of cognitive flexibility. It measures the number of correct responses a subject can give.
Correct Responses	40	104	61	
Omission Errors*	9	104	61	
Commission Errors*	0	106	70	
Choice Reaction Time Correct*	400	99	47	

The CNS Vital Signs Neurocognitive Assessment Report is designed to present the testing results in a **SUMMARY DOMAIN DASHBOARD** and a **DETAILED REPORT** format immediately following the testing session. The CNS Vital Signs reports are logical and intuitive making the reports interpretation by a qualified health professional relatively straightforward. All assessment results should be considered with other relevant clinical information such as history, physical examination, other psychological or neuropsychological tests, lab results, imaging studies, etc., in accordance with good clinical practice standards.

Serial administered neurocognitive tests can also be presented in a **LONGITUDINAL REPORT** format to track disease progression, outcomes, or treatment effects.

Longitudinal View





Evaluate Effort – Validity Indicator

Patient Profile:	Percentile Range				A	> 74	25 - 74	9 - 24	2 - 8	< 2
	Standard Score Range			> 109		90 - 109	80 - 89	70 - 79	< 70	
Domain Scores	Subject Score	Standard Score	Percentile	VI **	Above	Average	Low Average	Low	Very Low	
Neurocognition Index (NCI)	NA	85	16	Yes			x			
Composite Memory	103	103	58	Yes		x				
Verbal Memory	51	93	32	Yes		x				
Visual Memory	51	110	75	Yes	x					
Psychomotor Speed	174	93	32	Yes		x				
Reaction Time*	555	107	68	Yes		x				
Complex Attention*	21	56	1	Yes					x	
Cognitive Flexibility	26	63	1	Yes					x	
Processing Speed	48	79	8	Yes				x		
Executive Function	28	75	5	Yes				x		
Single Attention	49	108	70	Yes		x				
Motor Speed	124	105	63	Yes		x				

Evaluate Validity: The Validity Indicator (VI) helps identify the possibility of an invalid test.

Embedded measures helps evaluate whether the patient is manipulating testing performance for a secondary gain or they simply did not read the test instructions. Examples of secondary gain include drug or disability seeking, academic accommodation, malingering, symptom feigning, etc.

WHY? When analyzing test data, either in research, or in clinical practice, it is important to know whether a test result is valid or not. Clinicians need to know if testing subjects misunderstood the instructions or are generating “dubious results” or a “non-credible response pattern.” CNS Vital Signs has developed “validity indicators” for its tests and domains that indicate whether the patient gave poor effort or generated invalid results (feigning, malingering, etc.) Across the span of neurological and psychiatric disorders, it is important to have “valid” tests to get a true evaluation of a patient.

WHAT? The CNS Vital Signs **A** Validity Indicator (VI) is a guideline identifying the possibility of an invalid test or domain score. When reviewing a report, a “No” in the VI column suggests the clinician should evaluate whether the test subject understood the test, put forth their best effort, or has a clinical condition requiring further evaluation. The CLINICAL DOMAIN validity indicators are identified as **B** “Possibly Invalid” based on validity data and is indicated on the suspected test(s). *The NCI (Neurocognition Index) is invalid if any test or domain is invalid.*

Non Verbal Reasoning Test (NVRT)	Score	Standard	Percentile	B	Possibly Invalid
Correct Responses	7	98	45		
Average Correct Reaction Time*	7208	84	14		
Commission Errors*	8	93	32		
Omission Errors*	0	118	88		
* = NVRT %		Score	Percentile		

The **NVRT** measures how well a subject can perceive and understand the meaning of visual or abstract information and recognizing relationships between visual-abstract concepts. The **NVRT** is comprised of 16 matrices, or visual analogies. The matrices are progressively more difficult. Each is presented for 14.5 seconds. Non-verbal reasoning is the process of perceiving and reaching conclusions through the use of symbols and patterns.

Non-Verbal Reasoning: correct responses > = 4 and Correct > incorrect responses.

NOTE: The CNS Vital Signs batteries can be successfully completed, without assistance, by a normal child with a 4th grade reading level. Likewise, elderly with MMSE scores above 22 can complete the battery. Keep in mind, it is not uncommon for patients to generate an invalid result on one test in the battery due to misreading the instructions or giving-up on the test. *Proper pretest instruction leads to a better testing experience.*



Evaluate Effort – Validity Indicator

HOW? The Validity Indicator alerts the clinician to the possibility of an invalid test allowing the clinician, examiner or testing technician to question the testing subject: Do the testing results reflect an understanding of the test and the instructions? Did the testing subject put forth their best effort? Did they get a good night's sleep? Does the subject have poor vision and need their glasses? Do the results suggest willful exaggeration, e.g., malingering?

Should a subject test abnormally low triggering an "invalid" test (NO as displayed in the Validity Indicator section of the report) then that would be a reason for retesting the individual, unless your clinical judgment makes you believe that is the best score the patient can achieve. Like any suspicious lab, the test should be re-administered, and it can be done with CNS Vital Signs through the RETEST function.

Before Retesting, the test examiner or technician should reinforce the need for the subject to give a good testing effort and use the "Validity Indicator" as a tool to help with the reinforcement. To RETEST a subject go to MENU > RETEST SUBJECT > and select the appropriate subject and retest the subject. Upon retest, should a subject test abnormally low again triggering yet another "invalid" test (NO as displayed in the Validity Indicator section of the report) and the clinician believes it was the patient's best effort further evaluation or referrals should be considered.

CNS Vital Signs Embedded Indicators of Valid Effort

Clinical Domains	TEST VALIDITY INDICATORS
Composite Memory	Both Verbal and Visual Memory are Valid.
Verbal Memory	Verbal Memory raw score > 30.
Visual Memory	Visual Memory raw score > 30.
Psychomotor Speed	Both FTT and SDC are Valid
Reaction Time	Stroop: Simple RT < Complex RT < Stroop RT
Complex Attention	Valid Stroop, CPT, and SAT. Correct > incorrect response in all tests.
Cognitive Flexibility	Valid Stroop and SAT. Correct > incorrect responses in all tests.
Processing Speed	SDC: Correct Responses >= 20 AND Correct Responses > Errors
Executive Function	SAT: errors < correct responses.
Non-Verbal Reasoning	NVR: correct responses >= 4 and Correct > incorrect responses.
Social Acuity	POET: correct responses > 3. Correct > incorrect responses
Sustained Attention	4PCPT: Part 2 > 2 correct; part 3 > 5 correct; part 4 > 5 correct.
Working Memory	Correct > incorrect responses in all parts.
Simple Attention	CPT: if >= 10 years old, CPT is valid if Correct Responses - Commission Errors* >= 30, if < 10 years old CPT is valid if Correct Responses - Commission Errors* >= 25
Motor Speed	FTT: total taps >= 40

FTT - Finger Tapping Test; SAT - Shifting Attention Test; SDC - Symbol Digit Coding Test; RT - Reaction Time; CPT - Continuous Performance Test; POET - Perception of Emotions Test; NVR - Non-verbal Reasoning; 4PCPT - Four Part CPT
The "Validity Indicator" scoring algorithm is based on research presented (Detecting Invalidity in Neurocognitive Tests) at International Society for CNS Clinical Trials and Methodology (ISCTM) in 2009. The poster is available on the CNS Vital Signs website.

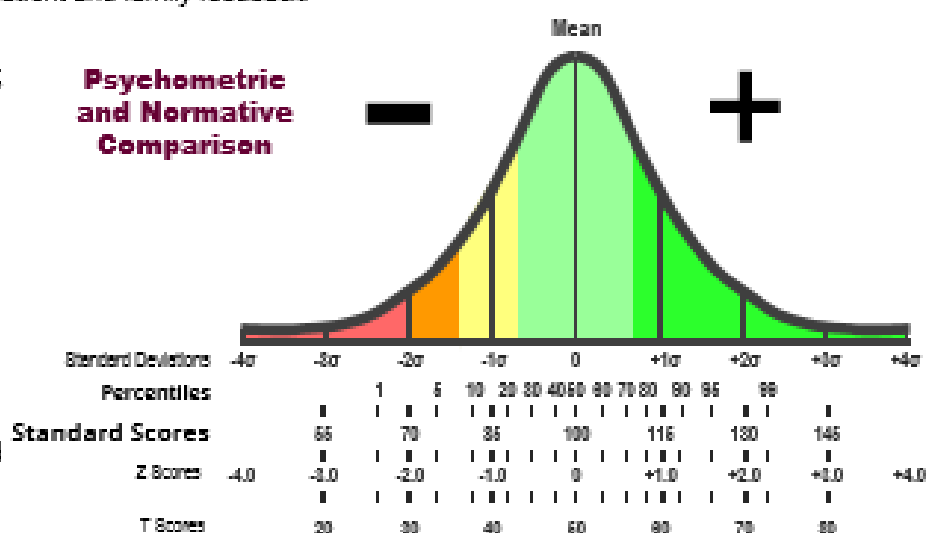


Evaluate Severity – Impairment Status

Evaluate Severity: The scores help identify cognitive deficits and their level of impairment.

Assess even slight cognitive impairment (millisecond precision) providing immediate clinical insight into a patient's cognitive deficits and level of impairment. This gives patients, family members and caregivers knowledge of cognitive domains that underpin the ability to conduct activities of daily living. CNS Vital Signs grades **severity of impairment** based on an age-matched normative comparison database. Most neuropsychiatric and neurodegenerative conditions are multifactorial in nature. Effective evaluation of neurocognitive and behavioral issues can provide a standardized and efficient method of collecting valid and important neuropsychiatric clinical endpoints. These neuropsychiatric clinical endpoints can systematically document a patient's clinical course. Altogether, CNS Vital Signs computerized testing can facilitate a more complete assessment and provide a basis for patient and family feedback.

The CNS Vital Signs STANDARD SCORES and PERCENTILE RANKS are auto-scored using an algorithm based on a normative data set of 1600+ subjects, ranging from Ages 8 – 90. In the age-matched normative sample subjects were: (1) in good health, (2) had no past or present psychiatric or neurological disorders, head injury, or learning disabilities, and the (3) Sample subjects were free of any centrally acting medications. The CNS Vital Signs normative data is presented in ten age groups: less



Above:	> 110	> 74	High Function and High Capacity
Average:	90 - 110	25 - 74	Normal Function and Normal Capacity
Low Average:	80 - 90	9 - 24	Slight Deficit and Slight Impairment
Low:	70 - 79	2 - 8	Moderate Deficit and Impairment Possible
Very Low:	< 70	< 2	Deficit and Impairment Likely
	<i>Standard Scores</i>	<i>Percentile Scores</i>	

than 10 years old, 10–14, 15–19; in deciles to 79, and finally, 80 years or older. The standard scores are normalized with a mean of 100 and standard deviation of 15. Percentile Ranks is a mathematical transformation of the standard score and an index of how the subject scored compared to other subjects of the same age on a scale of 1 to 99. NORMAL AGING affects performance on all CNS Vital Signs tests. A patient's standard scores are based on data from normal controls that are the same age. EDUCATION and SPECIAL SKILLS may also affect test performance; therefore, concern should be taken for patients that are very intelligent or well educated yet their scores are below average. Like any laboratory test, an abnormal result should be the occasion for further evaluation. As with any neuropsychological tests, results can be affected by motivation or effort level and the Validity Indicator will help identify those patients.



Evaluate Severity



Neurocognitive Domain Dashboard

Patient Profile:	Percentile Range								
	Standard Score Range								
Domain Scores	Subject Score	Standard Score	Percentile	VS**	Above	Average	Low Average	Low	Very Low
Neurocognition Index (NCI)	NA	85	16	Yes			x		
Composite Memory	103	103	58	Yes		x			
Verbal Memory	51	93	32	Yes		x			
Visual Memory	51	110	75	Yes	x				
Psychomotor Speed	124	93	32	Yes		x			
Reaction Time*	555	107	68	Yes		x			
Complex Attention*	21	56	1	Yes					x
Cognitive Flexibility	26	63	1	Yes					x
Processing Speed	48	79	8	Yes				x	
Executive Function	34	75	5	Yes				x	
Single Attention	40	108	70	Yes		x			
Motor Speed	124	105	63	Yes		x			

1

2

3

SD = Standard Deviation from the MEAN

CNS Vital Signs presents testing results in Subject (raw), Standard Scores, and Percentile Ranks. Results obtained from a CNS Vital Signs assessment can be used to evaluate or monitor a patient's condition and the subsequent treatment and management of that patient. Below, is a description of each domain category:

- Subject Scores** are computed from raw score calculations using the data values of individual subtests and are simply the number of correct responses, incorrect responses, and reaction times. Reaction times are in milliseconds. An ASTERISK (*) denotes that "lower score is better" e.g., timing, otherwise higher scores are better.
- Standard Scores** are normalized from raw scores and present an age matched score relative to other people in a normative sample. CNS Vital Signs standardized have a mean of 100 and a standard deviation is 15. Higher scores are always better. The schema where the mean is 100 and the standard deviation is 15 is similar to the presentation of IQ scores where the mean for normal is 100.
- Percentile Scores** is a mathematical transformation of the standard score and an index of how the subject scored compared to other subjects of the same age on a scale of 1 to 99. If an individual obtained a score at the 52nd percentile (50th percentile is average), this would mean that their performance would be equal to 52% of his same-aged peers in the general population. Higher scores are always better.

Severity Classification Grade:

Above:	> 110	> 74	High Function and High Capacity
Average:	90 - 110	25 - 74	Normal Function and Normal Capacity
Low Average:	80 - 90	9 - 24	Slight Deficit and Slight Impairment
Low:	70 - 79	2 - 8	Moderate Deficit and Impairment Possible
Very Low:	< 70	< 2	Deficit and Impairment Likely
	Standard Scores	Percentile Scores	

Quick View
Age-Matched
Normative
Scores

4



Evaluate Pattern – Enabling Personalized Medicine

Variation in neurocognitive scores can be multifactorial in nature.

The brain develops and ages... *based on genetics and external environmental challenges e.g. maternal health, education, exercise, diet, life experiences, socioeconomic status, health status, attitudinal and emotional factors, physical / medical comorbidities, treatments, etc.*

Evaluate Pattern: Impairment pattern helps identify pathologies and possible comorbidities.

CNS Vital Signs cognitive testing procedure provides valid and reliable clinical endpoints to help in the evaluation and management of patients. Many conditions at the group level are associated with cognitive impairments. Attention should be paid to the nature (speed and accuracy) and response pattern as well as errors. Patient's scoring well below average in one domain or below average in two domain areas, might well be impaired and should be evaluated further. The first step in evaluating such a patient is to repeat the test under more favorable circumstances. Like any laboratory test, repetitive results outside of normal should be investigated. If the scores are low the second time, a targeted work-up may be necessary.

Psychometric Measures to Evaluate Treatment Response and Outcomes



Adapted From:
Effect of Methylphenidate on
Neurocognitive Test Battery;
Journal of Clinical Psychopharmacology;
Volume 34, Number 4, August 2014

...Findings revealed controls
scored better than ADHD
subjects and ADHD subjects
scored better on MPH than
with no drug

Evaluate the neuropsychological characteristics of PI - predominantly inattentive,
R - restrictive, and CB - combined (inattentive & hyperactive) AD/HD subtypes...

Comparisons of CNSVS Domain Scores Between the ADHD Groups Before MPH Medication Administration

	PI	R	CB	Control	P	Pairwise Comparisons
Baseline Measurements	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)		
Neurocognition Index	87.82 (14.88)	90.71 (11.77)	90.25 (11.14)	98.91 (10.87)	<0.001*	(PI=R=CB) < control
Composite Memory	84.58 (21.88)	87.97 (19.5)	91.89 (20.92)	98.73 (18.82)	0.01	PI < control
Psychomotor speed	92.98 (10.49)	94.12 (10.87)	93.83 (12.54)	99.77 (10.58)	<0.001	(PI=R=CB) < control
Reaction time	78.54 (21.83)	83.15 (18.42)	81.88 (18.49)	83.28 (28.57)	0.85*	
Complex attention	91.38 (24.8)	94.92 (18.81)	90.77 (18.41)	102.15 (12.45)	<0.001*	(PI=R=CB) < control
Cognitive flexibility	90.84 (18.15)	93.32 (15.51)	91.15 (14.1)	102.82 (15.28)	<0.001	(PI=R=CB) < control
Symbol Digit Coding (Processing Speed Domain)						
Correct responses	41.24 (12.73)	41.82 (13.8)	40.23 (12.38)	48.18 (11.77)	<0.001	(PI=R=CB) < control
Errors	0.92 (1.18)	1.09 (1.28)	1 (2.28)	3.6 (5.53)	<0.001*	(PI=R=CB) < control
Shifting Attention Test (Executive Function Domain)						
Correct responses	34.44 (10.06)	35.43 (11.33)	34.07 (9.95)	42.23 (9.98)	<0.001	(PI=R=CB) < control
Errors	15.34 (7.83)	15.71 (9.41)	17.52 (8.02)	11.55 (8.08)	<0.001*	(PI=R=CB) > control
Correct reaction time	1290.6 (133.52)	1224.91 (236.4)	1233.39 (175)	1188.8 (222.75)	0.01*	CB > control
CPT (Simple Attention Domain)						
CPT Correct	38.54 (2.81)	37.84 (5.25)	38.3 (2.71)	39.19 (1.14)	<0.001*	R > control
Omission	1.48 (2.81)	1.81 (2.15)	1.7 (2.71)	0.81 (1.14)	<0.001*	CB > control
Commission errors	3.42 (4.85)	11.59 (86.7)	3.89 (4.82)	1.71 (1.88)	<0.001*	R > control, CB > control
Choice RT correct	508.84 (79.92)	490.2 (100.28)	515.38 (81.98)	470.5 (88.55)	<0.001	PI < control

*The Wilcoxon signed-rank test was used for comparisons between diagnostic groups, and post hoc comparisons were performed with Tukey's HSD test. All other comparisons were performed with the Wilcoxon test, and post hoc tests were performed with the Tukey test.

*** Attention-deficit/hyperactivity disorder (ADHD); Simon, Sallquist, & van der Ende. Journal of Clinical Psychiatry (2014) 75 (Suppl 1):S44-S48

*** RESTRICTIVE (DSM-IV): If criterion A1 (inattentive) is met, but no more than two symptoms from criterion A2 (hyperactivity / impulsivity) have been present for the past 6 months.

Comparisons After MPH Administration

PI	R	CB
Mean (SD)	Mean (SD)	Mean (SD)
85.53 (11.98)	88.88 (11.82)	97.38 (10)
81.27 (22.57)	85.59 (20.44)	85.9 (17.7)
98.88 (9.77)	99.8 (11.08)	99.73 (10.52)
88.25 (19.19)	89.88 (17.98)	89.43 (17.92)
105.51 (18.27)	108.53 (17.14)	107.58 (12.83)
104.77 (15.83)	108.42 (14.14)	108.58 (13.74)

...Study included 360 children and adolescents (277 boys, 83 girls) between 7 and 15 years of age who had been diagnosed with ADHD at the Department of Child and Adolescent Psychiatry using K-SADS-PL and DSM-IV

...Subjects were grouped according to ADHD subtypes as PI (n = 51), R (n = 65), and CB (n = 165). Seventy-nine healthy children were recruited into the study as the control group



Evaluate Pattern – Enabling Personalized Medicine

Amnesic MCI Baseline: 60-Year-Old Male Initial MMSE 25*

Patient Profile:	Percentile Range				1-33		33-66		66-84		84-99	
	Percentile	Score	Percentile	Score	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Neurocognitive Index (NCI)	85	85	85	85	85	85	85	85	85	85	85	85
Memory	85	85	85	85	85	85	85	85	85	85	85	85
Verbal Memory	85	85	85	85	85	85	85	85	85	85	85	85
Visual Memory	85	85	85	85	85	85	85	85	85	85	85	85
Processing Speed	85	85	85	85	85	85	85	85	85	85	85	85
Executive Function	85	85	85	85	85	85	85	85	85	85	85	85
Psychomotor Speed	85	85	85	85	85	85	85	85	85	85	85	85
Reaction Time	85	85	85	85	85	85	85	85	85	85	85	85
Complex Attention	85	85	85	85	85	85	85	85	85	85	85	85
Cognitive Flexibility	85	85	85	85	85	85	85	85	85	85	85	85

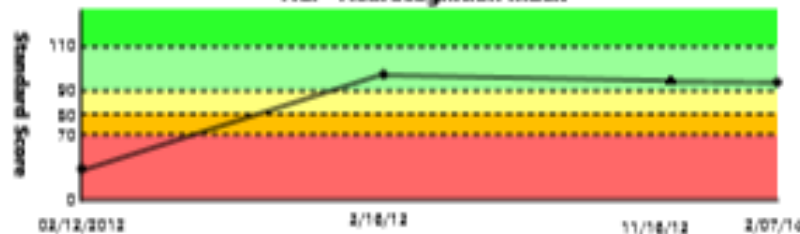
Joe, a 60-year-old male is presenting with memory and concentration concerns and was given CNS Vital Signs Clinical Battery and scored below average compared to his peers in 6 of 11 cognitive domains. His lowest scores were in domains sensitive to amnesic (memory related) MCI.

After considering the H&P, lab results, patient and informant memory questionnaire, sleep scales and the cognitive test results; Joe was referred for a sleep study. Later he was prescribed CPAP and appropriate therapy.

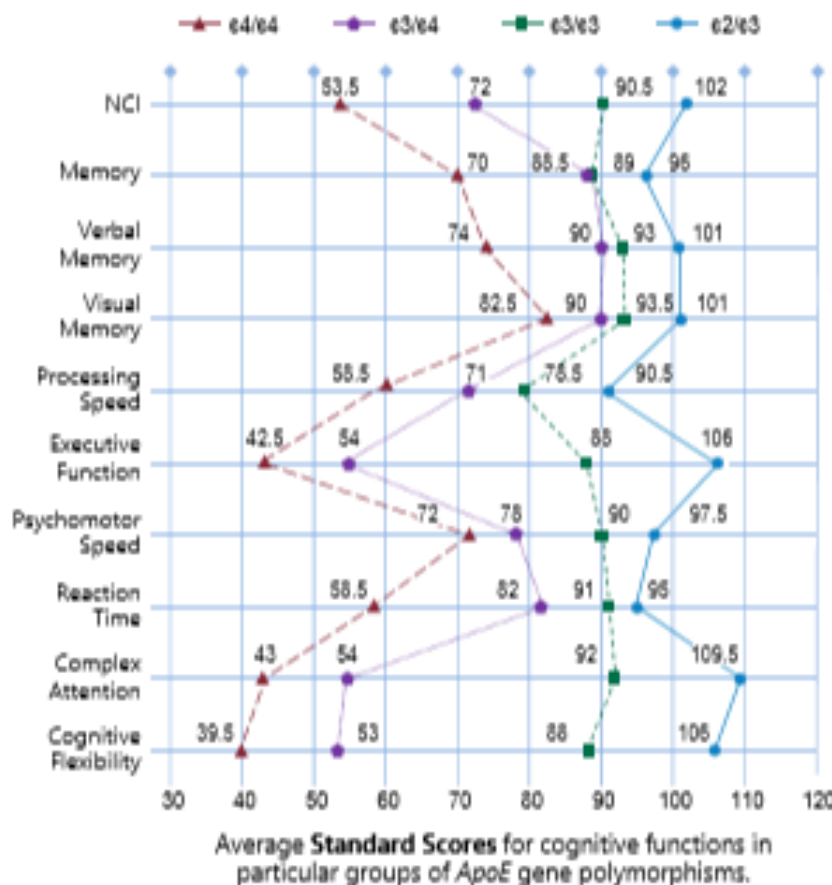
CNS Vital Signs allowed a fine characterization of Joe's clinical course, including apparent variation due to compliance with therapy. Patient and wife were positively influenced by revelation of objective cognitive testing performance, which proved useful in demonstrating probable effects of compliance.

Adapted from: Engelhardt et al. International Congress Alzheimer's Disease 2011

Amnesic MCI Longitudinal View: 60-Year-Old Male NCI - Neurocognition Index



CNS VS Correlation to Alzheimer's ApoE Polymorphisms



Correlation to Biological Markers

Polymorphisms of apolipoprotein E gene and cognitive functions of postmenopausal women, measured by battery of computer tests – Central Nervous System Vital Signs

Engelhardt et al. Alzheimer's Disease 2011

...Study included 107 postmenopausal women between the ages of 52 and 65 (mean 56.6 ± 3.5)

...Subjects were qualified as "normal" with MOCA scores between 26 and 30

...Findings revealed ApoE polymorphisms correlated to levels of cognitive function where as expected ε3/ε4, or ε4/ε4 scored poorly while ε2/ε3 groups scored much better.

Adapted from: Engelhardt et al. Alzheimer's Disease 2011



Evaluate Pattern – Suggestive Pathology

Like most neuropsychological or psychological tests, clinicians will recognize, over time, which domains reveal the clinical conditions of their patients. The profiles below may help clinicians evaluate test results. The profiles are based on thousands of well-characterized patients, as well as a review of published literature and data.

Nature of Pattern ● = Most Sensitive ● = Moderate Sensitivity ○ = Less Sensitivity

BRIEF-CORE BRAIN FUNCTION DOMAINS	Composite Memory	Verbal Memory	Visual Memory	Psychomotor Speed	Reaction Time	Complex Attention	Cognitive Flexibility	Processing Speed	Executive Function	Simple Attention	Motor Speed
ADD – AD/HD	○	○	●	●	●	●	●	●	●	●	○
Mild Cog Impair -MCI	●	●	●	●	●	●	●	●	●	●	●
Amnesic MCI	●	●	●	○	○	○	○	○	○	○	○
Non-Amnesic MCI	○	○	○	●	●	●	●	●	●	●	●
Early Dementia	●	●	●	●	●	●	●	●	○	●	●
Multiple Sclerosis	●	●	●	●	●	●	●	●	●	○	●
Sleep	○	○	○	●	●	●	●	●	●	●	●
Depression	○	○	○	●	●	●	●	●	●	○	○
Chemo Brain	●	●	●	●	●	●	●	●	●	○	●
mTBI – Concussion	●	●	●	●	●	●	●	●	●	●	●

Brain injury and Stroke domain score performance may vary depending on a number of factors that include type of blow to the head, site of the blow, location of stroke and the patient's individual history.






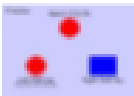

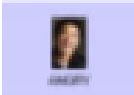

Epilepsy Neurocognitive Function is dependent on the type of epilepsy and medication effect. Note: Cognitive function is more frequently impaired in people with epilepsy than in the general population, and the degree of cognitive impairment varies according to the epilepsy syndrome. Behavioral disorders are also more frequent in people with epilepsy than in individuals who do not have epilepsy. Behavioral disturbance is observed more frequently in people with drug-resistant epilepsy, frequent seizures, and/or associated neurological or mental abnormalities. In children and adolescents, some data suggests a close link between behavior/cognition and some specific epilepsy syndromes. Optimal management requires a careful balance between, on the one hand, the desire to reach early and maximal seizure control and, on the other, the need to avoid tolerability problems related to cognitive and behavioral impairments.

Chronic Pain Neurocognitive Function is dependent on medication effect and pain pathology. CNS VS is ideal for measuring a baseline status and treatment outcomes.

The Nature of the Pattern can vary based on many intrinsic and extrinsic factors: "Over the past century, the syndrome currently referred to as attention-deficit hyperactivity disorder (AD/HD) has been conceptualized in relation to varying cognitive problems including attention, reward response, executive functioning, and other cognitive processes. More recently, it has become clear that whereas ADHD is associated at the group level with a range of cognitive impairments, no single cognitive dysfunction characterizes all children with ADHD. In other words, ADHD is not a one-size-fits-all phenomenon. Patients with this syndrome do not fit into any one category and present with widely differing co-occurring disorders—including varying cognitive profiles."

Source: Cognitive Impairments With ADHD, Psychiatric Times, Vol. 26 No. 3, 2009

10 Normed Neurocognitive Tests

Verbal Memory (VBM) <i>Approx. 3 Minutes</i>		<ul style="list-style-type: none"> Learning Words Memory for Words Word Recognition Immediate and Delayed Recall 	VBM measures recognition memory for WORDS. Fifteen words are presented, one by one, on the screen every two seconds. For immediate recognition (learning phase), the participant must identify those words nested among fifteen new words. Then, after six more tests, there is a delayed recognition memory trial. Subjects respond using the SPACE BAR.
Visual Memory (VIM) <i>Approx. 3 Minutes</i>		<ul style="list-style-type: none"> Learning Shapes Memory for Shapes Shapes Recognition Immediate and Delayed Recall 	VIM measures recognition memory for ABSTRACT FIGURES or SHAPES. Fifteen geometric figures are presented, one by one, on the screen. For immediate recognition (learning phase), the participant must identify those figures nested among fifteen new figures. Then, after five more tests, there is a delayed recognition memory trial. Subjects respond using the SPACE BAR.
Finger Tapping (FTT) <i>Approx. 2 Minutes</i>		<ul style="list-style-type: none"> Motor Speed Fine Motor Control 	FTT test has subjects respond by pressing the SPACE BAR with their right index finger as many times as they can in 10 seconds. They do this once for practice, and then there are three test trials. The test is repeated with the left hand.
Symbol Digit Coding (SDC) <i>Approx. 4 Minutes</i>		<ul style="list-style-type: none"> Complex Information Processing Accuracy Complex Attention Visual-Perceptual Speed Information Processing Speed 	SDC test consists of serial presentations of screens, each of which contains a bank of eight symbols above and eight empty boxes below. The participant types in the number on the NUMBER ROW that corresponds to the symbol that is highlighted. Only the digits from 2 through 9 are used; this is to avoid the confusion between "1" and "7" on the keyboard. The computer program does not allow a person to use a numerical pad preventing a distinct advantage for those who are skilled at using the numerical pad or for those that are right- versus left-handed.
Stroop Test (ST) <i>Approx. 4 - 5 Minutes</i>		<ul style="list-style-type: none"> Simple Reaction Time Complex Reaction Time Stroop Reaction Time Inhibition / Disinhibition Frontal or Executive Skills 	Stroop test has three parts. In the first part, the words RED, YELLOW, BLUE, and GREEN (printed in black) appear at random on the screen, and the participant presses the space bar as soon as the test subject sees the word. In the second part, the words RED, YELLOW, BLUE, and GREEN appear on the screen, printed in color. The participant is asked to press the space bar when the color of the word matches what the word says. In the third part, the words RED, YELLOW, BLUE, and GREEN appear on the screen, printed in color. The participant is asked to press the SPACE BAR when the color of the word does not match what the word says.
Shifting Attention (SAT) <i>Approx. 2.5 Minutes</i>		<ul style="list-style-type: none"> Executive Function Shifting Sets: Rules, Categories, & Rapid Decision Making Reaction Time 	SAT test is a measure of ability to shift from one instruction set to another quickly and accurately. Participants are instructed to match geometric objects either by shape or by color. Three figures appear on the screen, one on top and two on the bottom. The top figure is either a square or a circle. The bottom figures are a square and a circle. The figures are either red or blue (mixed randomly). The participant is asked to match one of the bottom figures to the top figure. The rules change at random (i.e., match the figures by shape, for another, by color) and subject responds by pressing the two SHIFT KEYS.
Continuous Performance (CPT) <i>Approx. 5 Minutes</i>		<ul style="list-style-type: none"> Sustained Attention Choice Reaction Time Impulsivity 	CPT test is a measure of vigilance or sustained attention or attention over time. The test subject is asked to respond to the target stimulus "B" but not to any other letter. The stimuli are presented at random. Subject responds by pressing the SPACE BAR.
Perception of Emotions (POET) <i>Approx. 2 Minutes</i>		<ul style="list-style-type: none"> Social Cognition or Emotional Acuity Choice Reaction Time 	The POET measures how well a subject can perceive and identify specific emotions. "Social cognition" or "emotional acuity" has been defined as "the way in which people make sense of other people and themselves". It is the ability to perceive and understand social information. The reaction times in POET are much longer than in the other tests, indicating the complexity of central processes governing emotional acuity. Subjects respond using the SPACE BAR.
Non-Verbal Reasoning (NVRT) <i>Approx. 3.5 Minutes</i>		<ul style="list-style-type: none"> Reasoning Reasoning Recognition Speed 	The NVRT measures how well a subject can perceive and understand the meaning of visual or abstract information and recognizing relationships between visual-abstract concepts. The NVRT is comprised of 15 matrices, or visual analogies. The matrices are progressively more difficult. Non-verbal or visual-abstract reasoning is the process of perceiving issues and reaching conclusions using symbols or generalizations rather than concrete information. Subjects respond using the SPACE BAR.
4-Part Continuous Performance (4PCPT) <i>Approx. 7 Minutes</i>		<ul style="list-style-type: none"> Sustained Attention Working Memory 	The 4PCPT test is a four-part test that measures a subject's working memory and sustained attention. PART ONE - is a simple reaction time test, PART TWO - is a variant of the continuous performance test, the reaction times that are generated are "choice reaction times", PART THREE - is a "one back" CPT. The subject must respond to a figure only if the figure immediately preceding was the same. PART FOUR - is a "two-back" CPT. It is a difficult task and is used to measure working memory. Parts two, three, and four of the tests are used to calculate sustained attention domain. Subjects respond using the SPACE BAR.

CNS Vital Signs Clinical Domain Description

Single Test Domain

Multiple Test Domain

Neurocognitive Index (NCI)	Measure: An average score derived from the domain scores or a general assessment of the overall neurocognitive status of the patient. Relevance: Summary views tend to be most informative when evaluating a population, a condition category, and outcomes.
Composite Memory	Measure: How well subject can recognize, remember, and retrieve words and geometric figures. Relevance: Remembering a scheduled test, recalling an appointment, taking medications, and attending class.
Verbal Memory	Measure: How well subject can recognize, remember, and retrieve words. Relevance: Remembering a scheduled test, recalling an appointment, taking medications, and attending class.
Visual Memory	Measure: How well subject can recognize, remember and retrieve geometric figures. Relevance: Remembering graphic instructions, navigating, operating machines, recalling images, and/or remember a calendar of events.
Psychomotor Speed	Measure: How well a subject perceives, attends, responds to visual-perceptual information, and performs motor speed and fine motor coordination. Relevance: Ability perform simple motor skills and dexterity through cognitive functions i.e., use of precision instruments or tools, performing mental and physical coordination i.e., driving a car, playing a musical instrument.
Reaction Time*	Measure: How quickly the subject can react, in milliseconds, to a simple and increasingly complex direction set. Relevance: Driving a car, attending to conversation, tracking and responding to a set of simple instructions, taking longer to decide what response to make.
Complex Attention	Measure: Ability to track and respond to a variety of stimuli over lengthy periods of time and/or perform mental tasks requiring vigilance quickly and accurately. Relevance: Self-regulation and behavioral control.
Cognitive Flexibility	Measure: How well subject is able to adapt to rapidly changing and increasingly complex set of directions and/or to manipulate the information. Relevance: Reasoning, switching tasks, decision-making, impulse control, strategy formation, attending to conversation.
Processing Speed	Measure: How well a subject recognizes and processes information i.e., perceiving, attending/responding to incoming information, motor speed, fine motor coordination, and visual-perceptual ability. Relevance: Ability to recognize and respond/react i.e., fitness-to-drive, occupation issues, possible danger/risk signs or issues with accuracy and detail.
Executive Function	Measure: How well a subject recognizes rules, categories, and manages or navigates rapid decision making. Relevance: Ability to sequence tasks and manage multiple tasks simultaneously as well as tracking and responding to a set of instructions.
Simple Attention	Measure: Ability to track and respond to a single defined stimulus over lengthy periods of time while performing vigilance and response inhibition quickly and accurately. Relevance: Self-regulation and simple attention control.
Motor Speed	Measure: Ability to perform movements to produce and satisfy an intention towards a manual action and goal. Relevance: Preparation and production of simple manual dexterity actions e.g. manipulate and maneuver objects.
Social Acuity	Measure: How well a subject can perceive, process, and respond to emotional cues. Relevance: Spectrum screen, ability to recognize social cues or read facial expressions. Provides insight into inappropriate behavior, decreased inhibition, insensitivity to social standards, and social behavioral regulation.
Reasoning	Measure: How well is subject able to recognize, reason and respond to non-verbal visual-abstract stimuli. Relevance: Problem solving skills, ability to forge insights, discern meaning, and ability to perceive relationships.
Sustained Attention	Measure: How well a subject can direct and focus cognitive activity on specific stimuli. Relevance: How well a subject can focus and complete task or activity, sequence action, and focus during complex thought.
Working Memory	Measure: How well a subject can perceive and attend to symbols using short-term memory processes (4PCPT). Relevance: Ability to carry out short-term memory tasks that support decision making, problem solving, planning, and execution. Enables "right-now" responses.

Formulas for Calculating the Neurocognitive Domain Scores:

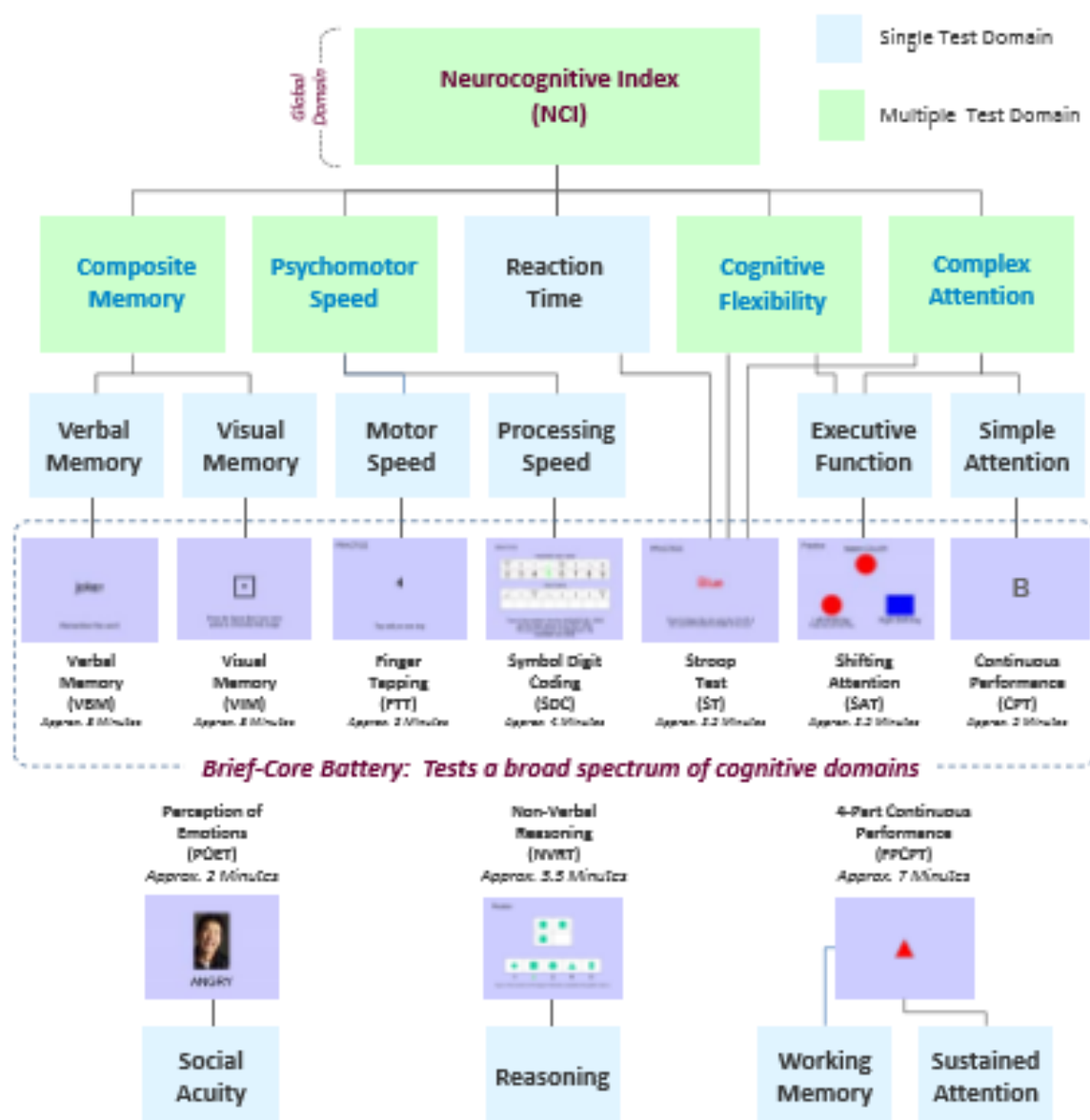
	Single Test Domain	Multiple Test Domain
BRIEF-CORE Clinical Domains		Domain Score Calculations: 1600+ Norms, Ages 8 to 90
Neurocognition Index - NCI		Average of five domain scores: Composite Memory, Psychomotor Speed, Reaction Time, Complex Attention, and Cognitive Flexibility; representing a form of a global score of neurocognition
Composite Memory		VBM Correct Hits Immediate + VBM Correct Passes Immediate + VBM Correct Hits Delay + VBM Correct Passes Delay + VIM Correct Hits Immediate + VIM Correct Passes Immediate + VIM Correct Hits Delay + VIM Correct Passes Delay
Verbal Memory		VBM Correct Hits Immediate + VBM Correct Passes Immediate + VBM Correct Hits Delay + VBM Correct Passes Delay
Visual Memory		VIM Correct Hits Immediate + VIM Correct Passes Immediate + VIM Correct Hits Delay + VIM Correct Passes Delay
Psychomotor Speed		FTT Right Taps Average + FTT Left Taps Average + SDC Correct Responses
Reaction Time		(ST Complex Reaction Time Correct + Stroop Reaction Time Correct) / 2
Complex Attention		Stroop Commission Errors + SAT Errors + CPT Commission Errors + CPT Omission Errors
Cognitive Flexibility		SAT Correct Responses - SAT Errors - Stroop Commission Errors
Processing Speed		SDC Correct Responses - SDC Errors
Executive Function		SAT Correct Responses - SAT Errors
Simple Attention		Continuous Performance (CPT) Correct Responses minus CPT Commission Errors
Motor Speed		Finger Tapping Test Right Taps Average + Finger Tapping Test Left Taps Average
Clinical Domains		Domain Score Calculations: 700+ Norms, Ages 8 to 90
Working Memory		(4PCPT Part 4 Correct Responses) - (4PCPT Part 4 Incorrect Responses)
Sustained Attention		(4PCPT Part 2 Correct Responses + 4PCPT Part 3 Correct Responses + 4PCPT Part 4 Correct Responses) - (4PCPT Part 2 Incorrect Responses + 4PCPT Part 3 Incorrect Responses + 4PCPT Part 4 Incorrect Responses)
Social Acuity		POET Correct Responses - POET Commission Errors
Reasoning (non-verbal)		NVRT Correct Responses - NVRT Commission Errors

Abbreviations Defined:

VBM – Verbal Memory Test; VIM – Visual Memory Test; SDC – Symbol Digit Coding Test; SAT – Shifting Attention Test; FTT - Finger Tapping Test; ST – Stroop Test; CPT – Continuous Performance Test; 4PCPT – Four Part CPT; POET – Perception of Emotions Test; NVR – Non-verbal Reasoning Test.

Neurocognitive Tests and Domain Scoring Process

The CNS Vital Signs domain scores are derived by summing primary raw scores from one (blue shaded box) or multiple (green shaded box) tests. Domain scores are presented as Subject (raw) Scores, Standard Scores, and Percentile Ranks. Subject Scores are computed from raw score calculations using the data values of individual subtests and are simply the number of correct responses, incorrect responses, commission responses, omission responses and reaction times. The Brief-Core Battery of the seven tests below score eleven Neurocognitive Domains and the Neurocognitive Index. All ten tests can be custom configured to meet clinical testing or research needs.



Appendix E: Respondents Letter of Consent



CONSENT

Statement of Agreement to Participate in the Research Study:

- I hereby confirm that I have been informed by the researcher, _____ (name of researcher), about the nature, conduct, benefits and risks of this study - Research Ethics Clearance Number: _____,
- I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.
- I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerised system by the researcher.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.
- I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

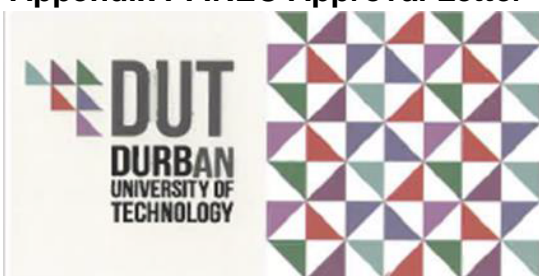
_____	_____	_____	_____
Full Name of Participant	Date	Time	Signature/Right Thumbprint

I, _____ (name of researcher) herewith confirm that the above participant has been fully

informed about the nature, conduct and risks of the above study.

_____	_____	_____
Full Name of Researcher	Date	Signature
_____	_____	_____
Full Name of Witness (If applicable)	Date	Signature
_____	_____	_____
Full Name of Legal Guardian (If applicable)	Date	Signature

Appendix F: IREC Approval Letter



Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology
P O Box 1334, Durban, South Africa, 4001
Tel: 031 373 2375
Email: izivishad@dut.ac.za
http://www.dut.ac.za/research/institutional_research_ethics
www.dut.ac.za

15 August 2019

Ms E L Skelding
6 Huntley Place
Westville

Dear Ms Skelding

Cognitive function among first division KwaZulu-Natal Rugby Union players and its associations with duration of exposure to the sport and a history of concussion.

I am pleased to inform you that Full Approval has been granted to your proposal.

The Proposal has been allocated the following Ethical Clearance number **IREC 062/19**. Please use this number in all communication with this office.

Approval has been granted for a period of **ONE YEAR**, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures [SOP's] of the IREC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's.

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

Professor J K Adam
Chairperson: IREC



Appendix G: IREC Recertification approval letter



Institutional Research Ethics Committee
Research and Postgraduate Support Directorate
2nd Floor, Berwyn Court
Gate 1, Steve Biko Campus
Durban University of Technology

P O Box 1334, Durban, South Africa, 4001

Tel: 031 373 2375

Email: lavishad@dut.ac.za

http://www.dut.ac.za/research/institutional_research_ethics

www.dut.ac.za

14 July 2020

Ms E L Skelding
6 Huntley Place
Westville

Dear Ms Skelding

Cognitive function among first division KwaZulu-Natal Rugby Union players and its associations with duration of exposure to the sport and a history of concussion.

Ethical Clearance number: IREC 062/19

The Institutional Research Ethics Committee acknowledges receipt of your Safety Monitoring and Annual Recertification report.

I am pleased to inform you that the study has been approved to continue.

Please note that ethical approval has been extended till **15 August 2021** if the research is not complete within this time, you will be required to apply for recertification three months before the expiry date.

Yours Sincerely

Professor J K Adam
Chairperson: IREC

Appendix H: Gatekeeper's permission letter

19 June 2019

Mr. S. Jafta and Mr. V. Chetty

General Manager and Club Rugby Administrator: KwaZulu-Natal rugby union

Request for Permission to Conduct Research

Dear Mr. S. Jafta and Mr. V. Chetty

My name is Emily Skelding, a MTech: Chiropractic student at the Durban University of Technology. The research I wish to conduct for my master's dissertation involves "The cognitive function among first division KwaZulu-Natal Rugby Union players and its associations with duration of exposure to the sport and a history of concussion".

I am hereby seeking your consent to access and conduct my research at the four following rugby clubs: Westville Old Boys (WOB), Hillcrest and University of KwaZulu-Natal (UKZN).

I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/ or assent forms to be used in the research process, as well as a copy of the provisional approval letter which I received from the Institutional Research Ethics Committee (IREC).

If you require any further information, please do not hesitate to contact me (0720513033; emilyskelding1@gmail.com). Thank you for your time and consideration in this matter.

Yours sincerely,

Emily Skelding
Durban University of Technology

Appendix I: Coach/manager Permission Letter

19 June 2019

MR (*Coach/Manager name*)

(*Details of which rugby club e.g. Westville Old Boys Rugby club*)

Request for Permission to Conduct Research

Dear Mr. (*Coach/Manager*)

My name is Emily Skelding, a MTech: Chiropractic student at the Durban University of Technology. The research I wish to conduct for my master's dissertation involves "The cognitive function among first division KwaZulu-Natal Rugby Union players and its associations with duration of exposure to the sport and a history of concussion".

I am hereby seeking your consent to access and conduct my research at (*Westville Old Boys (WOB), Hillcrest and University of KwaZulu-Natal (UKZN)*).



I have provided you with a copy of my proposal which includes copies of the data collection tools and consent and/ or assent forms to be used in the research process, as well as a copy of the provisional approval letter which I received from the Institutional Research Ethics Committee (IREC).

If you require any further information, please do not hesitate to contact me (0720513033; emilyskelding1@gmail.com). Thank you for your time and consideration in this matter.

Yours sincerely,

Emily Skelding
Durban University of Technology

Appendix J: Email from KZNRU Club Administrator permission to conduct research at clubs



**BRUMBIES VS
CELL C SHARKS**
SATURDAY, 22 JUNE | 12H05
CANBERRA


**QUARTER
-FINAL**

Good Afternoon All

Trust you All are well , Emily permission has been granted by the KZNRU .
Please Guys assist Emily with her research .

Best of Luck Emily .

KIND REGARDS




Vernon Chetty
KZNRU CLUB ADMINISTRATOR
Email: [REDACTED]

Black and white **Nothing else matters.**

Tel: [REDACTED]
Postal: [REDACTED]

sharkarugby.co.za



Appendix K: Editing Certificate

DR RICHARD STEELE

BA, HDE, MTech(Hom)

HOMEOPATH

Registration No. A07309 HM

Practice No. 0807524

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Associate member: Professional Editors'

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031-201-6508

082-928-6208

Email: rsteele@vodamail.co.za

EDITING CERTIFICATE

Re: Emily Lauren Skelding

Master's dissertation: **Cognitive function among first division KwaZulu-Natal Rugby Union players and its associations with duration of exposure to the sport and a history of concussion**

I confirm that I have edited this dissertation and the references for clarity, language and layout. I returned the document to the author with track changes so correct implementation of the changes and clarifications requested in the text and references is the responsibility of the author. I am a freelance editor specialising in proofreading and editing academic documents. My original tertiary degree which I obtained at the University of Cape Town was a B.A. with English as a major and I went on to complete an H.D.E. (P.G.) Sec. with English as my teaching subject. I obtained a distinction for my M.Tech. dissertation in the Department of Homoeopathy at Technikon Natal in 1999 (now the Durban University of Technology). I was a part-time lecturer in the Department of Homoeopathy at the Durban University of Technology for 13 years.

Dr Richard Steele

08 May 2021

per email