A CROSS SECTIONAL STUDY TO DETERMINE WHETHER THERE ARE CENTRAL NERVOUS SYSTEM CHANGES IN RUGBY PLAYERS WHO HAVE SUSTAINED RECURRENT ANKLE INJURIES

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DECLARATION

I, Alice Jane Rawlinson, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

Signed by candidate

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LIST OF ABBREVIATIONS

ACC	Anterior Cingulate Cortex
ATFL	Anterior Talofibular Ligament
CFL	Calcaneofibular Ligament
CLBP	Chronic Low Back Pain
CNS	Central Nervous System
CRPS	Complex Regional Pain Syndrome
fMRI	Functional Magnetic Resonance Imaging
IASP	The International Association for the Study of Pain
IRB	International Rugby Board
JPS	Joint Position Sense
LAI	Lateral Ankle Injury
M1	Primary Motor Cortex
PAG	Periaqueductal Grey
PF	Plantar Flexion
PFC	Prefrontal Cortex
PH	Player Hours
PLP	Phantom Limb Pain
PPDT	Pressure Pain Detection Threshold
PTFL	Posterior Talofibular Ligament
ROM	Range of Movement
RT	Recognition Time
RWC	Rugby World Cup
S1	Primary Somatosensory Cortex
S2	Secondary Somatosensory Cortex
TPD	Two Point Discrimination

GLOSSARY OF TERMS

Blood bin	A temporary substitution for a visibly bleeding player who must leave the field of play for first-aid treatment.[a]
International Rugby Board (IRB)	The world governing and law-making body for the sport of rugby union.[b]
Rugby World Cup	The premier international rugby union competition. The sport's governing body, the IRB, organizes the event.[c]
Joint Position Sense and Proprioception	The awareness of the position of the body or its parts in space, a combination of the sense of equilibrium and kinesthesia.[d]
Allodynia	Meaning "other pain", is a pain due to a stimulus, which does not normally provoke pain.[e]
Homunculus	The physical representation of the human body in the cortex of the brain.[f]
Hyperalgesia	Abnormally heightened sensitivity to pain.[g]
Central Processing	Central nervous system plasticity, an adaptive process occurring in the cortex.[h]

a) www.yourdictionary.com/**blood-bin**
b) www.en.wikipedia.org/wiki/**World_Rugby**
c) www.en.**wikipedia**.org/**wiki/Rugby_World_Cup**
d) www.thefreedictionary.com/**proprioception**
e) http://www.medicinenet.com/script/main/art.asp?articlekey=25197
f) https://en.wikipedia.org/wiki/Cortical_homunculus
g) http://www.oxforddictionaries.com/definition/english/hyperalgesia
h) https://en.wikipedia.org/wiki/Neuroplasticity

ABSTRACT

Background:

Rugby is a popular game played around the world and has one of the highest recorded injury rates in sport. The literature exposes ankle injuries as one of the most common areas injured in sport and this trend carries through in rugby too, with lateral ankle sprains predominating. Recurrent ankle injuries are commonly reported in the literature and account for high economic and social burden. There are many intrinsic and extrinsic risk factors credited with causing lateral ankle injuries but to date the literature does not show conclusive evidence for management and prevention of recurrent injuries. A new area of research that has not previously been explored is the neurological influence on recurrent injury. Central processing is a recognised form of learning seen in adults and children during normal development and training and more recently acknowledged in injury settings. This phenomenon has also been seen in abnormal states of development such as neglect and chronic pain.

Aim:

The purpose of this study was to investigate whether there are changes in the central nervous system of rugby players with recurrent ankle injuries.

Methods:

An experimental and control group was used for this cross sectional study. Participants were recruited from the Golden Lions Rugby Union. Forty-six players in total were recruited. The control group consisted of 22 players, and the recurrent injury group consisted of 24 players. Medical and Sports History Questionnaire was administered as well as a battery of four physical test procedures. The questionnaire asked participants to provide information regarding demographics, playing position, training and playing history, current general health, current and previous injury history, and specifically ankle injury history. The four testing procedures were: body image testing, laterality testing, two point discrimination testing and pressure-pain threshold testing.

Results:

The results were collected and recorded. Between group and within group comparisons were made for the control and recurrent injury groups. From the Medical and Sports History Questionnaire the results indicated that the recurrent injury group participated in a significantly shorter preseason training period compared to the control group. The laterality testing within group analysis had a significant difference, the injured side had a slower recognition time [1.4(1.3-1.6)] compared to the uninjured side [1.3(1.15-1.5) $p<0.01$]. Pressure pain threshold testing produced a significant difference for the control group on the ATFL test site and the PTFL site. The PTFL site also demonstrated significant difference in the between group comparison analysis.

The results from the two point discrimination testing and the body image testing produced interesting results. The two point discrimination tests performed on the both the recurrent injury group and the control group using within group comparison showed significant differences on the anterior talofibular ligament between the affected and non-affected limbs. The between group test result were also significant for the injured vs control side at the ATFL site. The affected side showed a poorer ability to differentiate between one and two points, needing a bigger area before two points were distinguished from one.

Similarly, body image testing showed significant differences in the within group comparison of total area drawn for the recurrent injury group only. In the recurrent injury group, the drawing of the affected foot was significantly larger than the drawing of the unaffected side. The control group showed no differences between sides.

Conclusion:

The study recommends that there is a relationship between central nervous system changes in recurrent ankle injuries in the sample group of professional rugby players. The data indicates that preseason length is a factor to be considered in recurrent ankle injuries. The clinical tests focussed specifically on central nervous system changes also produced some illuminating results. The recurrent injury group demonstrated significant difference between injured and uninjured sides in both two point discrimination testing of the ATFL ligaments and in the body image drawing of the foot and ankle. The control group in contrast didn't yield any differences between sides for these same tests. The

pressure pain testing and laterality testing producing significant results also indicate the central nervous system involvement in recurrent injury.

Clinical Relevance:

The results of this study indicate a relationship between central nervous system changes and recurrent ankle injuries in rugby players. This relationship is a new area of focus for research for both central nervous system research and recurrent ankle injury research. The argument for this focus is recognized with the results of this study but further research is necessary. For future studies wanting to look at central nervous system changes related to recurrent injury a larger sample group would be required representing a more general population group. A non-contact sporting population should be considered or a sport with a slightly lower injury rate as the high injury rate in rugby makes inclusion and exclusion criteria more limiting. The testing should be performed in a closed private environment, limiting external distractions with the tester and sample group blinded. Finally, the laterality test used should be aimed at detecting more subtle CNS changes and so should be performed at a much more challenging level

Keywords:

Rugby, lateral ankle sprain, instability, recurrent ankle injuries, chronic pain, central nervous system plasticity, central processing, laterality, two point discrimination, body image, pressure-pain.

CHAPTER ONE: INTRODUCTION AND SCOPE OF THESIS

Ankle injuries have been described in the literature as the most common sports injury, with anterior talofibular ligament sprains predominating.[1] Among English professional rugby players, the incidence of ankle injuries has been reported as the second most common injury sustained.[2] A study on New Zealand rugby players found that the ankle was the most common site of rugby related injury and that lateral ankle sprain was the most common diagnosis accounting for 14% of all rugby related injuries.[3] A study in South African professional rugby players over one season indicated an ankle injury incidence rate of 1.6 per 1000 player hours, with 25% of all injuries sustained being ankle ligament injuries.[4]

For a professional athlete, time away from training and competition has a direct effect on financial status with loss of earnings. Approximately one third of the total costs due to sports injuries are attributed to ankle injuries.[5] The literature identifies the potential "huge economic losses" as a result of key players' absence due to injury and as ankle injuries consistently have one of the highest incidence and severity rates they will contribute to this problem.[1,6] Notwithstanding the pain, these injuries may result in loss of playing time, medical expenditure, disability, permanent termination of sport participation and psychological problems.[1]

Numerous studies have indicated that the severity[a] of recurrent injuries in rugby players is greater than new injuries.[1,5,7,8] Further, joint/ligament pathologies account for the greatest severity among training injuries in terms of time lost per 1000 player hours, in comparison to muscle/tendon pathology and bone pathology. After 12 weeks, 60% to 90% of injured athletes return to pre-injury levels of play, but up to 50% of acute ankle injuries result in chronic ankle instability.[5]

The literature is inconclusive; numerous causes and risk factors associated with recurrent ankle injuries[b] have been investigated, however, to date central nervous system factors have not been considered as a potential influence and so have not yet been explored. Research done on child and adult learning has identified the adaptiveness of the brain to cognitive stimuli. This process is described as central nervous system plasticity.[9] Recently it has come to light that similar neurological adaptation is seen in injuries.[9–11] Chronic pain pathologies, amputation and limb immobilization studies have all revealed cortical changes and central nervous system adaptations similar to the findings seen in a normal learning processes.[9,12,13] Research to date has not looked at the possibility of a central nervous system adaptation contributing to recurrent injuries.

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[a] Severity: Injury severity was defined as the number of days taken to return to full fitness: "able to take full part in training activities (typically planned for that day) and be available for match selection.[7] Time (days) lost from competition and practice was accepted for defining injury severity:
The total number of days that elapsed from the day of injury to the day of the player's return to full participation in team training and availability for match selection.
Slight (0–1 days), minimal (2–3 days), mild (4–7 days), moderate (8–28 days), severe (>28 days), ''career-ending,'' and ''non- fatal catastrophic injuries.''[65]

[b] Recurrent ankle injury: two or more lateral ankle injuries on the same ankle.

In summary, recurrent ankle injuries are very common and costly problems experienced by professional rugby players and organisations.[1,6,14] There is inconclusive evidence in the literature regarding causes, prevention and rehabilitation strategies for recurrent ankle injuries.[1] Currently, there is no literature examining the central nervous system influence on recurrent or chronic injuries. There is evidence showing central nervous system changes in immobilised limbs and chronic pain conditions.[15,16] This study aims to investigate whether a link between central nervous system changes in recurrent injuries exists similar to the evidence for central nervous system changes in immobilised limbs and chronic pain conditions, focussing specifically on investigating recurrent ankle injuries in rugby players.

A comprehensive review of the literature on recurrent ankle injuries in rugby will be presented (Chapter 2, p.9). This will be followed by a description of the study designed to answer the above-mentioned questions (Chapter 3, p.46). The summary and conclusion section will complete this dissertation (Chapter 4, p.85).

CHAPTER TWO: LITERATURE REVIEW - RUGBY INJURIES, A CHRONIC PAIN IN THE ANKLE

2.1. Introduction

This literature review will briefly discuss the sport of rugby; and it will then discuss the injury epidemiology of rugby and specifically explore the incidence, causes and risk factors for acute and recurrent ankle injury in rugby. The review will then focus on parallels between recurrent ankle injuries and chronic pain pathology, with chronic pain and its pathophysiology being defined. Finally, current models for clinical testing of cortical reorganisation and central and peripheral sensitization will be described.

Recurrent ankle injuries are described in the literature using many different terms. Commonly used expressions are chronic ankle instability, chronic ankle injuries, recurrent instability, recurrent lateral ankle instability, lateral ankle instability, chronic ankle instability (CAI), chronic lateral ankle instability, ankle instability, residual ankle instability, chronic instability and chronic ankle sprain.[1,7,17,18] In this study the term recurrent ankle injury will be used throughout as defined by Postle et al.[19] Data for this review were sourced from sports, sports medicine, sports science, health science, medicine, psychology and pain literature. Searches through Google Scholar, PubMed and Pedro were utilised. Key words used in the searches included: “rugby”, “epidemiology”, “ankle injuries”, “lateral ankle injuries”, “chronic ankle instability”, “chronic pain”, “neuroplasticity”, “cortical reorganisation”, “laterality”, “two point discrimination”, “body

image", "pressure pain", "complex regional pain syndrome", "functional MRI studies" and "recurrent injury".

Rugby is a popular international contact sport played by over 100 countries across five continents.[2] It is played between two teams with 15 players on the field at one time. The game is structured with set plays and loose plays focused on contesting for possession of the ball.[20] Rugby has one of the highest reported incidences of injury in sport worldwide, regardless of the injury definition used.[2]

Ankle injuries represent between 8% and 20% of rugby injuries.[7] In particular, the lateral ankle sprain is the most frequently reported injury to the ankle. These injuries are responsible for a large percentage of the total time lost to injury.[7] The literature indicates that many athletes sustaining ankle injuries report recurrences and the development of chronic injuries.[7] Recurrent ankle injuries make up 27% of ankle injuries, with a higher incidence[c] of injury than any other body part in rugby injury statistics.[7]

Injury can lead to disuse of the affected area due to pain protection mechanisms.[13] Zanette et al. reported on research showing that immobilisation of a limb was associated with central motor changes after six weeks.[13] Langer et al. looked at magnetic resonance imaging (MRI) studies and found visible central changes after 16 days of limb

[c] Incidence rate was defined as the number of injuries per 1000 player-hours of match exposure for match injuries or injuries per 1000 player-hours of training for training injuries.

immobilization.[21] These findings are similar to those reported in studies of people with chronic pain.[9,10,12,13,22]

2.2 Rugby

Rugby originated in England in 1823 and has since grown to be a popular international sport played around the world. The game is played by men and women of all ages. The rules of the game are outlined and governed by the International Rugby Board (IRB). The game is played by two teams of 15 players on a field measuring 100 m by 70 m with two goal areas. The aim of the game is to score as many points as possible by carrying, passing, kicking and grounding the ball.[7]

2.2.1 Epidemiology of Rugby Injuries

Various studies have been conducted around the world over the last 17 years on injury statistics for international rugby. These studies, date from 1995, when rugby was still considered to be in the amateur era, until recently when it is considered a professional sport.[20,23–26] The most significant rugby competition currently held is the Rugby World Cup (RWC), which has been run every four years since 1987 by the IRB. This is an international competition where teams from all six continents compete.[23] The event is regarded as one of the largest sports competitions in the world and is subjected to worldwide media interest.[24]

Injury is a major concern in the sport of rugby, with a high incidence of acute and recurrent ankle injuries.[7] Injury data has been collected since the 1995 IRB RWC and continued through the 2003, 2007 and 2011 competitions. In 1995 there were 16 teams competing with a total of 55 matches played. The injuries were divided into pool game injuries and playoffs injuries. The data criteria collected has changed as more data has become available and knowledge and rules of the game have changed over the four studies done at each RWC so for some areas overall comparison is difficult to make.

The overall injury rate for the 1995 competition was 32/1000 player hours (ph) and 0.8 injuries per match.[25] Incidence increased to 43 injuries per 1000ph with a 0.6 injury per match ratio in the playoff games as apposed to 30/1000ph in the pool games. Although no severity data were collected, 30% of all the injuries recorded were ligament injuries and 3% of the injuries were to the ankle.[25]

Data collected by Best et al. from the 2003 tournament, when rugby had become a professional sport, showed a significant increase in injury rates.[23] Twenty teams competed and 48 games were played; 40 pool games and 8 playoff games. The total injury rate was 97.9 per 1000ph, which is a marked increase from 1995. There was also a change in incidence for pool and playoff games. Contrasting with the 1995 data, the pool stage games had a higher injury rate (103.1/1000ph) than the playoff matches (71/1000ph).[23] The literature suggests that the increase in injury rates demonstrated in the professional era is due to several factors, including an increase in player size;

resulting in greater speed and higher collision impacts. Further, the time the ball is in play has become longer in the professional era. Finally, an increase in training and playing volume is theorised to cause an increase in fatigue levels.[23,24] Another speculation on the increased injury rates in professionalism is the competitiveness for selection; with practices becoming more competitive as players need to be selected for economic reasons.[25]

Ankle and foot injuries were recorded as 14/1000ph, second after head and neck injuries in the 2003 tournament. The high rate of head and neck injuries has been called into question by the authors however as most of these were lacerations and 'blood bin' injuries (42% of all injuries were lacerations and contusions and 92% of these were on the head and face).[23] It was recommended that for future research the lacerations and blood bin injuries be recoded separately so as not to skew the data.[23] With the lacerations or open wound injuries removed, sprains are the most common injury recorded at the 2003 tournament and if you continue the same elimination procedure with lacerations and open wounds removed, ankle sprains are the most common reported area and type of Injury.[23]

The 2007 and 2011 RWC injury surveys took into account the recommendations put forward by Best et al. from 2003 and included markers of injury severity in the survey.[23,24,26] Both competitions were structured the same way as previously with 20 teams and a total of 48 matches. The total injury prevalence for 2007 and 2011 were

83.9/1000ph and 89.1/1000ph respectively. Both of these are decreased from the 2003 figures but increased from the amateur era in 1995, and are comparable to data reported for English elite professional rugby.[2,24,26] Ankle-specific injury data were 8.6/1000ph in 2007 and decreased to 6.3/1000ph in 2011. Both surveys demonstrated that ankle injuries were the third most common injuries after injuries to the shoulders and knee (2007) or posterior thigh (2011). The severity data collected represents training or match days lost as a result of injury. The severity of ankle injuries was reported to be 10 days and 14.4 days in 2007 and 2011 respectively, third after upper limb (21.4 days and 36.5 days) and knee (28.2 days and 67.8 days) injuries in both studies.[24,26]

The advent of professionalism has been associated with an increase in injury risk.[20] Literature indicates that the tackle phase of play is where the majority of injuries occur (58% to 88%) for both the tackler and the player being tackled.[6,20,23,24,26,27] As mentioned above, the literature also demonstrates that the ball is in play for longer periods of time during the professional game compared to the amateur era (31% in 1993 to 44% in 2007 and 2011), suggesting more room for the tackle phase of play.[24] This is demonstrated by a 51% increase in number of tackles, a 72% increase in number of tries and a decrease in number of kicks, mauls, scrums and lineouts. These factors indicate a more open game is being played allowing more tackle phases to occur. Roughly half of all match injuries occur during the tackle phase of play.[4,20]

Along with the increase in number of injuries, the severity of injuries sustained by professional rugby players has increased since the amateur era. Before professionalism 63% of injuries were classified as mild, 26% were moderate and 11% were severe. Since the advent of professionalism, 64% of injuries are mild, 12% are moderate and 24% are severe.[6,14,20] This data shows that the number of mild injuries has maintained since professionalism but the number of severe injuries has more then doubled, suggesting that the overall injury severity has increased since 1995.[6] A South African study that examined the incidence and nature of injuries in rugby players also highlighted the elevated injury rate in professional rugby and advocated for the need to limit injuries among this population group.[4] Best et al. also correlated severity of injury with time away from sport participation and increased burden on both medical support and the athlete.[23]

Kerkhoffs et al. identified the need to establish evidence-based guidelines for management of ankle injuries, and the associated high economic burden of ankle injuries in sport.[5] They state that approximately one-third of the total costs resulting from sports injuries are caused by ankle injuries.[5] Murphy et al. indicated that the total cost of sports injuries worldwide is estimated to be $1 billion.[8] Fong et al. recognised the broader effects of sports injuries, over and above the physical problem itself, such as chronic instability, permanent or prolonged cessation of sports participation and psychological problems.[1] They conclude that for commercial (professional) sports teams absence of key

players as a consequence of ankle injuries can lead to possible defeats and has major economic consequences.[1]

Since rugby has become a professional sport, the way that the game is played has evolved. This evolution has resulted in a more exciting brand of rugby but also an increase in the incidence and severity of injuries sustained during play.[20] Ankle injuries make up a high percentage of the total injuries in sport generally and rugby specifically.[1,7,24] As the sport is becoming more professional, the financial burden of injury – causing a cascade effect with loss of key players leading to loss of fan support and potential losses of games and limiting competition progression – becomes a more pressing factor as the sport has to financially support itself to maintain its professionalism.[1] In congruence with this, as injury prevalence increases, so too does the economic pressure.[1]

2.2.2 Prevalence of ankle injuries in rugby

In a review of 70 sports from 38 countries, Fong et al. found that rugby has the highest incidence of ankle injuries per 1000 player hours (4.20/1000ph).[1] The review also indicated that in rugby specifically, 77% of the ankle injuries are lateral ankle sprains and 73% involve a rupture or tear of the anterior talofibular ligament.[1] These findings are supported by those of Sankey et al. who also found that lateral ankle ligament injuries were the most common match and training ankle injuries in rugby.[7] They further stated

that ankle injuries in professional rugby union account for a considerable amount of time off (10-13% of total days absent due to injury) due to treatment and rehabilitation.[7]

High injury prevalence amongst younger players has been identified as a limiting factor on career length. Studies on younger sporting populations have found that the younger athletes who have higher injury rates do not continue to perform at a high level and end up with early retirement due to injury.[28–30] Erpič et al. found that the greatest number of athletes with termination of career due to injury was the youngest age group investigated; pre-adulthood to young adulthood (18 to 23 years)[30–32].

Ballet studies done on a professional ballet company in America found that the younger dancers had the greatest incidence of injury as well as the greatest number of injuries per dancer.[32] This is similar to findings reported in previous research on ballet dancers.[32] A similar pattern has been recorded in other youth sporting populations.[28,30]

In Drawer and Fullers' study on retirement of soccer players, they noted that significantly more respondents who had retired early had sustained moderate and major injuries to the ankle and knee joints and that the numbers of moderate injuries to the ankles were also significantly greater than the numbers of moderate injuries to the knees.[31]

This trend of injury-related early retirement from sport extends into rugby with 26% to 29% of retired athletes reporting their retirement was premature due to injury.[20] As has already been discussed, recurrent injuries account for greater severity of injury and greater cost to the player, and it may therefore be suggested that recurrent injuries could

be a leading cause of injury-related early retirement from professional sport. Ankle injuries are one of the most common injuries sustained by rugby players.[7] Sankey et al. and Brooks et al. both correlate the nature of the sport to the high incidence of ankle injuries with; the repeated explosive forces, changes in pattern, speed or surfaces to name a few.[7,20]

2.3 Ankle injuries

The literature indicates that the ankle is one of the most commonly injured body areas of all sports injuries and accounts for 10% to 30% of all sports injuries.[1,7] In support of the above studies focussing on the ankle in rugby, a systematic review found that the lateral ankle sprain is the most common type of ankle injury sustained by the sporting population, presenting in 80% to 100% of all ankle injuries.[1]

2.3.1 Acute and Chronic Ankle Injuries

Diagnosis of acute ankle injury can be made accurately if a haematoma is present, accompanied by local pressure pain on palpation and or a positive anterior drawer test after one initial incident.[5] Witchalls et al. explains recurrent ankle injury as "*pain, recurrent sprains and subjective feelings of instability up to three years post initial insult*".[18] Chronic ankle injuries appear to be relatively common. A systematic review on recurrent ankle sprains found that 34% of acute ankle injuries report a persistent problem within three years of their initial incident.[33] In addition, 40% of acute ankle injuries result in chronic instability in the general population.[33] For lateral ankle injuries specifically, 5% to 30% of patients reported pain and a feeling of instability in their ankle

after their initial injury, with up to 34% of first time injuries sustaining a recurrent incident.[5] Re-sprains were recorded anywhere from two weeks to 96 months post initial injury.[34]

In a cohort of professional rugby players, recurrent ankle injuries accounted for 27% of all ankle injuries sustained. The ankle was the body site most prone to recurrent injury and more specifically, the lateral ankle ligaments, anterior joint capsule and the Achilles tendon were the anatomical structures most commonly injured.[7] In terms of the severity of recurrent and acute ankle injuries, an average of 14 days and 19 days were lost to injuries respectively.[7] In contrast, studies on European professional rugby union players found that recurrent ankle injuries (27 days absence from training) had a significantly greater severity in terms of time lost to injury than that for acute injuries (16 days absence from training) in both forward and backline players.[2]

Intrinsic functional deficits associated with increased risk of ankle injury indicate that injury to an ankle places individuals at risk of chronic ankle dysfunction.[18] A study administered through a sports clinic, recruiting the general population found that approximately 73% of individuals experienced on-going symptoms up to 18 months after an acute ankle sprain. Of those, 40% had moderate to severe symptoms. In some cases, symptoms have been reported to persist beyond three years post initial injury.[18] One hypothesis suggests that control of movement and active stability of the ankle joint is attained through the interaction of sensory reception, peripheral motor output and central nervous system interpretation and movement planning.[18] Extrapolating this

hypothesis suggests that disruption of these systems would lead to the recurrence of injuries.[18]

The clinical course of acute ankle sprains was investigated by Van Rijn et al. in a systematic review of the literature.[34] The review indicated that the majority of patients had a significant reduction in pain during the first two weeks post acute ankle injury. After the initial two-week period the symptoms reduced further, but at a slower rate. However, 5% to 33% of patients included in the study still reported pain at one-year follow-up and 5% to 25% reported pain at three-year follow-up.[34] A re-sprain or re-injury was acknowledged from a time period of two weeks post initial injury to 96 months post initial injury and the percentage of re-sprains ranged from 3% to 34% of patients. Van Rijn et al. cited high level sports activity (training > 3 times per week) as a significant prognostic factor for residual symptoms compared to low level sports activity.[34]

2.3.2 Risk factors/ predisposing factors specific to ankle injuries in rugby

There is a large amount of literature on the causes and risk factors for ankle injury. Gissane et al. described two groupings of risk factors commonly found in the literature, namely intrinsic or subject related and extrinsic or externally related risk factors.[35] They go on to say that even this classification has its pitfalls as injuries are "*multi-risk phenomena*" and there is constant interplay of risk factors. Regardless of its weaknesses, this is the commonly used model to describe injury risk factors.[35]

2.3.2.1 Intrinsic risk factors

Intrinsic risk factors are defined as individual, biomechanical, biological and psychological characteristics. Commonly identified intrinsic risk factors for lateral ankle injuries include: postural sway, range of motion, muscle strength, proprioception, previous sprains, impaired balance, increased peroneal reaction time, decreased joint position sense, sensorimotor deficits, age, sex, inadequate rehabilitation, body size, limb dominance, flexibility, postural stability, anatomical alignment and foot morphology.[5,8,18,33,36,37]

Intrinsic risk factors identified by Witchalls et al. with the greatest effect were strength, postural stability and joint position sense.[18] More specifically, Witchalls et al. found weaker eccentric inversion strength at testing speeds slower than 110° and relative eversion weakness compared to inversion strength as well as higher concentric plantarflexion (PF) strength were the most indicative of injury risk.[18]

Reduced postural control and greater postural sway tested in functional tasks, balance in single leg stance and complex postures were also found to be positive for ankle injury.[18]

The results stated that inversion joint position strength correlates to injury risk but eversion joint position sense does not have sufficient significance to indicate an association. The review did not identify significant evidence for testing muscle reaction time, ROM and ligament stability to support any correlation. They proposed that either the quality of the testing, the study size or study design were not acceptable to produce accurate results, rather than that that those factors did not play a role.[18]

Strength, proprioception, range of movement and postural sway have also been investigated as risk factors for lateral ankle injuries.[37] A significant correlation between decreased ROM and ankle injury has been identified. There was a 5:1 risk ratio between individuals with decreased ROM (34° dorsiflexion ROM) and normal ROM (45° dorsiflexion ROM). The strength results indicated a significantly higher eversion/ inversion strength ratio and reduced passive inversion position sense in injured individuals compared to healthy controls. There is some evidence that postural sway may play a role in injury risk but the results are varied. Again the literature is inconclusive and provides varying and inconsistent results.[37]

In a similar level one evidence study; age, previous injury, inadequate rehabilitation, aerobic fitness, body size, limb dominance, flexibility, joint laxity, muscle strength, postural stability and foot morphology were examined as potential risk factors for lower extremity injury[8]. The authors found that 25 to 35 years of age was the highest risk age group for ankle injuries, comparable with previous literature.[8] Likewise, there was strong evidence for previous ankle injury increasing risk of recurrent ankle injury especially when combined with inadequate rehabilitation (including premature return to play).[8] This interpretation of the literature was emphasised by data stating that 25% of athletes who sustain a minor injury suffer a major injury within two months of their return to play if they return prematurely or were improperly rehabilitated. Of these injuries, 11% were of the same type and in the same location as their initial injury.[8]

In the above systematic review, the literature was not conclusive on the relationship between aerobic fitness and injury. The studies included used different methods to characterise aerobic fitness leading to inconclusive results.[8] In addition, the relationships between body size and injury, and limb dominance and injury were not convincing due to different data collection methods and varying study quality. Although increased broad-spectrum joint laxity was not found to be an injury risk factor, decreased broad-spectrum joint laxity in male athletes was found to be a risk factor.[8] There was some evidence of an association between specifically increased ankle joint laxity and injury. Athletes with ankle joint laxity accounted for 50% of the total non-contact injuries and 15% of the total contact injuries. The authors also identified a strong association between strength and ankle injury. In particular, injured athletes reported higher strength differences between eversion and inversion muscles; the ration of stronger eversion strength to inversion on the injured group was 1.0 compared with weaker eversion (0.8) in the uninjured group.[8] They also demonstrated higher plantar flexion strength compared to dorsiflexion.[8]

The relevance of torque strength testing is called into question by Murphy et al.[8] The testing techniques used in many of the studies were performed non-weight bearing and cannot replicate the speeds at which physical activity and injury happens.[8] The authors also looked at postural stability and concluded that the results were confounded by the many factors responsible for balance including visual cues, vestibular function and somatosensory feedback.[8] They recommended that more research with careful consideration of these variables is needed to establish the relationship properly. The last aspect investigated by Murphy et al. was anatomical alignment.[8] The authors commented

that the different methods of measuring foot and ankle alignment make it difficult to obtain conclusive evidence, but they did suggest a relationship between high foot arch structure and lateral ankle sprain.[8]

The literature indicates that there is a greater risk of re-injury (>70%) following an acute lateral ankle sprain due to functional and mechanical instability as discussed below. Recurrent injury to the ankle has commonly been shown to result in chronic ankle instability.[33,34,36,38,39] Numerous authors propose two aspects contributing to chronic ankle instability; functional ankle instability and mechanical ankle instability.[33,36] Functional instability is described as the perception that the ankle gives way.[33,36] Hubbard et al. described functional instability more specifically as proprioception impairments, altered neuromuscular control, strength deficits and decreased postural control.[38] Mechanical instability is explained as joint laxity from pathological ligamentous tissue, degenerative synovial changes and impaired arthrokinematics.[33,36,38]

A systematic review of the literature conducted by Hiller et al.[33] on the characteristics of people with recurrent ankle sprains conforms to the idea of mechanical and functional instability as contributing factors.[33] They identified a larger talar curve, decreased concentric inversion strength and increased postural sway during single leg standing on a hard surface with eyes closed as risk factors for recurrent ankle injuries.[33] The authors also observed increased foot inversion during gait with less foot ground clearance and an increased time to stabilisation after a jump.[33] The results observed for ankle ROM and

proprioception were similar to those of Murphy et al.[8] in that they were found to have no correlation to ankle injury.[8,33]

In summary, many studies have been conducted looking at intrinsic risk factors for ankle injuries. Inversion strength, loss of range of movement and proprioception deficits consistently emerge as influencing factors in many level two and below studies. [8,33,38] Level one evidence however, often indicates inconclusive results due to poor study quality and inconsistencies in data collection.[8,18,37]

2.3.2.2 Extrinsic risk factors

Extrinsic factors are defined as factors relating to the type of activity and the manner in which it is being practiced at the time of injury, factors independent of the injured person.[35] Various authors have investigated both rugby specific literature and general sporting populations to identify extrinsic risk factors for ankle injuries.[7,8,36,37]

There is a greater incidence[d] of injury in higher levels of competition.[8] It is suggested that this may be due to more aggressive, risk taking behaviour in competition compared to training and lower levels of competition. The research to establish whether this increased incidence is associated with different levels of skill is inconclusive. The literature is split with some studies showing low level of skill being associated with more

[d] Incidence rate was defined as the number of injuries per 1000 player-hours of match exposure for match injuries or injuries per 1000 player-hours of training for training injuries.

injuries whereas other studies showed high skill levels being associated with injuries.[8] Clearly, further research is needed in this area.

Preseason training has been brought into scrutiny with regard to in-season injury rates. Current data indicates that there is convincing evidence in adult epidemiological studies that decreased endurance, strength and preseason sport-specific training are associated with greater sports injury proportions.[40] High rates of rugby injury may be related to decreased endurance or strength associated with limited preseason training, as indicated in both adolescent and adult studies.[2,40,41]

A well researched area of extrinsic influences involved in ankle injury is ankle bracing.[7,8,42] The literature is mostly in agreement on the use of ankle bracing and taping decreasing the incidence of ankle injury.[7,8,42] Only 8% of ankle injuries were sustained by players wearing tape and most of these injuries were capsular sprains and re-injuries.[7] Murphy et al. hypothesised that this is due to an increased kinaesthetic awareness of ankle position and increased support of the ankle joint, especially hind foot inversion when the ankle is braced or taped.[8]

In a study examining ankle injuries in professional rugby union players, the majority of ankle injuries occurred in the second (30%) and fourth (35%) quarters of the match, more specifically during the latter part of each time period. Authors hypothesise this is due to fatigue or reckless play influenced by time pressure to score.[7] Of these injuries, 71% were lateral ankle injuries. With 52% of the ankle injuries sustained during contact with

another player, 35% non-contact injuries and 12% were unknown mechanisms. The phase of play that most commonly injured the lateral ankle structures was the lineout[e] (63%).[7] The authors found that the second-row forwards sustained the most ankle injuries and the back-row forwards sustained the least ankle injuries. Interestingly the authors found that the majority (60%) of match injuries occurred on hard or firm playing surfaces and 40% on slippery or heavy-grass surfaces[7]. Continuing rugby research is uncovering a multitude of variables that appear to contribute to lateral ankle injuries including time during the match, phase of play, set piece, player position and playing surface.

In a comprehensive study on New Zealand rugby injuries, playing position, body mass index, previous injury, strenuous activity and smoking history were all risk factors for injury.[43]

The authors found that players reporting injuries at the beginning of the season or during the season were significantly more at risk of re-injury and new injury then non-injured players. The authors also identified that players injured in the previous season were not at any greater risk then their injury free teammates so long as they started the preseason and season injury free. Based on these findings, the authors of the study emphasised the importance of rehabilitation post injury in agreement with Murphy et al.[8,43]

[e] Lineout: The purpose of the lineout is to restart play, quickly, safely and fairly, after the ball has gone into touch, with a throw-in between two lines of players. (IRB Law 19)

From the literature, there is very little agreement on risk factors for ankle injuries.[8,44] The extrinsic risk factors, specifically level of competition, bracing and playing surface have the strongest supporting evidence.[7,8,34,36] The intrinsic risk factors identified by the literature show mixed results and most of the authors site poor study design, diverse data models and lack of consensus on testing principles and data collection methods as confounding factors to the available literature.[7,8,33,36,37] The intrinsic risk factors for recurrent ankle injury with the most consistently strong evidence is a history of previous injury and poor proprioception or increased postural sway.[8,18,33]

The lack of conclusive information on risk factors for recurrent ankle injury leads the author to question the approach to the problem as reported in the literature. Strength, structure, history and proprioception have been tested; and level of play, position, playing surface and training have also been investigated. No variable emerges as undeniably conclusive.[7,8,33,36,37] Interventions for all these risk factors have been studied and implemented and yet a high percentage of recurrent injuries still occur.[1,5,34]
This leaves the central nervous system as an area that has not yet been investigated as a possible influencing factor for recurrent injury, one which would influence several of the intrinsic factors already identified.

The abundance of conflicting literature on causes, characteristics and risk factors for ankle injury and chronic ankle instability illuminate the multifactorial nature of ankle injuries and support the above hypothesis of a central nervous system role.[38] Both

Hubbard et al. and Munn et al. noted that, in postural sway testing, the results indicated between group differences.[36,38] However, in the between limb investigations there were no significant differences; individuals performed equally badly on their injured and non-injured legs.[36,38] Both studies attributed this phenomenon to possible central processing changes. They hypothesized that bilateral sensory motor deficits occur despite unilateral injury due to central processing of motor control information.[36,38] Therefore, it is appropriate to consider central processing as a risk factor for recurrent injury.

2.4 Central Processing and Injury

Central processing has been described as central nervous system plasticity.[9–11] Henry et al. described central nervous system plasticity as an adaptive process occurring in the nervous system. It is associated with motor skill learning in the normal child and adult and occurs throughout life as a result of an individual's thoughts, experiences and actions over time.[11] Plasticity is also seen in recovery after central nervous system (CNS) injury.[11]

May suggested that these normal changes are not limited to the brain, but rather the entire established nervous system.[9] May and Henry et al. both described the mechanism of these changes as functional amendments to the intrinsic properties of the neurons and structural mechanisms.[9,11] Amendments such as alterations in the number and location of synapses.[11]

Flor and colleagues.[45] identified the primary somatosensory and motor areas of the cortex as the areas most prone to plastic changes as a result of injury or stimulation.[22,45]

Cortical representation areas in the brain that are altered by injury are also altered by behaviourally relevant stimulation and training as reported by Flor who found that training of individual fingers led to the expansion of the associated cortical representation zone in the brain.[10] Therefore, biological systems adapt according to use and biological advantage. This phenomenon of cortical plasticity has been demonstrated in both amputee and chronic pain studies. Functional MRI studies showed changes in cortical representation, as a change in homuncular organisation in accordance with the area suffering neglect in people with amputations and pain in patients with chronic pain.[13,22,46] The studies demonstrated an invasion of adjacent uninjured representational areas into the cortical representation zone of the neglected areas. The larger the area neglected, the greater the cortical reorganization.[13,22,46]

Tactile perception, pain and other physical feelings can be thought of as outputs of the brain that are based on an informed interpretation of the information coming in from the body and the environment.[22] Acute pain is a normal response to physical injury; it is used as protection against further injury.[22]

Acute pain results from the stimulation of nociceptive pathways by peripheral stimuli of adequate intensity to threaten or lead to tissue damage. Nociception is the detection of the noxious stimuli and is a protective process that helps prevent actual tissue damage by generating reflex withdrawal responses and can be so unpleasant that it causes complex behavioural strategies to avoid further damage.[47] A feature of this protection response is to sensitise the nociceptive system after repeated noxious stimuli. This results in the

threshold for activation of the system to drop so subsequent inputs are amplified.[47] Latremoliere and Woolf described it as use dependant expression of central nervous system synaptic plasticity.[47] In contrast to acute pain, persistent pain is often associated with a range of on-going perceptual and regulatory dysfunctions; disturbances which are not necessarily attributable to tissue injury.[22]

Kaneko et al. examined the effect of upper limb immobilisation on reorganisation in the motor cortex.[15] Their results suggested that a functional reorganization of the area of the cerebral cortex involved in executing movement (the motor cortex) likely decreases the motor capability to produce voluntary muscle output after immobilization.[15] Konishi et al. observed vibration stimulation to the quadriceps muscle in post ACL reconstruction patients and non-injured matched controls[48]. There were altered neuromuscular responses in the injured and contralateral uninjured leg of the ACL reconstruction group compared to the control group, which also suggested central processing changes post injury.[48] Studies by Langer et al support the findings described by Kaneko et al. After two weeks of limb immobilisation with reorganisation of the motor cortex seen as a decrease in cortical thickness on magnetic resonance imaging studies.[15,21] Both these studies however had small sample sizes and no follow-up after the immobilization period.

As injury causes inherent protective mechanisms to the injured area, this resulting disuse could cause maladaptive cortical reorganization as seen in chronic pain states. The literature focusing on chronic pain provides more insight into central nervous system plasticity and changes, which may contribute to recurrent ankle injuries.

2.4.1 Chronic pain

May described chronic pain as *"neuroplasticity at several levels of the nervous system…related to the propagation of pain long after the original cause is gone, depriving pain of its functional role and becoming the disease itself*".[9] Apkarian and colleagues described chronic pain as *"uncontrolled, on-going pain in the absence of any external stimulation"*.[12] Moseley and Flor[22] explained that when pain persists, the reorganisation of the brain that occurs may contribute to the chronicity of the pain.[22] The neuroplastic changes identified concern the function, structure and chemical profile of both the peripheral and central nervous systems. Changes have been recorded in the spinal cord, the immune system and in higher cognitive structures of people suffering from chronic pain. The deviations identified in the peripheral nervous system are receptor and ion-channel reorganisation and neurotransmitter changes resulting in a sensitised system, while CNS deviations include functional changes to the representation fields in the cortex homunculus and sensitisation and disinhibition in the spinal cord.[9]

2.4.2 Pathology and physiology of chronic pain

As indicated by Flor, the reorganisation of the brain that occurs as a result of CNS plasticity which has been recorded following immobilisation, is also seen in chronic pain states.[10,22] In chronic pain this is called maladaptive plasticity. Many authors describe a "*pain matrix*"; areas of the brain that are commonly activated during pain perception.[11,12] Functional magnetic resonance imaging (fMRI) studies have shed more light onto the

specific roles of the different areas of the brain involved in pain perception and the regions that may become more active in chronic pain states.[11,12] Henry et al. interpreted the pain matrix to include the homunculus in the primary (S1) and secondary (S2) somatosensory cortex, insula, anterior cingulate cortex (ACC), amygdala, prefrontal cortex (PFC) and thalamus.[11]

Central sensitization is described by Moseley and Flor as an example of adaptation to stimulation.[22] Clinical manifestations of this are allodynia and hyperalgesia, which occur with repeated activation of spinal nociceptors. This causes increased sensitivity to peripheral inputs, which increases the probability of tissue healing and decreases the risk of secondary injury.[22] However, in the case of chronic pain, this mechanism becomes faulty and loses its adaptive value and becomes a propagator of the problem.[22] Henry et al. suggested that the most prominent difference between acute and chronic pain from a structural point of view is that brain regions involved in cognitive and emotional processing of pain become more active in chronic pain states.[11]

In studies of chronic pain various physiological changes have been identified including maladaptive plasticity.[9,11,22] Maladaptive peripheral sensitization is characterised by decreased threshold of nociceptor afferent peripheral terminals, degeneration of C-fibre terminals and spontaneous sprouting of A-fibres and ectopic foci in the dorsal root ganglion, decreased GABA receptor activity, down regulation of opioid receptors and sympathetic nociceptor activation.[11] As a result of peripheral sensitization, inflammatory mediators including histamines, leukotrienes, norepinephrine, cytokines, nerve growth

factor, serotonin, prostaglandins and bradykinin can also be produced, thus potentially resulting in an acute inflammatory response distally.[11] In central sensitization, activity-dependant increases in spinal nerve excitability occur with MNDA receptor and glutamate mediated denervation hypersensitivity and synaptic structural changes. New afferent excitatory neurons are laid down where previously inhibitory neurons existed and establish abnormal excitatory synaptic connections.[11] Henry et al. further indicated that these CNS changes are possibly aggravated by factors such as depression, anxiety, medication use and decreased physical activity and social stimulation.[11]

Central sensitization changes are also seen in the cortex in chronic pain states.[9] Studies on chronic pain patients have shown cortical reorganisation of the representational zone in the homunculus of S1 and S2 of the affected limb with adjacent representational fields moving into the representational zone of the painful limb. This functional cortical reorganisation has been identified in patients with chronic lower back pain and phantom limb pain.

In phantom limb pain patients the adjacent zones move in to the area representing the deafferented limb.[9,11,12] Pleger and colleagues revealed a change in size of the representational field of the affected hand in complex regional pain syndrome patients. They described the attenuation of the hand's representational field in the contralateral primary sensory motor cortex.[49] Moseley described similar cortical reorganisation of the representational field of patients with chronic lower back pain compared to healthy controls.[50]

The evidence of cortical reorganisation is well described by the literature in chronic pain conditions. May illustrated altered local brain chemistry as well as functional reorganisation of the cortex.[9] This elucidates the idea that chronic pain can be seen as an altered functional state but also a consequence of central plasticity.[12,22] These changes are seen in all chronic pain states and in cases of limb immobilisation and amputees with phantom limb pain.[9,12,13,22,49]

2.4.3 Central processing and injury prevalence

Complex regional pain syndrome, phantom limb pain and chronic low back pain (CLBP) are all well documented examples of chronic pain.[22] Complex regional pain syndrome type 1 (CRPS) is known to occur after trauma to a body part and is characterised by pain disproportional to the initial trauma.[49] Incidence rates for CRPS are unclear and range from 5.5 – 26.2 per 100 000 person years in the USA and Netherlands.[51]

Phantom limb pain (PLP) occurs in about 80% of amputees, and is described as moderate to severe and somewhat or extremely bothersome[11,52] with PLP rather than impairment causing 40% of amputees to be completely disabled.[52] Moseley attests that back pain is the most common chronic painful condition.[50] This is reinforced by Hoy et al. describing CLBP as a substantial personal community and financial burden with a prevalence rate of 24% in the global population.[53]

2.4.4 Chronic Pain, Distorted Body Image and Cortical Reorganisation

Common to all the chronic pain states mentioned is the idea of the distorted body image.[50,52] Various authors suggest that part of the CNS plasticity identified in chronic pain states is the reorganisation of the individuals' body image or body schema.[22,50–52,54–56] Lotze and Moseley explain the idea of body image from a sensorimotor perspective as the inherent maps in the brain that encode the movement, position and anthropometric features of the body.[52] From a more lay point of view Lotze and Moseley describe "*body image is the way one's body feels to its owner*".[52] The malleable body image is maintained by constant tactile, proprioceptive and visual input and tempered by memory, belief and psychosocial influences.[52] When this body image is disrupted as in chronic pain disorders, Moseley and Flor refer to it as cortical reorganisation.[22]

These physical body representations have been localised using fMRI studies to the S1 and S2 and the primary motor cortex (M1). S1 and M1 are closely linked and are responsible for movement control and execution. The correct bodily representation is maintained by lateral cortical inhibition; that is to say that input from one body part exerts an excitatory effect on its target S1 representation and inhibitory effect on adjacent body parts' S1 representations.[52] It is proposed that the symptoms of chronic pain occur as a result of central sensitization causing increased afferent stimulation and cortical disinhibition. The result is that body representation areas in S1, S2 and M1 in the cortex shift into adjacent areas and can change size depending on the particular chronic pain disorder.[22,49]

These changes are not unique to people with chronic pain, having been recorded in people following acute injuries. Cortical reorganisation has been confirmed after four weeks of upper limb immobilization following an acute injury.[15] However, unlike in the chronic pain states discussed above, cortical changes associated with sensorimotor restriction rather than differentiation was investigated.[13] Motor cortex hyper-excitability was observed in the cortex of the immobilised limb subjects.[13] These findings have been reproduced in a further study using fMRI investigations, which recorded cortical changes in upper limb representation after only two weeks of immobilisation after an acute injury.[21]

Intensity of symptoms of pain and not duration of pain have been linked with chronic pain development.[9] Intensity of pain is a subjective measure and not a physiologically measurable symptom. As chronic pain is shown to be unrelated to actual tissue damage and rather to a perception of tissue damage, injury intensity is also a perception rather than a physiological mechanism.[22] Persons with more severe pain also demonstrate greater immobilisation of the painful limb.

Thus it may be that the perception of severe pain is associated with immobilisation of the limb leading to altered cortical representation.[13,21]

The topic of cortical reorganisation and central sensitization has been well researched in recent literature by various authors including Moseley, Flor, Pleger, Apkarion and May.[9,10,12,49,56,57] The focus for these studies has been on cortical reorganisation in chronic pain patients. While fMRI has been used as the primary outcome in the above

studies, several clinical tests have also been applied and found to correlate to the cortical changes recorded. These clinical tests include two point discrimination, body image drawing, laterality testing and pressure pain measures. Due to the expense of the fMRI testing and the specificity of the patients the studies have been limited with small sample sizes and no follow-ups.

2.5 Instrumentation

This instrumentation section describes the methods used to interpret and investigate how central processing mechanisms can be clinically assessed.

2.5.1 Laterality

Disrupted motor imagery is a common problem experienced by chronic pain patients that has been attributed to central sensitization and explained as a result of altered body image.[54–56,58] Laterality is the term coined to describe the brains internal ability to recognise the left or right side of the body using the bodies schematic representation in the cortex.[54,55]

Evidence illustrates that patients with chronic pain conditions such as CRPS and chronic pain had difficulty recognising their painful body part and differentiating the laterality of their affected limb.[55,56] Moseley links the problem with laterality that chronic pain patients experience back to the idea of altered body image.[56] He offers two theories as to why recognition time (RT) of the laterality of the affected limb is longer than recognition time for images of the unaffected limb. Firstly, Moseley raised the possibility that the

pain related disuse has the same effect as seen in neglect.[56] The body image changes as the proprioceptive and tactile input changes through lack of use and so the brain takes longer to recognise the affected area as it has been essentially marginalized.[54,56] The second theory proposed by Moseley is the idea that guarding takes place to protect the painful limb.[56] There is evidence that similar cortical networks are activated during motor imagery tasks and motor execution of the same task.[56] This lends support to Moseley's second theory that, even though the patients do not report any pain while doing the laterality recognition task, they still have to mentally repeat the positioning of the limb in the laterality task in order to verify its correct laterality.[55,56]

The NoiGroup, Recognise[TM] product has been found to be a valid and reliable instrument for testing laterality (http://www.noigroup.com/en/Product/BTRON).[59] The product uses a collection of abstract images of the affected limbs which respondents must identify as either right or left. Respondent's speed to recognition and their correct establishment of left or right are recorded.

The test can be made more difficult by decreasing the time allowed for viewing each image and by increasing the complexity of the images.

2.5.2 Two Point Discrimination

Maintenance of body image is provided by continuous feedback from proprioceptive, tactile and visual input from the body.[52] It has been argued that faulty proprioception and reduced tactile acuity contribute to the altered body image of people with chronic

pain.[49,50,52,54,56,60] Two point discrimination (TPD) has been shown to be an effective way to measure tactile acuity.[52] Moseley found increased TPD over the painful areas in his chronic back pain patient group and normal TPD comparable with the controls over the contralateral side and ipsilateral non-painful levels.[50] Pleger et al. observed the same findings in a study performed on CRPS and Lotze and Moseley echoed these findings among amputees when TPD was assessed on their stump and contralateral limb. [49,52] The authors hypothesized that the tactile changes and hypoesthesia seen in chronic pain patients are a result of the augmented activation of neurons that normally respond to nociceptive inputs, this, in turn induces recruitment and stimulation of adjacent neurons as explained by peripheral (CRPS and chronic pain) and central sensitization.[49,50,52] Pleger et al. noted the close relationship between the amount of tactile impairment, the intensity of the pain experienced and the signal changes attendant with cortical reorganisation.[49]

TPD is a well-documented testing procedure for tactile acuity and has been found to be a valid and reliable measure for cortical changes in chronic pain studies. Its test-retest reliability is high, and it has good face and content validity.[50] TPD is often tested alongside fMRI evaluation and correlating results indicate high criterion and construct validity.[49,52]

2.5.3 Body Image

Both CRPS and PLP patients have been found to have distorted body image pertaining to their painful or amputated limb and report the pathological limb as feeling bigger or heavier than normal.[45,50,52] Chronic back pain patients report the painful area as smaller

than it is, or missing, reporting that they "*can't find it*".[50] These findings insinuate that where cortical reorganisation causes expansion of the representational area, the painful limb feels smaller to the individual and where the representational area is decreased or taken over by adjacent areas the painful limb feels bigger, demonstrating a converse relationship.[50]

Moseley performed a study on chronic back pain to assess the functional implications of the distorted body image.[50] He used an approach previously used by Gandevia and Phegan ($p<0.001$) to assess body image specifically looking at perceptual distortions of the body image produced by anaesthesia, pain and cutaneous stimulation relating to the hand and face.[50,61] In this study, participants were blindfolded and asked to draw a single line drawing of their thumb before and after an intervention of local anaesthetic was given.

Patients were asked to "*draw an outline which represents the size of the body part*"[50] and to "*concentrate on how big the body part feels*"[50]. The drawings were digitized and areas were calculated and compared before intervention and after intervention.[61] Reliability and validity for the technique described was previously established for Moseley's study on chronic back pain and Gandevia and Phegans' study on the hand and face.[50,61] The tests were appropriate for body image testing, both studies performed similar test procedures and had similar results indicating construct, criterion and content validity.[61]

This method was then adapted for Moseley's, study on chronic back pain.[50] Patients and matched controls were placed standing in front of a waist high bench. They were asked to draw their backs on a template piece of paper (with a vague outline of a back on it) without looking at, or touching their backs. They were instructed to: "*Concentrate on your back. Add to this drawing by following the outline of your own back as you track it in your mind. Concentrate on where you feel your back to be. Also draw in the vertebra that you can feel. Do this without touching your back. Your drawing should relate to your own sense of your back. Don't draw any part you can't sense. Do not draw what you think your back looks like – draw what it feels like*".[50] The drawings were then compared for area and detail. Moseley reported the control group drawings were 'unremarkable' but the patient drawings were not.[50] The patients could not delineate their backs, vertebra were missing and skewed from the midline towards the painful side. The missing outline of the body coincided with the patients' painful area.[50]

The non-painful side and the non-painful levels on the ipsilateral side were similar to the controls.[50] The patients demonstrated distorted body image isolated to their level and area of pain and their belief that their painful anatomical site is smaller than in reality.[50] Moseley also tested tactile acuity and two point discrimination during this study.[50] As previously stated in Sections 2.3.1 looking at TPD, Moseley's' study on chronic lower back pain also demonstrated a change in tactile acuity with the painful area soring higher than the control or non-painful areas.[50]

Area is used to quantify body image perception. The templates are used to calculate the mm^2 of the images drawn by the participants. Moseley and Gandevia and Phegans both used digital calculations of area. [50,61] Moseley also looked at detail of the drawings and compared them between the painful and non-painful side.[50,61] To augment his findings in the body image drawing testing, Moseley also used TPD and pressure pain threshold testing in his Chronic Lower Back pain study.[50]

2.5.4 Pressure Pain Threshold

In line with tactile changes seen in chronic pain disorders, studies have revealed symptoms of allodynia and hyperalgesia.[9,11,12,49,51,62,63] Giesbrecht et al. illuminate research demonstrating generalised hyperalgesia in people diagnosed with chronic pain, fibromyalgia, chronic whiplash, CRPS and recurrent headaches.[63] Hyperalgesia, in various chronic pain studies has been attributed to cortical reorganisation and central sensitization.[51,62,63] Giesbrecht et al's. research indicated that patients with chronic pain had a lower pressure pain detection threshold (PPDT) compared to normal controls.[63] They suggest that global hypersensitivity may be common to all chronic pain pathologies as a result of central sensitization.[63]

The International Association for the Study of Pain (IASP) definition of pressure pain detection threshold (PPDT) was used for the present study; the lowest stimulus that gives rise to the earliest perception of pain. Previous methods of testing PPT have reported varying reliability attributed to tissue consistency and inability to obtain proper

perpendicular alignment on the test sight.[63] To control for this, pressure should be applied to the test subjects at a rate of 2lb/s, and the average of three measurements taken for each sight with a 10 second recovery time between repeated test sights. This method described by Giesbrecht et al. has good reliability.[63]

2.6 Conclusion

Recurrent lateral ankle injuries in rugby remain a problem both economically and socially for the athletes and the sport. The abundance of literature available currently on recurrent lateral ankle injuries is inconclusive about causes and risk factors with poor acquiescence demonstrated in the level one evidence studies. These authors suggest more research is needed and other avenues investigated to shed more light on the problem of factors contributing to recurrent ankle injuries.

This void of information, they suggest, points to a neural component, specifically central nervous system components contributing to recurrent ankle injuries. [3,20,22,23,26,27]

Normal learning and immobilisation studies using fMRI techniques have indicated central nervous system changes occurring in a normal learning setting and acute pain setting, where no chronic pain diagnoses are established.[13,21] This indicates that cortical representation changes can occur in the absence of chronic pain.[21] However, there is much we still do not know. With the lack of outright empirical evidence for risk factors, specifically intrinsic risk factors, for recurrent ankle injuries in the literature to date, it is

possible that an area of knowledge has been overlooked in this regard.[7,8,12,18,33,36,37] With the growing body of research in the chronic pain sphere an avenue of research could be exploring the possibility of central nervous system changes as a risk factor for recurrent ankle injury.[12]

CHAPTER 3: CENTRAL NERVOUS SYSTEM CHANGES ASSOCIATED WITH RECURRENT ANKLE INJURIES: A CROSS SECTIONAL STUDY

3.1 Introduction

Current research indicates that ankle injuries are the most common injuries sustained by the sporting population, with anterior talofibular ligament sprains being the most prevalent of all ankle injuries.[1] In South African professional rugby players a single season ankle injury incidence rate of 1.6/1000ph was recorded.[4] In addition, literature describes the potential economic loss as a result of absence due to injury.[1] Approximately one third of the total costs due to sports injuries are attributed to ankle injuries.[5]

In terms of severity of injury when looking at ankle injuries and rugby, joint and ligament impairments account for the greatest time loss per 1000 player hours over muscle/tendon pathology and bone pathology. Numerous studies have indicated that the severity of recurrent injuries is greater than new injuries.[1] Statistics on recurrence of ankle injuries goes as high as 50% resulting in chronic ankle instability.[1,7,18]

As discussed in the literature review, the data on the causes and risk factors associated with recurrent ankle injuries is to date inconclusive.[8,44] The central nervous system is an area that has not yet been investigated as a possible influencing factor.

3.2 Significance of the Study

Considerable research and information is available on CNS changes in chronic pain and limb immobilisation but very little data are available on CNS changes in recurrent injuries. This study proposes to investigate the relationship between recurrent injury and CNS changes previously found to be associated with limb immobilisation and chronic pain.

3.3 Aims and Objectives

3.3.1 Aim

To determine whether there are changes in the CNS of rugby players with recurrent ankle injuries.

3.3.2 Objectives

The specific objectives of the study were:

In a group of professional rugby players with recurrent ankle injuries and a matched control group of rugby players without a history of recurrent ankle injuries.

1 To describe the demographic and training characteristics of the sample through administration of:

1.1 Medical and Sports History Questionnaire (Appendix III)

1.2 Body composition assessment (Appendix VI)

2 To determine whether there are changes in the somatosensory representation of the affected areas of the recurrent injury group compared with a control group using

   2.1 Laterality testing[50,54,56]

   2.2 Limb perception drawing[50]

   2.3 Two point discrimination testing[50]

3 To determine whether there are changes in the somatosensory representation of the affected areas of the affected limb compared with the unaffected limb of the recurrent injury group using

   3.1 Laterality testing[50,54,56]

   3.2 Limb perception drawing[50]

   3.3 Two point discrimination testing[50]

4 To determine whether there are changes in the CNS firing threshold in the recurrent injury group compared with a control group using

   4.1 Pressure pain threshold testing[50]

3.4 Methods

3.4.1 Participants and Study Design

A descriptive cross-sectional analytical study was conducted. The study was submitted and approved by the Faculty of Health Sciences Human Research Ethics Committee, University of Cape Town (HREC REF: 415/ 2013) (Appendix I).

The study was presented to all the contracted senior rugby players at the Golden Lions Rugby Union. All of the rugby players agreed to participate and indicated their agreement by filling in a form that could ascertain their suitability for the study according to the inclusion criteria. On initial assessment 64 players were deemed suitable and were given the Participant Informed Consent Form (Appendix II) to read and sign.

They were also given the Medical and Sports History Questionnaire to complete (Appendix III). This questionnaire had more specific details on inclusion and exclusion criteria.

From the 64 players that completed the Participant Informed Consent Form (Appendix II) and the Medical and Sports History Questionnaire (Appendix III), only 59 players were deemed suitable for participation in the study. All 59 initial participants were required to give informed consent before completing the questionnaire and before any data were taken. The Participant Informed Consent Form (Appendix II) explained the purpose of the study, voluntary participation with no risk to the participant, how confidentiality and anonymity would be ensured and the right to withdraw from the study without prejudice. During the study period, a further 13 dropped out. Three suffered re-injury to the ankle, one suffered a severe injury to the same limb, five were transferred on loan to another rugby union for the season, three had their Golden Lions Rugby Union contracts terminated before testing was completed and one stopped playing rugby. This left 46 participants in total to complete the study.

3.4.2. Sample Size Calculation

With the consideration that this was a cross-sectional descriptive study, sample size was calculated using the most sensitive outcome measure to provide the largest possible sample size required for sufficient statistical power. Recognition time on laterality testing was selected to determine the required sample size, as the previous literature demonstrated that this outcome had the largest variation in standard deviation of all the parameters to be measured. The large variation in standard deviation meant that the sample size calculated using laterality testing data would be the largest sample size required. The sample size was calculated using data from previous studies which had used the methodology of laterality recognition.[54–56,58]

Required sample size for laterality recognition time was calculated using a smallest meaningful difference of 3015.4ms, and a standard deviation of 1330ms. With statistical significance accepted as $p \leq 0.05$, a group of 11 participants in each group (22 participants in total) would provide 95% statistical power. A total of 46 participants were recruited for this study; 24 experimental participants and 22 control participants, to allow for dropout and to ensure sufficient statistical power.

3.4.3 Inclusion Criteria

The Inclusion criteria for all participants were: healthy male rugby players between the ages of 18 and 35 years. All participants were injury free and participating in full training as identified and decided by the official team doctor and strength and conditioning coach. They were contracted or on full-time trial with a professional rugby team (Gauteng Lions

Rugby Union). The recurrent injury group participants had all suffered a late recurrence injury, i.e. had a history of at least two ankle injuries during the previous 12 months on the same side.[65] The injuries were all considered to be at least mild (absent from full team participation for four to seven days) according to the 2007 Consensus Statement on Injury Definitions and Data Collection Procedures.[18,65] Participants in the control group had no previous history of ankle injury.

3.4.4 Exclusion Criteria

Participants were excluded from the study if they had a history of bilateral ankle injury during the previous 12 months.[18] They were also excluded if they had sustained any other significant lower limb injury (absent from full team participation for four to seven days)[65] during this time frame. All participants were assumed to be fit and healthy and free from any injury as they were involved in full time training as professional rugby players.

3.4.5 Recruitment

Professional male rugby players were recruited through the Golden Lions Rugby Union following approval from the Gauteng Lions Rugby Union Management (Appendix IV). Potential participants were recruited at a team meeting where the study was presented to the players and coaching staff. The potential participants were provided with the Information Sheet (Appendix V) and Participant Informed Consent Form (Appendix II) and provided with an opportunity to have questions answered. The experimental and control participants that met the inclusion criteria were asked if they would be willing to

participate in the study. There was no randomization because the participants were specifically selected according to inclusion and exclusion criteria. The whole population of rugby players contracted with the Golden Lions Rugby Union was assessed for inclusion and exclusion criteria and suitability for participation.

3.4.6 Data Collection Tools or Instruments

3.4.6.1 Questionnaires

A Medical and Sports History Questionnaire (Appendix III) previously developed and used in a study on triathletes in 2009 was amended to be appropriate for a rugby-specific participant group. Total contact time, gym and game time were included as well as levels of competition achieved and duration of professional career. The amended questionnaire was trialled in the pilot study. It was used to collect information on demographics, playing position, training and playing history (Appendix III).[66] They were also asked to provide information regarding their general health, previous medication use and history of any previous and current injury. There was a specific section focussing on ankle injury history asking participants to provide information on any current and previous ankle injuries.

3.4.6.2 Anthropometry

Anthropometric testing was performed to fully describe the participants involved in the study and to ensure the control and recurrent injury group were comparable (Appendix VI). Body mass (kg) and height (cm) were recorded using a calibrated scale and stadiometer respectively (Portstad portable stadiometer®). Body fat was calculated using

the seven-site formula (chest, midaxilla, triceps, subscapular, suprailiac, thigh and abdomen).[64] Body fat was expressed as a percentage of body mass index.[64] The tester was experienced in the testing procedure and had performed a minimum of 50 tests prior to the study to ensure test-retest, intra- and inter-rater reliability.[67]

There were no risks associated with the measurement of mass, stature and skin fold thickness. There may however have been a minimal transient discomfort felt during the use of the calliper, when the skin fold measurements were taken.

3.4.6.3 Laterality

The NoiGroup, Recognise[TM] product was used to test laterality. (http://www.noigroup.com/en/Product/BTRON).[59] Validity and reliability have been previously established for the testing procedure by Dey et al.[58] Recognise[TM], the online programme used in this study and by Dey et al has previously demonstrated reliability in a large cross-sectional study with the 95% CI for all between day repeatability intraclass correlation coefficients being >0.7.

The picture recognition and response time technique previously described were used to measure laterality recognition.[54,58] The test was performed twice. The first test was done using 'Vanilla' images. These images are easy to recognise and in basic postures. This level is meant to be the beginner or easiest level of testing. The second test was done with the "Abstract" images. These are abstract images of feet in complicated postures to make it more difficult to recognise which foot is being displayed. This is the hardest and most

complicated level of the program. For each test a collection of 50 random images of feet were used. An unrotated image of the left and another similar image of the right foot were used as calibration images. The 50 test images were divided into two groups with 25 images being left foot images and the other 25 right foot images.[58]

The participants were randomly shown one left or right image at a time for a maximum of three seconds. They had to identify whether the image was a left or right foot and indicated their decision by pressing a button on the screen.[58]

The reaction times (RT) were recorded as the length of time elapsed between the image appearing and the pressing of the button indicating the laterality decision. The number of correct laterality decisions was also recorded and calculated as a percentage.

3.4.6.4 Two Point Discrimination

The method used to assess two point discrimination (TPD) was that previously described by Moseley.[50] Participants were asked to lie down on a plinth. A digital calliper was used which was calibrated between each participant. Reliability and validity of this method have been previously established by Moseley in a study on distorted body image and tactile dysfunction in patients with chronic back pain.[50,68] Moseley conducted his study on 6 patients with a history of low back pain. He adapted from a study by Elsig et al who performed TPD testing on 30 adults with a history of neck pain. This study procedure reported a confidence interval of 95%.

The test began with 0mm between the two points of a calliper. The calliper was applied to the skin until the first blanching of the skin appeared around the prongs. The prong was

removed, the distance between the prongs was increased by 1 mm and reapplied to the skin. This process was repeated until the participant could perceive 2 points instead of one. Participants were asked to close their eyes and look away from the testing, they were also instructed to say "one" when one point was felt and "two" when two points were felt. The point at which the participant was able to discriminate two points was recorded. The test was then repeated in reverse from a point 1cm wider than the previously established 2-point discrimination point. The calliper was moved 1mm at a time closer towards 0mm until the participant identified only one point instead of two. The point at which the participant said 'one' was recorded.

Two point discrimination was tested bilaterally; three points on each side of the lateral surface of the ankle were tested. The three points were 1) on the lateral malleolus over the anterior talofibula ligament (ATFL), 2) 1cm below the lateral malleolus over the calcaneofibular ligament (CFL) and 3) 1cm posterior of the lateral malleolus on the posterior talofibular ligament (PTFL). A practice test was performed on the upper limb to ensure the participant were not guessing and understood the testing process. Three measurements were taken for each of the three points and an average per point was used.[50]

3.4.6.5 Body Image

Body image techniques were adapted from previous studies in chronic back pain by Moseley, 2008.[50] The test was conducted as follows: Participants stood in front of a waist high bench and were given line drawings showing the lateral surface of a left and right

foot and ankle with only the top and bottom of the picture drawn (Appendix VII). Participants were asked to continue the drawing and complete the pictures of their own feet. They were instructed to draw the lateral surface of their foot and ankle, as they perceive it to be without looking or touching their own foot and ankle. The instructions given to participants were as described by Moseley and adapted to correspond with a foot and ankle drawing (Appendix VIII)[50]:

''Concentrate on your foot and ankle. Add to this drawing by following the outline of your own foot and ankle as you track it in your mind. Concentrate on where you feel your foot and ankle to be. Also draw in the bones that you can feel. Do this without touching your foot. Your drawing should relate to your own sense of your foot and ankle.

Don't draw any part you can't sense. Do not draw what you think your foot looks like – draw what it feels like."[50]

The images were then collected and body image was calculated manually on area using a template to calculate mm^2 for total area of the drawings.

3.4.6.6 Pressure Pain Threshold

Pressure Pain Threshold (PPT) is defined by the International Association for the Study of Pain (IASP) as the lowest intensity stimulus that the subject perceives as painful. [63] A pressure-pain algometer was used in this test using the procedure described by Kosek et al. in a study on increased pressure pain sensibility in fibromyalgia patients.[62] Validity and reliability was established on 16 patients with fibromyalgia in their study with a p value < 0.001.[62] Studies done on PPDT reliability have shown Pearson correlation coefficients

ranging from 0.65 to 0.96 for intrarater reliability and from 0.47 to 0.89 for interrater reliability.[63]

The algometer was used to investigate pressure threshold measurements i.e. the smallest amount of pressure causing pain. It was calibrated before each participant's testing by resetting the algometer to 0mmhg and assessing accuracy by using a 100g weight designed to fit with the ergometer to measure accuracy.[69]

Test sites were measured bilaterally following the protocol described by Giesbrecht et al.[63] The test points used were the same as those tested in the previous test for Two Point Discrimination. These measurement points were identified and marked on the participants' skin with a felt tip permanent marker pen. Additional points were tested in the middle of the Tibialis Anterior muscle and mid-belly of the forearm extensor muscles for catch test purposes.

An electronic pressure threshold meter (algometer) with a 1 cm stimulation surface area was placed perpendicular to the skin surface at each test sight.

The participant was instructed to say "stop" and press the record button attached to the algometer as soon as they began to feel any discomfort or pain.[63,69] Three measurements were taken for each of the points with a 10 second recovery interval between each recording on the same site. An average measure per point was used.[63]

3.4.7 Procedure

The CEO of the Golden Lion Rugby Union was contacted and informed about the study. Once consent was obtained to conduct the study using players affiliated to the Union (Appendix IV), a pilot study was conducted.

Three suitable participants were recruited from the player group for the pilot study. The aim of the pilot study was to test the procedure to be used for the main study. They were familiarised with the study, their consent was attained and they underwent the same testing procedure and protocol as laid out for the main study. Their results were recorded and kept in a password secured document. The study procedure was found to be appropriate and no changes were made prior to recruiting the full sample.

On completion of the pilot study, all the players contracted to the Golden Lions Rugby Union were informed of the study via a formal presentation as described in Section 3.4.5 on recruitment above. Players were informed of the purpose of the study, a brief overview of what participation in the study would involve and the testing procedures used. Participation was requested of all players.

The players who consented to participate in the study and fulfilled the inclusion criteria were then given an Information Sheet (Appendix V) on the study and asked to sign an informed consent document (Appendix II). On completion of these documents, they were then given the Medical and Sports History Questionnaire (Appendix III) to complete. Based on this information participants were recruited to the study and allocated to either

the recurrent injury group or control group by the researcher. On completion of recruitment, participants were randomly assigned numbers to maintain confidentiality in the data collection and analysis process. An appointment time was made with each participant for the testing procedures to take place to assist with time efficiency and convenience for players and the researcher. All the testing was to be performed in the open plan team physiotherapy treatment area, and not in private. At the appointment, anthropometric testing was performed first by the single research assistant. The researcher then administered the four physical tests. A single researcher, to ensure test reliability, tested both participant groups concurrently in random order. All four tests were conducted consecutively to minimise time cost to participants. The researcher was familiar with the participants so there was no blinding in this study. Hiring of a blind assessor was not possible due to budgetary constraints. All data were stored electronically in password-protected files.

3.4.8 Statistical Analyses

Based on the distribution of the data for laterality recognition, two-point discrimination, limb perception and pressure pain threshold, nonparametric statistics were used throughout. Results are presented as median and interquartile ranges (IQR). Descriptive statistics were used to summarise the sociodemographic, training and physical characteristics of the recurrent injury and control groups with data presented as medians (IQR).

Differences between groups (recurrent injury group and control group) in laterality testing (recognition times and percentage of correct judgements); two-point discrimination and pressure pain thresholds were analysed using the Mann-Whitney U test. Differences within groups in laterality testing (recognition times and percentage of correct judgements); two-point discrimination and limb perception drawing were analysed using the Wilcoxon signed-rank test for paired samples. Significance was accepted at $p \leq 0.05$.

Table 1: Data Type and analysis explanation

	Objective	Instrument	Type of data	Method of statistical analysis
1	To describe the demographic and training characteristics of the sample	Medical and sport questionnaire	Continuous and categorical	Descriptive: medians and interquartile ranges
2	To determine whether there are changes in the somatosensory representation of the affected areas of the recurrent injury group compared with a control group	Laterality testing[50,54,56] Limb perception drawing[50] Two point discrimination testing[50]	Interval and ratio	Mann –Whitney U
3	To determine whether there are changes in the somatosensory representation of the affected areas of the affected limb compared with the unaffected limb of the recurrent injury group using	Laterality testing[50,54,56] Two point discrimination testing[50] Limb perception drawing[50]	Interval and ratio	Wilcoxon signed rank
4	To determine whether there are changes in the CNS firing threshold in the recurrent injury group compared with a control group	Pressure pain threshold testing[50]	Interval	Wilcoxon signed rank (for within group analysis)

3.4.9 Ethical Considerations

This study was performed in accordance with the principles outlined in the Declaration of Helsinki (Fortaleza, Brazil, 2013).[70] Ethical approval was granted by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (HREC REF: 415/2013) (Appendix I). Informed consent and permission to conduct research using their player base was obtained from the Gauteng Lions Rugby (Appendix IV). Autonomy was ensured in this study by the willingness to participate in this study and Participant Informed Consent Form (Appendix II). The purpose of the study, the testing procedures, benefits and possible risks of the study were explained to the participants. Participants were given the opportunity to raise any questions or concerns they may have had during the information session. Participants were also informed of their right to withdraw from the study at any stage. All data were treated with confidentiality. The Participant Informed Consent Form (Appendix II) contained all relevant information regarding the testing procedure, and the potential risks and benefits of the study. Participants were informed and permission requested for the publication of the results of their testing.

Beneficence was ensured in this study by aiming to improve the understanding of recurrent injury among athletes and possibly prevent future injuries. Non-maleficence was ensured in this study as the testing procedures were previously validated and found to present minimal risk to the participants of experiencing pain during testing procedures. There were no risks associated with the laterality testing or limb perception testing. There may have been minimal transient pain with two point discrimination testing. There may have been minimal transient pain associated with the pressure pain threshold testing. Participants were instructed to inform the researcher immediately of pain or discomfort,

at which point the algometer was withdrawn. No tissue damage has previously been recorded using this method and no tissue damage was observed in the course of the present study.

Justice was addressed by the selection of participants without bias or prejudice. Any participants who were willing and complied with the inclusion and exclusion criteria were eligible for the study. No participants sustained any injury during the testing procedures or as a result of participation in this study. The participants were informed that they would not receive any remuneration for participation in the study and informed consent for publishing any test data and information was obtained in the Participant Informed Consent Form (Appendix II).

3.5 Results

This research was presented to the entire contracted player group of the Gauteng Lions Rugby Union. Of the 59 players meeting inclusion criteria, appointments were set up individually with the participants at their convenience to conduct the physical testing. Based on the inclusion and exclusion criteria, the players were divided into the control (n=22) and recurrent injury groups (n=24). As illustrated in Figure 1, a further 13 participants were excluded from the study for failure to participate in all the physical tests, changing rugby unions, or suffering an injury thereby excluding themselves from the study.

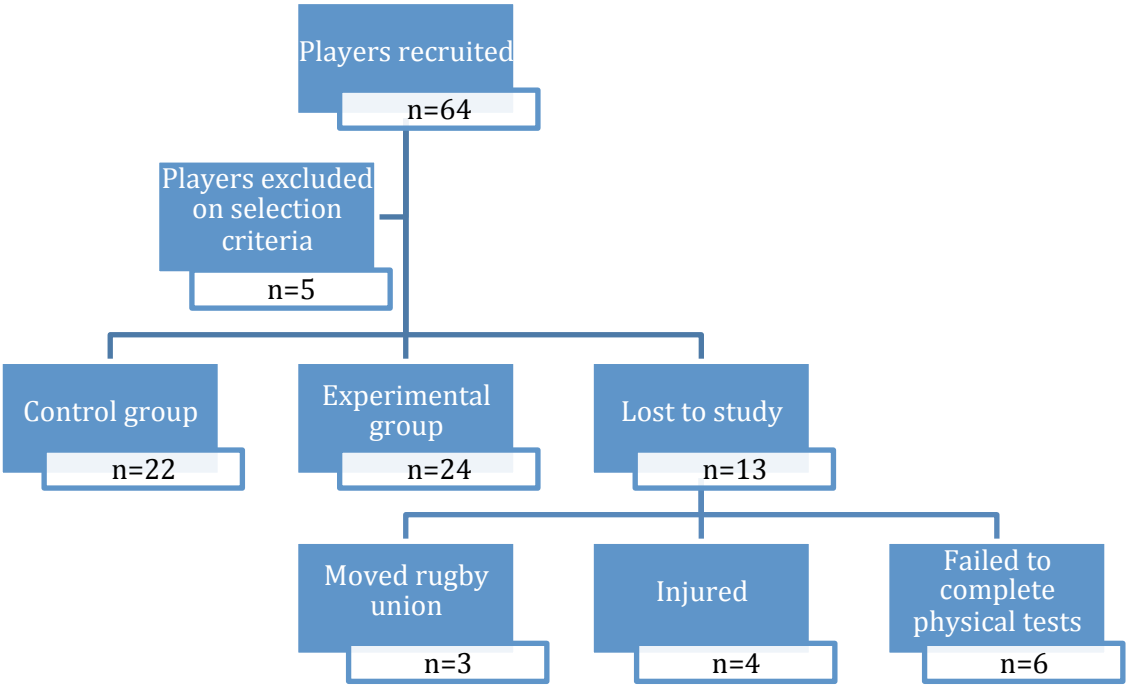

Figure 1: Description of study sample

3.5.1 Demographics

The demographics of the sample group were similar for both the experimental and control groups. There were no significant differences between the two groups for age, height, weight or BMI (Table 2). The recurrent injury group were slightly younger, shorter, lighter and had a lower BMI. Two of the participants for the recurrent injury group were not available for demographic testing, this accounts for the difference in sample size in the following table.

Table 2: Demographic characteristics of the sample (N=44)

	Sample N=44 Median (IQR)	Recurrent Injury n=22 Median (IQR)	Control n=22 Median (IQR)	Significance Test
Age (y)	23.5 (20-25)	21 (20-24.5)	24.5 (20-26)	U=183; p=0.08
Height (cm)	185.5 (179-191)	183.5 (176.5-191.5)	187.5 (181-191)	U=210; p=0.24
Weight (kg)	101 (92-110)	100 (85.5-105)	107.5 (96-112)	U=177; p=0.06
BMI (kg/m^2)	28.37 (26.8-31)	28.19 (26.8-30)	31 (27.1-31.2)	U=189; p=0.32

3.5.2 Training History

The results from the questionnaire on training and medical history revealed that there was a significant difference in the total number of years the participants had been playing professional rugby (Table 2). The players in the control group had a significantly higher number of years playing professional rugby [6y (2-7)] compared to the recurrent injury group [3y (2-6); p=0.04].

The total number of days of preseason training was also significantly different between the two groups (Table 3).

The control group participated in significantly more days of preseason training [78d(45-90)] compared to the recurrent injury group [50d(30-69)d; p=0.02]. There were no other significant differences between the groups in other training history variables. A lack of

thorough previous injury history data limited the interpretation of some of the study findings in this regard so previous injury history data was not conclusive.

Table 3: Training History of the Experimental and Control Groups (N=46)

	Sample N=46 Median (IQR)	Recurrent Injury n=24 Median (IQR)	Control n=22 Median (IQR)	Significance Test
Total years playing (y)	14.5 (13-19)	14.5 (13-17.5)	14.5 (12-19)	U=239.5; p=0.6
*Total professional years (y)	4 (2-6)	3 (2-6)	6 (2-7)	**U=171.5; p=0.04**
Games in last 6 months	8 (6-12)	8 (5-12.5)	7.5 (6-10)	U=261.5; p=0.96
Total minutes in last 6 months (min)	450 (260-800)	560 (210-1000)	410 (260-600)	U=207.5; p=0.31
Total training hours per week (h)	13 (10-15)	13 (10-17.5)	12.5 (12-14)	U=248.0; p=0.73
Total hours pre/rehab per week (h)	1.5 (1-2)	1.25 (1-2)	1.5 (1-2)	U=234; p=0.52
Total gym hours per week (h)	4 (3-6)	4 (3.5-6)	4.5 (3-5)	U=245; p=0.68
Total additional conditioning hours per week (h)	1.75 (1-3)	2 (1-3)	1.25 (1-3)	U=247; p=0.72
Total hours team training per week (h)	8 (7-12)	8 (6.75-10)	9 (7-12)	U=249; p=0.75
Total hours contact training per week (h)	2 (1-2)	2 (1-2)	2 (1-2)	U=261; p=0.96
Total preseason days training for current season (d)	56 (40-78)	50 (30-69)	78 (45-90)	**U=161; p=0.02**
Average hours per day preseason training (h)	3 (3-5)	3 (3-5)	3.25 (3-4.5)	U=235; p=0.52
Preseason training blocks completed over previous 3 years	3 (2-3)	3 (2-3)	3 (2-3)	U=231; p=0.47

*indicates significant difference with p≤0.05

3.5.3 Laterality

Laterality testing was done twice, once at an easy entry level called “vanilla” and a second time at a more complex level called “abstract”. Both within group analysis and between group analysis was done.

There were no significant differences found for the between group testing using the “vanilla” test or the “abstract” test (table 4). The within group analysis (table 5) demonstrated a significant difference for the recurrent injury group on the abstract test recognition time. The injured side had a slower recognition time [1.4(1.3-1.6)] compared to the uninjured side [1.3(1.15-1.5) $p<0.01$].

Table 4: Differences in laterality recognition time and percentage correct between Reinjured group and Control group in laterality recognition test (N=46)

	Recurrent Injury (n=24) Median (IQR)	Control (n=22) Median (IQR	Significance Test
"Vanilla" Test			
Uninjured side Recognition time (s)	1.4 (1.15-1.7)	1.35 (1.2-1.7)	U=260; p=0.94
Uninjured side Recognition correct (%)	94 (84-100)	94 (89-95)	U=222.5; p=0.37
Injured side Recognition time (s)	1.4 (1.1-1.7)	1.35 (1.1-1.8)	U=251; p=0.78
Injured side Recognition correct (%)	88.5 (85-93)	89 (82-95)	U=197; p=0.14
"Abstract" Test			
Uninjured side Recognition time (s)	1.3 (1.15-1.5)	1.3 (1.2-1.4)	U=260.5; p=0.95
Uninjured side Recognition correct (%)	84.5 (75-90)	87.5 (81-91)	U=212.5; p=0.26
Injured side Recognition time (s)	1.4 (1.3-1.6)	1.3 (1.1-1.4)	U=202.5; p=0.17
Injured side Recognition correct (%)	84 (75.5-89.5)	85 (78-95)	U=225.5; p=0.4

Table 5: Differences in laterality recognition time and percentage correct between sides (injured vs uninjured or left vs. right) in Recurrent Injury Group and Control Group (N=46)

	Injured side Median (IQR)	Uninjured side Median (IQR)	Significance Test
Recurrent Injury group			
Vanilla test Recognition time (s)	1.4 (1.1-1.7)	1.4 (1.15-1.7)	T=104; p=0.97
Vanilla test Recognition correct (%)	88.5 (85-93)	94 (84-100)	T=85; p=0.18
*Abstract test Recognition time (s)	1.4 (1.3-1.6)	1.3 (1.15-1.5)	**T=11; p<0.01**
Abstract test Recognition correct (%)	84 (75.5-89.5)	84.5 (75-90)	T=141.5; p=0.81
	Right Median (IQR)	Left Median (IQR	Significance Test
Control Group			
Vanilla Test Recognition time (s)	1.35 (1.2-1.7)	1.35 (1.1-1.8)	T=52.5; p=0.43
Vanilla Test Recognition correct (%)	94 (89-95)	89 (82-95)	T=115; p=0.71
Abstract Test Recognition time (s)	1.3 (1.2-1.4)	1.3 (1.1-1.4)	T=36.5; p=0.63
Abstract Test Recognition correct (%)	87.5 (81-91)	85 (78-95)	T=91; p=0.25

*indicates significant difference with p≤0.05

3.5.4 Two Point Discrimination

Two point discrimination was tested on all three lateral ankle ligaments, anterior talofibula ligament, calcaneofibular ligament and the posterior talofibular ligament.

The results were also analysed for between group differences and within group differences between the three ligaments on the affected and unaffected limbs (Table 6).

There is significant differences between the groups on the ATFL test site ($p<0.01$) as well as significance in the within group differences analysis ($p=0.05$).

Table 6: Two-point discrimination (mm) at ATFL, CFL and PTFL (N=46)

	Recurrent Injury (n=24) Median (IQR)	Control (n=22) Median (IQR)	*Significance Test*
ATFL			
Uninjured side	29 (15-38)	21 (13-30)	U=211; p=0.25
Injured side	38 (31-43)	31 (16-41)	**U=173; p=0.05***
Significance Test	**T=42; p<0.01***	**T=55; p=0.02***	
CFL			
Uninjured side	25 (11-33)	20 (13-26)	U=194; p=0.13
Injured side	23 (17-31)	20 (11-27)	U=198; p=0.15
Significance Test	T=130; p=0.57	T=120; p=0.83	
PTFL			
Uninjured side	29 (11-33)	18 (10-36)	U=192; p=0.12
Injured side	26 (36-24)	22 (14-27)	U=182; p=0.07
Significance Test	T=147; p=0.93	T=113; p=0.66	

*indicates significant difference with p≤0.05

3.5.5 Body Image

Body image was calculated on area using a template to calculate mm^2 for total area of the drawings. Within group differences in body image drawings were calculated comparing area of affected limb to area of unaffected limb (Table 7).

The recurrent injury group drew significantly larger feet representing the affected limb compared to the unaffected limb [194.35(188.4-197.97) vs. 191.83(186.26-194.43), p=0.03]. There was no significant difference in area of limb drawings in the control group [190.85(183.74-193.53) vs. 193.29(189.49-196.78)].

Table 7: Body image drawings of affected and unaffected feet in mm^2 (N=46)

	Affected Median (IQR)	Unaffected Median (IQR)	Significance Test
*Experimental (n=24)	194.35 (188.4-197.97)	191.83 (186.26-194.43)	**T=65; p=0.03**
Control (n=22)	190.85 (183.74-193.53)	193.29 (189.49-196.78)	T=68; p=0.06

*indicates significant difference with p≤0.05

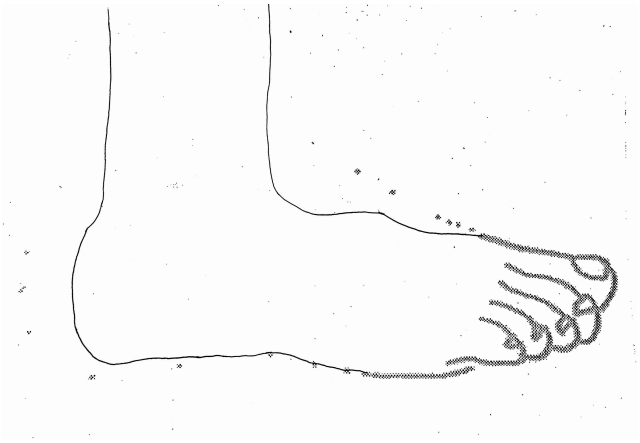

Figure 2: Recurrent injury group Participant Drawing Right Foot

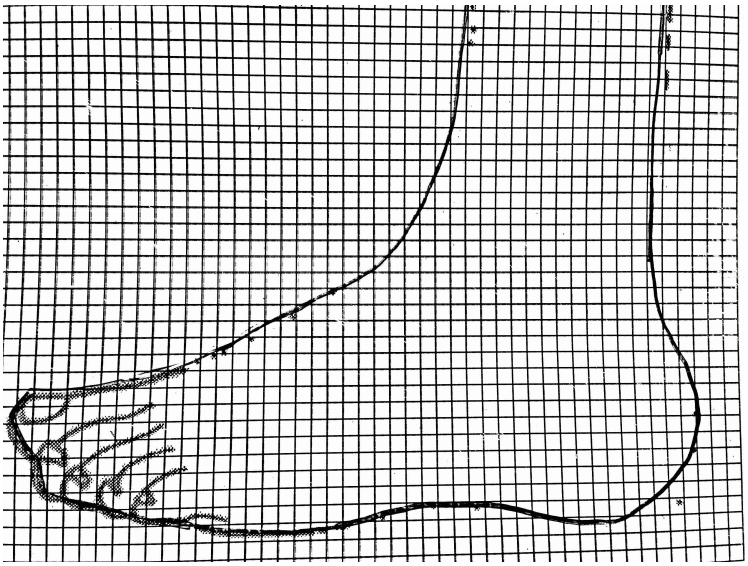

Figure 3: Control Group Drawing of Left Foot with Area Calculation Tool

3.5.6 Pressure Pain Threshold

Pressure pain threshold was tested on the same points as the two point discrimination testing, the ATFL, CFL and the PTFL. There was significant difference for the control group on the ATFL test site and the PTFL site. The between group comparison analysis on the

PTFL site demonstrated significant difference. (Table 7). This result is noteworthy and will need further investigation.

Table 8: Pressure Pain Threshold Between group differences for mean ATFL and CFL and PTFL (kg/cm^2)

	Recurrent Injury (n=24) Median (IQR)	Control (n=22) Median (IQR)	*Significance Test*
ATFL			
Uninjured side	667 (443.7-925.8)	642.5 (505-747.7)	U=262; p=0.97
Injured side	605.5 (448.3-811.3)	729.2 (554.7-712.7)	U=214; p=0.28
Significance Test	T=150; p=1.0	***T=52; p= 0.02**	
CFL			
Uninjured side	640 (447.3-837.7)	625.7 (427.3-715)	U=232; p=0.49
Injured side	649.8 (446.2-809.8)	644 (509.3-712.7)	U=252; p=1.0
Significance Test	T=114.5; p=0.47	T=74; p=0.15	
PTFL			
Uninjured side	443.8 (370.2-652.5)	555 (378.3-627)	U=236; 0.55
Injured side	573 (412.7-728)	746.2 (549.7-850.7)	*U=167.5; p=0.04
Significance Test	T=85; p=0.06	***T=1; p<0.01**	

*indicates significant difference with p≤0.05

3.5.7 Summary of Results

In summary, the main findings of this study were that there were no significant differences between the control and the recurrent injury groups in demographic factors making them comparable. The results of the Medical and Sports History Questionnaire indicate that the participants in the recurrent injury group participated in fewer days of preseason training with the control group having a longer preseason 78d(45-90) then the recurrent injury group 50d(45-90) by a mean of 28 days (p=0.06).

There were no significant differences in the between group analysis of laterality testing. The within group analysis of the abstract test results demonstrated a significant difference for the recurrent injury group on the slower recognition time achieved.

There was a significant difference in two point discrimination testing on the anterior talofibular ligament between the affected and unaffected limbs (within group analysis) in the control and the recurrent injury group. The results also indicated a significant difference in the between group comparison on the ATFL site.

Body image testing similarly showed significance in the within group comparison of total area drawn. The recurrent injury group area drawn was significantly larger on their affected side compared to their unaffected side. Finally, the results of the pressure pain testing analysis indicated significant differences in the within group comparison for the ATFL and PTFL in the control group. The PTFL test sight had significant results for the between group investigation of the recurrent Injury group and the control group.

3.6 Discussion

As presented in the literature review, rugby is a popular sport, played around the world.[20] It has one of the highest injury rates in sport with lateral ankle injuries one of the most common.[23,25,26] There is an abundance of information on causes and risk factors for ankle injuries but there is still no conclusive answer as to methods to prevent these injuries nor methods to prevent and treat recurrent ankle injuries.[1,7]

This study explored possible central nervous system involvement as a contributing risk factor for recurrent ankle injuries. The sample group was taken from healthy professional male rugby players with a median age of 23.5y(20-25). Only rugby players were involved in the study, no other sporting codes were looked at, and recurrent lateral ankle injuries were the only injuries investigated.

The initial recruitment process concluded with a sample size of 59 participants, there was a dropout of 13 participants during the testing process, which left 46 participants in total to complete the study. This sample size is in accord with previous chronic pain studies using similar methodology by Moseley et al. 2008 (N=5), Walsh et al. 2011 (N=20), Pleger et al. 2006 (N=17), McCormick et al. 2007 (N=22), Moseley, 2004 (N=36) and the laterality study that the sample size was calculated on by Dey et al. 2012 (N=57).[49,50,54,56,58,60] With

statistical significance accepted as p≤0.05, a group of 11 participants would provide 95% statistical power. The total number of 46 participants recruited for this study; 24 sample participants and 22 control participants, therefore ensures sufficient statistical power.

Central nervous system studies in the literature, have to date, only explored chronic pain conditions and limb immobilization.[9,12,13,22,49] At the time of this study, published literature looking at central nervous system relationships with recurrent injury could not be found. It would appear that central nervous system changes have not yet been investigated as potential contributors to recurrent injuries in professional rugby players.

3.6.1 Demographic Characteristics

No significant differences were found in the demographic analysis. Therefore, the control and recurrent injury groups were comparable. The demographic results in this study are comparable with international standards as shown by previous studies so can be generalised to other professional rugby players.[3,14,20,42,43]

3.6.1.1 Training History

Total number of years playing professional rugby was significantly greater for the control group [6y(2-7)] compared to the recurrent injury group [3y(2-6); p=0.04]. This could be attributed to a 'survival of the fittest' selection phenomenon observed in professional sport. This phenomenon has been recognized in ballet dancers and professional soccer players among other sporting codes.[30–32] Ankle injuries and specifically recurrent ankle

injuries accounted for the majority of injuries causing early retirement.[31] Younger athletes who suffer more injuries than their less injured colleagues are more likely to retire earlier from their chosen sport.[30]

Preseason training length in days was significantly higher for the control group [78d(45-90)] than the recurrent injury group [50d(30-69); p=0.02]. The shorter preseason for the recurrent injury group could be a reflection of having had previous injuries and so not being fit for participation in the full period of preseason. The literature has conflicting viewpoints on preseason training with the more contemporary research advocating for a full preseason.[2,41] The literature has explored preseason participation and recurrent injury and found comparative results between length of preseason training and injury occurrence and recurrence during the following season, shortened preseason was proportionate to increased injury risk.[2,41] The reason behind the short preseason could be injury related or a lack of commitment from the individual athlete. Quarrie et al. found that players injured in the previous season were not at greater risk than their injury free teammates so long as they started the preseason and season injury free allowing for full participation in the preseason program.[8,43,71]

3.6.2 Laterality Recognition

The testing process used in this study did not show any statistical significance in the between group comparisons. The between sides analysis demonstrated a significant difference for the more difficult “abstract” test on recognition time. Participants with

recurrent ankle injuries had slower recognition times for the previously injured ankle compared to the uninjured side. Previous studies in people with chronic pain conditions have demonstrated that delays in laterality recognition are associated with cortical changes in the somatosensory homuncular representation of the affected area.[55,56] The findings in this study suggest that similar changes may occur with recurrent ankle injuries.[10] To confirm that the changes in laterality recognition times were associated with cortical changes in representation, functional MRI studies would be needed.[13,22,46] The high level of testing (abstract images) needed to produce a significant result intimate that the central nervous system changes might not be as exaggerated in this sample as in those observed in chronic pain patients. The sample group used in this study were all high functioning elite athletes who were involved in full training during the time the study took place. The samples used in the previous studies done on chronic pain are all patients who are seeking help for their problems which suggests there are not as highly functioning.[55,56] The higher functionality of the sample group would be indicative of the level of testing needed to pick up a difference.

3.6.3 Two Point Discrimination

The two point discrimination testing demonstrated significant differences at the anterior talofibular ligament test site. The control group and the recurrent injury group both had significant differences for the within group comparison analysis. In addition, there were significant differences between groups for two point discrimination. The within group differences may suggest a role of the CNS in the epidemiology of ATFL injuries. The ATFL is

the most commonly injured ligament in the lateral ankle ligament complex (73%).[1] Considering the high injury rates experienced in rugby, it is suggested that most of the players have experienced mild ankle sprains during their careers.[7] A history of mild ankle sprain may have contributed to altered two point discrimination.

In the recurrent injury group, the TPD accuracy was poorer on the affected side compared to the unaffected side. These findings suggest that there could be changes to the proprioception and tactile acuity of the affected area. This is in keeping with the altered body image found in chronic pain studies as explained by peripheral and central sensitization.[49,50,52,54,56,60] This also advocates for the chronic pain principle that the amount of tactile impairment is correlated to the intensity of the pain experienced and the signal changes attendant with cortical reorganisation.[49] These results are reinforcing and reinforced by the results seen in laterality testing as changes in laterality are also attributed to changes in somatosensory representation of the homunculus.[50,56]

Clinically this phenomenon can cause a spiral effect with the linear relationship between central changes and recurrent injury. As the central changes increase as a result of the number of ankle injuries increasing so causing an increase in the predisposition to reinjury. Such as the amount of cortical reorganisation seen in amputee patients and chronic pain patients is proportional to the amount of pain they initially experienced. [22,45] In this study this can be seen with the pressure pain, TPD and laterality results. The control groups demonstrated significant results in their between sides analysis and both

groups in their between group analysis. As mentioned above this is attributed to the high incidence of mild ankle injuries not reported as injuries because they do not prevent training or playing.[7]

3.6.4 Body Image

The recurrent injury group showed differences for within group analysis of body image with the drawings of the recurrent injury ankle being larger than the uninjured ankle. In contrast to studies of people with chronic pain, the participants drew their injured side significantly larger than their non-injured side. The chronic pain theory is that with pain, the cortex neglects the affected area and the homuncular representation of the area becomes smaller and gets infiltrated by the adjacent areas. The chronic pain studies demonstrate this hypothesis with the affected side drawn smaller or having big gaps and "missing" sections to the drawings compared to the unaffected side.[50] The larger drawings of the recurrent injury ankle need further investigation to ascertain if the representation of the affected area in the brain becomes larger and moves into adjacent areas on the homunculus or if there is another reason for this occurrence. Such studies would need to be done using fMRI to shed light on these findings.

3.6.5 Pressure Pain Threshold

Pressure pain threshold testing identified a significant differences in two of the three test sites. The ATFL and PTFL sites both had significant differences for the control group. The

sample group analysis showed significant results for the injured side comparison (the control group was randomly allocated an injured side and uninjured side as both sides were effectively uninjured) in the between group data analysis at the PTFL site. This finding indicates that there could be a possibility of a global increase in the sensitivity of the neural system un the recurrent injury group but the data is more in line with the possibility of more specific changes to the somatosensory cortices. This is indicative of a local increase in sensitivity to the neural system, restricted to the homuncular representation zone of the affected body part area and adjacent areas and not a generalized heightening of sensitivity of the neural system.[62,72] Hyperalgesia and allodynia are common to most chronic pain conditions and have been attributed to cortical reorganisation and central sensitization.[51,62,63] Global hypersensitivity may be common to chronic pain pathologies as a result of central sensitization but does not appear to contribute to recurrent ankle injuries in this sample.[63] The lack of global hyperalgesia suggests that the central processing changes are specific to the specific representation area in the somatosensory cortices.[51]

The control group results could be attributed to the high number of minor ankle sprains occurring in rugby that are not reported as injuries.

3.6.6 Limitations of the Study

Rugby is a high collision and injury prevalent sport.[2] This fact alone can affect the data as most players have probably had many previous confounding injuries that do not get reported or that are not recorded as time loss injuries. This limits the study to professional contact sport athletes, not the general athletic population.

Based on the results of this study, future studies using athletes who meet the criteria of training volume and previous injury history are indicated. This would widen the generalizability of the results to be more representative of the South African athletic population.

The participants were wholly made up of professional rugby players; by virtue of the fact that they are professional they need to play to earn a living. It may be that professional players will play through injuries and pain and not report injuries to the medical staff. Based the above points, there is a selection bias in the study as the population is only reflective of a professional rugby playing population, not a general sporting population. This limits the results to this particular population. Further research using a generalized population would have to be done as the bias from professional athletes not reporting injuries because of financial and selection reasons as is suggested in this study would skew the data.[1]

There was no blinding in this study; the tester was familiar with the medical history of the players. This influences the study results, as the tester knew the previously injured side and could potentially bias data collection. Further, all the testing was completed in the

team environment; where distractions and interruptions were common. The participants' concentration might have been affected during the testing procedure and the competitive environment may have influenced responses on pressure pain threshold testing.[73] For future studies a blinded independent assessor should be used and the sample groups should be kept blinded to the aims of the study. The body image drawing, TPD and PP tests are subjective and can be easily manipulated if the subject knows what the aims of the tests are. Testing procedure should be carried out in a closed private room to eliminate distractions and competitive influence.

There are self-reported data limitations and method bias in this study arising from the use of a questionnaire.[74] The data are subject to construct variability, the information gathered could be viewed as formative-indicators of constructs rather than as reflective-indicators of constructs, as the responses to the questionnaires are influenced by the environment the participant is experiencing when answering and their perception of the correct answer.[74] Participants have selective memory when completing a Medical and Sports History Questionnaire. As information on previous training and medical history was collected retrospectively, the accuracy of this information may have been affected by players' memory recall. Participants were also at a disadvantage when asked to complete training data because they were passive in their training experience; their training routine is completely controlled by external sources such as their coaches. Therefore differences in training may not be a reflection of player choice but of coaches' decision making.

In this study the level at which the laterality testing identified the subtle changes in laterality at the higher "abstract" level of testing. Future studies increasing the difficulty of laterality testing by decreasing the time allowed for limb recognition are indicated. This method may determine the more delicate changes which may be present in this population group. The laterality test was developed for the chronic pain population where large changes have been recorded in the CNS homuncular representation of the painful area. The CNS changes seen in this test population might be more subtle than the original intended test population.[56,59]

Therefore it is recommended that the laterality test procedure be developed to a more challenging level for this population.

3.6.7 Clinical Implications

The results in the study indicate a link between central nervous system changes and recurrent ankle injuries. The findings of this study indicate a need for broader study and further research using tests of greater sensitivity in methodologically sound designs including blinding of data collectors and sample groups. Clinicians should be aware of possible contributing factors when treating recurrent injuries and especially consider central nervous system changes and treatment options if their patients are not responding to standard treatment regimes. Clinicians should also be aware of evolving literature in this area as it is a new area of research and the results obtained in this study strongly indicate a new research path to follow when looking at recurrent injury.

There is a paucity of research on central nervous system changes in the presence of recurrent injuries. Recurrent injury is an acknowledged problem among the active population and in professional sport in particular.

The clinical implications to be considered in light of these results is that there could be central nervous system changes with recurrent injury needing to be addressed during the rehabilitation process and that could be influencing the chronicity of ankle injuries.

3.7 Conclusion

The results of this study identified a change in laterality recognition, an altered body image and a change in the proprioception and tactile acuity of the affected area on the recurrent injury group participants. Despite the limitations to this study, there is some conclusive significance in the results obtained which indicates a link and an interesting new area worthy of further investigation in the treatment of recurrent ankle injuries.

CHAPTER FOUR: SUMMARY AND CONCLUSION

Recurrent ankle injuries are a common and well-documented problem in the sporting population. The present literature is not conclusive on the causes, risk factors and prevention of recurrent ankle injuries.[1,5,7,8,18,33–37,42] Rugby has a very high incidence of injury and ankle injuries account for many of the acute and chronic injuries reported in the rugby literature.[6,20,23–27] Central nervous system influence on injury and recurrent injury has not yet been fully examined with this area of research limited to chronic pain studies thus far. A link has been established between central nervous system changes and chronic pain pathologies.[9–13,22,45,46,49] Research using fMRI and limb immobilization in acute injuries have yielded similar results to the chronic pain studies effect on the central nervous system.[21,22,49–52,54–56] This indicates central nervous system malleability in normal patients, not only patients presenting with chronic pain.[13,21]

The overall aim of the present study was to determine whether there was a relationship between central nervous system changes and recurrent ankle injuries, specifically among rugby players. Based on the evidence provided in this thesis, the study objectives, as described in Chapter 3 p.37, may be answered as follows:

Objective 1:

In a group of professional rugby players with recurrent ankle injuries and a matched control group of rugby players without a history of recurrent ankle injuries.

1. *To describe the demographic and training characteristics of the sample through administration of a Body composition assessment and a Medical and Sports History Questionnaire.*

The recurrent injury group and control group had no significant differences in the body composition assessments. The two groups were analogous for comparison purposes. They were also comparable with other international and professional rugby player groups.[3,14,20] The Medical and Sports History Questionnaire indicated two areas of significance; the total number of years playing professional rugby and the total number of days of preseason participation. The non-injured control group had significantly more years as professional rugby players than the previously injured recurrent injury group suggesting recurrent injury could be a limiting factor on professional career length. Furthermore, the control group had significantly more days of preseason participation compared to the recurrent injury group. Similarly, this result is commonly reported in the literature in professional and adolescent sport with incidence of injury increasing with limited preseason training.[2,40,41]

2. *To determine whether there are changes in the somatosensory representation of the affected areas of the sample group compared with a control group using laterality testing,[50,54,56] limb perception drawing[50] and two point discrimination testing.[50]*

The somatosensory representation of the ankle in the somatosensory cortices of the brain (homunculus) was investigated using previously validated tests from chronic pain studies. The recognition time results from the laterality testing were significantly different between the reinjured and uninjured sides for the complex “abstract’ test in the recurrent injury group. This indicates a possible change in somatosensory representation of the

affected ankle area. These results suggest a need for further testing in this population using greater complexity to the test administered.

The limb perception drawing, or body image testing returned significant results for the recurrent injury group within group comparison. There was a significant difference in area between the affected side and unaffected side in the recurrent injury group with the drawn area being larger. This is in contrast to previous studies on people with chronic pain conditions where the affected area is drawn smaller than the unaffected side.[50] Further investigation will be required to establish the reason for this finding. However, this finding, like that for the laterality testing, suggests that there is an alteration in the homuncular cortical representation of the injured ankle.

Two point discrimination testing produced further supporting results. The within group comparison of the data from the anterior talofibular ligament test site was significant for both the control group and the recurrent injury group. The between group analysis also demonstrated significance on the recurrent injury side.

The ATFL is the most commonly injured ligament in the lateral ankle complex. It is hypothesized low grade recurrent sprains of these ligaments may have contributed to an increase in sensitivity for all the participants. As two point discrimination is an investigation of cortical changes, these results further support those of the laterality

testing and the body image drawings suggesting changes in the somatosensory representation of the ankle.

3. *To determine whether there are changes in the CNS firing threshold compared with a control group using pressure pain threshold testing.*[50]

Central sensitization is examined in this testing procedure. The result from this test indicated significant differences for the control group within group assessment of pressure pain at the ATFL and the PTFL sites. This result can also be attributed to the high incidence of non-reported mild ankle sprains seen in professional rugby.[1] The significance seen in the between group assessment of the recurrent injury groups injured side compared to the control group indicates changes to the central nervous system firing threshold centrally. These results further reinforce the argument for central nervous system changes as a result of recurrent ankle injuries.

Based on the findings of the present study, central nervous system changes should be considered in further research exploring the epidemiology and management of recurrent ankle injuries in professional rugby players. Central nervous system changes should not only be considered in the clinical setting for the management and understanding of chronic pain but also in the treatment and prevention of recurrent injury.

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APPENDIX I: ETHICS APPROVAL

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences
Faculty of Health Sciences Human Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • **Facsimile** [021] 406 6411
e-mail: sumayah.ariefdien@uct.ac.za
www.health.uct.ac.za/research/humanethics/forms

22 July 2013

HREC REF: 415/2013

Dr R Parker
Physiotherapy
Health & Rehab Sciences
F-45
OMB

Dear Dr Parker

PROJECT TITLE: A CROSS SECTIONAL STUDY TO DETERMINE WHETHER THERE ARE CENTRAL NERVOUS SYSTEM CHANGES IN RUGBY PLAYERS WHO HAVE SUSTAINED RECURRENT ANKLE INJURIES

Thank you for submitting your study to the Faculty of Health Sciences Human Research Ethics Committee for review.

It is a pleasure to inform you that the HREC has **formally approved** the above mentioned study.

Approval is granted for one year till the 28 July 2014.

Please submit a progress form, using the standardised Annual Report Form, if the study continues beyond the approval period. Please submit a Standard Closure form if the study is completed within the approval period.

Please note that the on-going ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

Yours sincerely

Signed

PROFESSOR M BLOCKMAN
CHAIRPERSON, HSF HUMAN ETHICS

Federal Wide Assurance Number: FWA00001637.
Institutional Review Board (IRB) number: IRB00001938

sAriefdien

This serves to confirm that the University of Cape Town Research Ethics Committee complies to the Ethics Standards for Clinical Research with a new drug in patients, based on the Medical Research Council (MRC-SA), Food and Drug Administration (FDA-USA), International Convention on Harmonisation Good Clinical Practice (ICH GCP) and Declaration of Helsinki guidelines.

The Research Ethics Committee granting this approval is in compliance with the ICH Harmonised Tripartite Guidelines E6: Note for Guidance on Good Clinical Practice (CPMP/ICH/135/95) and FDA Code Federal Regulation Part 50, 56 and 312.

sAriefdien

APPENDIX II: INFORMED CONSENT – PARTICIPANT

A CROSS SECTIONAL STUDY TO DETERMINE WHETHER THERE ARE CENTRAL NERVOUS SYSTEM CHANGES IN RUGBY PLAYERS WHO HAVE SUSTAINED RECURRENT ANKLE INJURIES

Dear Participant

I am an MPhil Student in the Division of Physiotherapy, University of Cape Town. I will be conducting a study to determine whether there are changes in the central nervous system in rugby players who have sustained recurrent ankle injuries. There is evidence of changes to the central nervous system in patients with chronic pain and new treatment methods focussing on central nervous system training have shown very positive results in the treatment of chronic pain. Chronic pain is pain that is still felt when the physical injury has healed, is disproportionate to the physical injury or in the absence of physical injury. We aim to investigate if there might be similar central nervous system changes in recurrent injury as has been observed in chronic pain.

Ankle injuries are the most common sports injuries reported and previous injury is the biggest risk factor for an ankle injury. As recurrent ankle injuries make up a significant part of rugby injuries I am conducting my research in this area. This study aims to increase our knowledge of recurrent ankle injuries and give clinicians more insight into the rehabilitation of recurrent injuries.

You have been invited to participate in this study as you have sustained a recurrent ankle injury over the last 12 months. The information obtained in this study will be used for the completion of a mini-dissertation as required for the partial fulfilment of the Masters in Philosophy in Sports Physiotherapy (MPhil Sports Physiotherapy) from the University of Cape Town. This study has been given ethical approval by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (HREC).

Should you agree to take part in the study, you will be asked to attend an individual testing session lasting approximately 40 minutes. The session will be conducted in the Johannesburg Stadium level -2 Gauteng Lion Rugby Union (GLRU) Physiotherapy

rooms. You will be required to travel to the venues at your own cost, as there is no funding for this study and you will receive no remuneration for your participation. Dr Theresa Burgess and Romy Parker, Senior Lecturers in Physiotherapy at the University of Cape Town will supervise the study.

Should you agree to participation in this study you agree to sanction the publication of your testing information and results.

Participation in this study is voluntary. Should you wish to withdraw at any time you are free to do so at any time.

Please read through this form carefully before signing this document. If you have any questions regarding this form or the study detailed please feel free to ask.

The Study will involve the following sessions:

1. You will be asked to report to the Johannesburg Stadium GLRU physiotherapy rooms, -2 level, Johannesburg Stadium, 124 Van Beek Street, New Doornfontein.
2. During this session you will be required to complete this informed consent form. You will also be asked to complete a Medical and Sports History Questionnaire and Physical Activity Readiness Questionnaire. The Medical and Sports History Questionnaire details your basic personal information, your rugby sporting history and your previous and current injury history.
3. The physical testing aspect of the study. Your weight, height and skinfold measurements will be taken to calculate your fat percentage and body mass index. A series of four (4) different tests will then be completed: laterality testing, limb perception testing, two point discrimination testing and pressure-pain threshold testing.

Laterality Testing: You will be shown a series of images on a computer screen showing different pictures of left and right feet. You will be asked to indicate if the image shows a left or right foot by pressing a button on the computer keyboard. This process will be timed.

Limb Perception: You will be given a piece of paper with a half drawn picture of a lower limb. You will be asked to complete the drawing of your own previously injured foot. You will not be allowed to look or touch the foot you are drawing. You will be asked to draw your foot as accurately as possible including the bones and joints as you imagine them in your mind.

Two Point Discrimination: You will be asked to lie down on the physiotherapy plinth and asked to close your eyes. A calliper will be placed on your skin over your ankle in 3 separate points, 3 times at each point. You will be asked to say "one" if you feel one point against your skin and "two" if you feel two points against your skin. Tests will be conducted on both your left and right ankles. Before testing begins a practise test will be done on your arm.

Pressure-Pain Threshold: A Pressure-Pain Algometer will be used for this testing. The algometer will be placed against your skin on the same 3 points as used in the previous test. The machine will apply pressure to the area until you feel discomfort or pain. Tests will be conducted on both your left and right ankles. Before testing begins a practise test will be done on your arm.

Benefits to Participants

You will receive all your data (anthropometric measurements, laterality, proprioception, tactile acuity) in an information pack at the end of the study. The data may provide some insight to help with rehabilitation for recurrent ankle injuries in the future.

You are under no obligation to participate in this study and you can withdraw from the study at any time without incurring any penalty or providing explanation. All the personal information that you provide for the study will be kept confidential in a password controlled document for five years and no names will be disclosed during the study.

Risks to Participants

There may be a minimal transient discomfort felt during the use of the calliper, when the skin fold measurements are taken. There may be minimal transient pain with two point discrimination testing. There will be minimal transient pain associated with the pressure pain threshold testing. If you experience pain beyond what you are willing to endure you are free to stop testing and withdraw from the study without penalty. If you suffer any injury during the testing procedure you will be referred back to your team medical personal responsible for your medical care.

Concerns:

If you have any concerns or questions during this study please feel free to contact myself, Alice Rawlinson or one of my supervisors.

Alice Rawlinson

Cell: 0836440098

Email: alicepies@yahoo.co.uk

Should you have any further queries please contact:

Dr Theresa Burgess

Physical address: Division of Physiotherapy
Departmentof Health and Rehabilitation
University of Cape Town
Groote Schuur Hospital
Anzio Road
Observatory 7725

Tel number: 021 406 6171

Fax number: 021 406 6323

Romy Parker Division of Physiotherapy
Departmentof Health and Rehabilitation
University of Cape Town
Groote Schuur Hospital
Anzio Road
Observatory 7725

Tel number: 021 406 6431

Fax number: 021 406 6323

If you have any questions or concerns about your rights as a research participant, please contact:

Prof Marc Blockman

Faculty of Health Sciences Human Research Ethics Committee

Telephone: 021 406 6492

Please note that UCT does offer a no-fault insurance that will cover all participants in the event that something may go wrong. This insurance will provide prompt payment of compensation for any trial-related injury in accordance with the Association of the British Pharmaceutical Industry (ABPI) guidelines (1991). These guidelines recommend that UCT, without any legal commitment, should compensate you without you having to prove that UCT is at fault. An injury is considered trial-related if, and to the extent that, it is caused by study activities. You must notify the study investigators immediately of any injuries during the trial. whether they are research-related or other related complications. UCT reserves the right not to provide compensation if, and to the extent that, your injury came about because you chose not to follow the instructions that you were given while taking part in the study. Your right in law to claim compensation for injury where you prove negligence is not affected.

By placing your signature below, it serves as confirmation that you have had adequate time to read through and have any questions answered. You have understood the consent form and that you are willing to participate in this study. You have the right to withdraw at any time without incurring any penalty or providing an explanation. You may ask questions at any time during the study. All the information recorded will be confidential. Your signature is further confirmation that you are aware of the possible risks involved in this study.

_____	_____	_____
Signature of Volunteer	Name (Please Print)	Date
_____	_____	_____
Signature of Investigator	Name (Please Print)	Date

APPENDIX III: MEDICAL AND SPORTS HISTORY QUESTIONNAIRE

Thank you for taking the time to complete this questionnaire, which will take 10 minutes of your valuable time to complete. The completion of the questionnaire is voluntary and all the information will be kept confidential. The information collected will only be used for research purposes.

Instructions:

Please complete Sections A, B, C, D

Section A Personal Details
Section B Playing History
Section C Training History
Section D Injury History

Section A: Personal Details			
Surname			
First Name			
Language			
Postal Address		Postal/ Zip Code	
E-mail address		Phone (day time)	code number
Date of birth	y y y y - m m - d d	Cell	
Height	cm		
Weight	kg	Age	
Rugby Institution			
Current Playing Possition		Preferred Playing Position	

If you do not play rugby currently and are not affiliated to the GLRU or UJ Rugby clubs please skip sections B,C and D

Section B: Playing History	
Year First Playing Team Rugby	
Total Years Playing Team Rugby	
Teams Represented since 16 years of age	
Highest Team Represented	

First Year Playing Professional / Contracted Rugby	
Total Years Playing Professional / Contracted Rugby?	
Number of games played in last 6 months	
Total Minutes Played in Last 6 months	

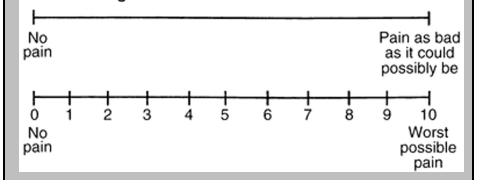
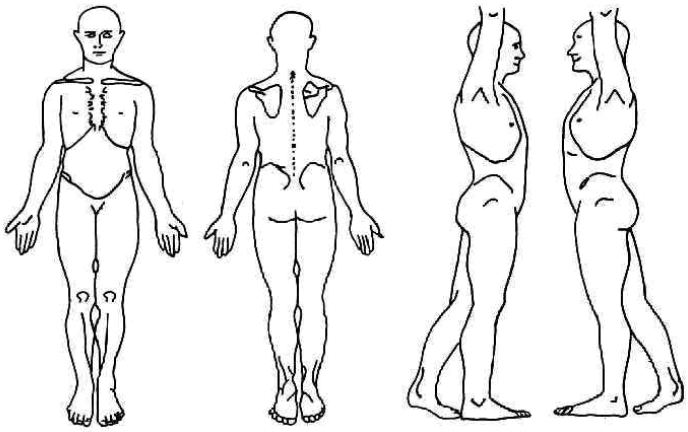
Section C: Training History			
Total number of Training hours per week			
Total number of Hours Pre / Rehab per week			
Total number of hours Gym Training per week			
Total number of additional hours Conditioning Training per week			
Total number hours Team Training per week			
Total number hours Contact Training per week			
Average week training hours for previous 6 Months			
Total days Pre-season Training for current rugby season		Average Hours per day Pre-season Training	
Preseason training blocks completed over previous 3 years			

Section D: Injury History	
Significant Injury sustained over previous 12 months? (Prevent team training for more than 7 days)	Yes: ☐ If Yes, How many? : _____ No: ☐

Areas affected: (If more than one injury per area, indicate how many with a number)	☐ Head ☐ Elbow ☐ Hamstring ☐ Neck ☐ Forearm ☐ Quadriceps ☐ Face ☐ Wrist ☐ Knee ☐ Front chest ☐ Finger ☐ Shin ☐ Back chest ☐ Lower back ☐ Achilles ☐ Shoulder ☐ Hip ☐ Ankle ☐ Upper arm ☐ Thigh ☐ Foot Other Specify: _____
Structures injured?	☐ Muscle ☐ Ligament ☐ Tendon ☐ Joint ☐ Bone Other Specify: _____
Areas affected by Re-injury:	
Date of first Ankle injury:	y y y y - m m - d d Left: ☐ Right: ☐
Ankle structures injured?	☐ Muscle ☐ Ligament ☐ Tendon ☐ Joint ☐ Bone Other Specify: _____
Please indicate the severity of the injury (tick one box please)	☐ Grade 1 - I only experience symptoms after exercise ☐ Grade 2 - I experience symptoms during exercise, but it does not interfere with training ☐ Grade 3 - I experience symptoms during exercise that may interfere with my training / playing ☐ Grade 4 - I am so painful that I may not be able to train or play
Please indicate how your injury was	☐ Rest ☐ Tablets

treated to date? (you can tick more than one)	☐ Stretches ☐ Cortisone injection ☐ Physiotherapy ☐ Other injection ☐ Surgery ☐ Orthotics ☐ Strengthening exercises ☐ Equipment change Other Specify: _____
Length of time from injury to return to full team training?	days - weeks - months
Date of second Ankle injury:	yyyy-mm-dd Left: ☐ Right: ☐
Structures injured?	☐ Muscle ☐ Ligament ☐ Tendon ☐ Joint ☐ Bone Other Specify: _____
Please indicate the severity of the injury (tick one box please)	☐ Grade 1 - I only experience symptoms after exercise ☐ Grade 2 - I experience symptoms during exercise, but it does not interfere with training ☐ Grade 3 - I experience symptoms during exercise that may interfere with my training / playing ☐ Grade 4 - I am so painful that I may not be able to train or play
Please indicate how your injury was treated to date? (you can tick more than one)	☐ Rest ☐ Tablets ☐ Stretches ☐ Cortisone injection ☐ Physiotherapy ☐ Platelet Injection ☐ Orthotics ☐ Other injection ☐ Surgery ☐ Equipment change ☐ Strengthening exercises Other Specify: _____
Length of time from injury to return to full team training?	days - weeks - months

Date of subsequent Ankle Injuries:	y y y y - m m - d d y y y y - m m - d d y y y y - m m - d d	Left: ☐ Right: ☐
Structures injured?	☐ Muscle ☐ Ligament ☐ Tendon ☐ Joint ☐ Bone Other Specify: _____	
Please indicate the severity of the injury (tick one box please)	☐ Grade 1 - I only experience symptoms after exercise ☐ Grade 2 - I experience symptoms during exercise, but it does not interfere with training ☐ Grade 3 - I experience symptoms during exercise that may interfere with my training / playing ☐ Grade 4 - I am so painful that I may not be able to train or play	
Please indicate how your injury was treated to date? (you can tick more than one)	☐ Rest ☐ Tablets ☐ Stretches ☐ Cortisone injection ☐ Physiotherapy ☐ Platelet Injection ☐ Orthotics ☐ Other injection ☐ Surgery ☐ Equipment change ☐ Strengthening exercises Other Specify: _____	
Length of time from injury to return to full team training?	d a y s - w e e k s - m o n t h s	
Current Injuries:	Yes: ☐ No: ☐	
Areas affected:	☐ Head ☐ Elbow ☐ Hamstring ☐ Neck ☐ Forearm ☐ Quadriceps ☐ Face ☐ Wrist ☐ Knee ☐ Front chest ☐ Finger ☐ Shin ☐ Back chest ☐ Lower back ☐ Achilles	

	☐ Shoulder ☐ Hip ☐ Ankle ☐ Upper arm ☐ Thigh ☐ Foot Other Specify: _____
Indicate on diagram where injuries occurred and severity out of 10. **Verbal Numerical Scale** If "0" is "no pain" and "10" is the worst pain you can imagine, where is your pain now? on average? at its worst? at its best? **Word Scale** None Mild Moderate Severe Excruciating **Visual Analogue Scales**  	

APPENDIX IV: INFORMED CONSENT – RUGBY UNION CONTRACTING BODY

A CROSS SECTIONAL STUDY TO DETERMINE WHETHER THERE ARE CENTRAL NERVOUS SYSTEM CHANGES IN RUGBY PLAYERS WHO HAVE SUSTAINED RECURRENT ANKLE INJURIES

To whom it may concern,

I am an MPhil Student in the Division of Physiotherapy, University of Cape Town. I will be conducting a study to determine whether there are changes in the central nervous system in rugby players who have sustained recurrent ankle injuries. There is evidence of changes to the central nervous system in patients with chronic pain and new treatment methods focussing on central nervous system training have shown very positive results in the treatment of chronic pain. Chronic pain is pain that is still felt when the physical injury has healed, is disproportionate to the physical injury or in the absence of physical injury. We aim to investigate if there might be similar central nervous system changes in recurrent injury as has been observed in chronic pain.

Ankle injuries are the most common sports injuries reported and previous injury is the biggest risk factor for injury. As recurrent ankle injuries make up a significant part of rugby injuries I am conducting my research in this area. This study aims to increase our knowledge of recurrent ankle injuries and give clinicians more insight into the rehabilitation of recurrent injuries.

I request to conduct my research using rugby players contracted to The Gauteng Lions Rugby Union / University of Johannesburg Rugby Club. I am requesting permission to recruit players for this study from among your player group and for any testing information and results to be allowed to be published. Players will be asked to attend an individual testing session lasting for approximately 40 minutes. The session will be conducted in the Johannesburg Stadium level -2 Gauteng Lion Rugby Union (GLRU) Physiotherapy rooms. The Player will be required to travel to the venues at their own cost, as there is no funding for this study and they will not receive any remuneration for their participation.

The information obtained in this study will be used for the completion of a mini-dissertation as required for the partial fulfilment of the Masters in Philosophy in Sports Physiotherapy (MPhil Sports Physiotherapy) from the University of Cape Town. This study has been given ethical approval by the University of Cape Town, Faculty of Health Sciences Human Research Ethics Committee (HREC). Dr Theresa Burgess and Romy Parker, Senior Lecturers in Physiotherapy at the University of Cape Town will supervise the Study.

Participation in this study is voluntary. Should players wish to withdraw at any time they are free to do so with no penalty incurred.

The Study will involve the following:

1. They will be asked to report to the Johannesburg Stadium GLRU physiotherapy rooms, -2 level, Johannesburg Stadium, 124 Van Beek Street, New Doornfontein
2. During the session the player will be asked to complete this informed consent form. The player will also be asked to complete a Medical and Sports History Questionnaire. The Medical and Sports History Questionnaire details their basic personal information, their rugby sporting history and their previous and current injury history.
3. The physical testing aspect of the study. The players' weight, height and skinfold measurements will be taken to calculate their fat percentage and body mass index. A series of four (4) different tests will then be completed: laterality testing, limb perception testing, two point discrimination testing and pressure-pain threshold testing.

Laterality Testing: The player will be shown a series of images on a computer screen showing different pictures of left and right feet. They will be asked to indicate if the image shows a left or right foot by pressing a button on the computer keyboard. This process will be timed.

Limb Perception: The player will be given a piece of paper with a half drawn picture of a lower limb. They will be asked to complete the drawing of their own previously injured foot. They will not be allowed to look or touch the foot they are drawing. They will be asked to draw their foot as accurately as possible including the bones and joints as they imagine them in their mind. Their drawing will be compared with their real foot to assess the accuracy of their drawing.

Two Point Discrimination: The player will be asked to lie down on the physiotherapy plinth and asked to close their eyes. A calliper will be placed on their skin over their ankle in three (3) separate points, 3 times at each point. They will be asked to say "one" if they feel one point against their skin and "two" if they feel two points against their skin. Tests will be conducted on both left and right ankles. Before testing begins a practise test will be done on an arm.

Pressure-Pain Threshold: A Pressure-Pain Algometer will be used for this testing. The algometer will be placed against the players' skin on the same 3 points as used in the previous test. The machine will apply pressure to the area until they feel discomfort or pain. Tests will be conducted on both left and right ankles. Before testing begins a practise test will be done on an arm.

Benefits to participants

The participants will receive all their data (anthropometric measurements, laterality, proprioception, tactile acuity) in an information pack at the end of the study. The data may provide some insight to help with rehabilitation for their recurrent ankle injuries in the future.

The GLRU / UJ and the players are under no obligation to participate in this study and the GLRU / UJ and the player can withdraw from the study at any time with no penalty incurred. All the personal information that is provided for the study will be kept confidential in a password controlled document for five years and no names will be disclosed during the study.

Risks to Participants

There may be a minimal transient discomfort felt during the use of the calliper, when the skin fold measurements are taken. There may be minimal transient pain with two point discrimination testing. There will be minimal transient pain associated with the pressure pain threshold testing. If you suffer any injury during the testing procedure you will be referred back to your team medical personal responsible for your medical care.

Concerns:

If you have any concerns or questions during this study please feel free to contact myself Alice Rawlinson or one of my supervisors. Any concerns will be managed by the researcher promptly.

Alice Rawlinson

Cell: 0836440098

Email: alicepies@yahoo.co.uk

Should you have any further queries please contact:

Dr Theresa Burgess

Physical address: Division of Physiotherapy
Department of Health and Rehabilitation
University of Cape Town
Groote Schuur Hospital
Anzio Road
Observatory 7725

Tel number: 021 406 6171

Fax number: 021 406 6323

Romy Parker Division of Physiotherapy
Departmentof Health and Rehabilitation
University of Cape Town
Groote Schuur Hospital
Anzio Road
Observatory 7725

Tel number: 021 406 6431

Fax number: 021 406 6323

If you have any questions or concerns about the players' rights as research participants, please contact:

Prof Marc Blockman

Faculty of Health Sciences Human Research Ethics Committee

Telephone: 021 406 6492

Please note that UCT does offer a no-fault insurance that will cover all participants in the event that something may go wrong. This insurance will provide prompt payment of compensation for any trial-related injury in accordance with the Association of the British Pharmaceutical Industry (ABPI) guidelines (1991). These guidelines recommend that UCT, without any legal commitment, should compensate the participant without them having to prove that UCT is at fault. An injury is considered trial-related if, and to the extent that, it is caused by study activities. The Participant must notify the study investigators immediately of any injuries during the trial. whether they are research-related or other related complications. UCT reserves the right not to provide compensation if, and to the extent that, the participants' injury came about because they chose not to follow the instructions that they were given while taking part in the study. The Participants right in law to claim compensation for injury where they prove negligence is not affected.

By placing your signature below, it serves as confirmation that you have had adequate time to read through and have any questions answered. You have understood the consent form and that you are willing to allow recruitment of participants in this study from your player group. You have the right to withdraw permission at any time without penalty or providing an explanation. You may ask questions at any time during the study. All the information recorded will be confidential. Your signature is further confirmation that you are aware of the possible risks involved in this study.

_____	_____	_____
Signature for GLRU / UJ	Name (Please Print)	Date
_____	_____	_____
Signature of Investigator	Name (Please Print)	Date

APPENDIX V: INFORMATION SHEET

UCT/MRC Research Unit for Exercise Science and Sports Medicine
Department of Human Biology
Division of Physiotherapy, Department of Health & Rehabilitation Sciences
Faculty of Health Sciences
University of Cape Town, South Africa

To whom it may concern

I request permission to conduct my Mphil mini-dissertation research on rugby players contracted under your authority.

Study outline

I am a Masters student at UCT, investigating central nervous system changes occurring with recurrent ankle injuries. The study aims to provide information regarding the possible central nervous system changes that may occur as a result of recurrent ankle injuries.

The study requires participants to attend two sessions. In the first session participants will be required to complete a consent form, pre-participation screening questionnaire and a Medical and Sports History Questionnaire. At the second session height, weight and skinfolds will be measured as well as four testing exercises.

1. Laterality Testing
2. Limb Perception Testing
3. Two point Discrimination Testing
4. Pressure-Pain Threshold

The two sessions will take 30 and 40 minutes respectively and will not influence the normal training requirements of the athletes. The participants will not be adversely affected by the testing procedures.

Benefits of participating in the study include

- Individual anthropometric measurements (Height, weight, BMI, body fat %)
- Feedback regarding the results of the study

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APPENDIX VI: BODY COMPOSITION MEASUREMENTS

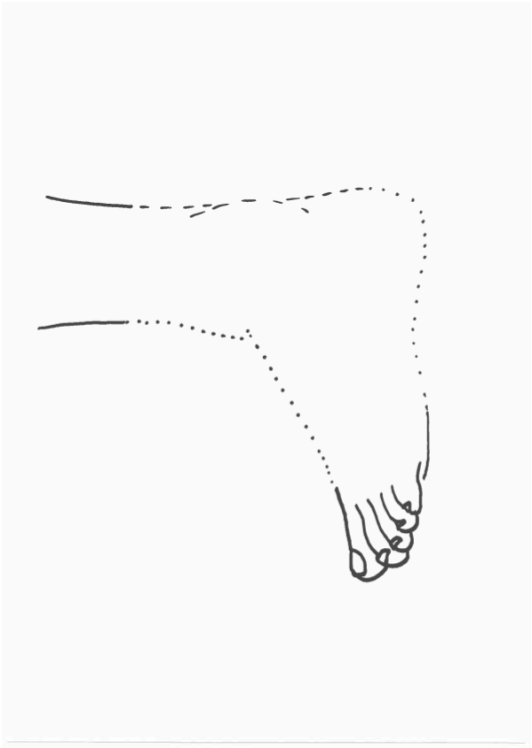
Name	
Body Mass	**Kg**
Stature	**Cm**
Body Mass Index	
Dominant Leg	

Skinfold measurements (mm)	
Triceps	
Biceps	
Sub-scapular	
Supra-iliac	
Thigh	
Calf	
Abdominal	

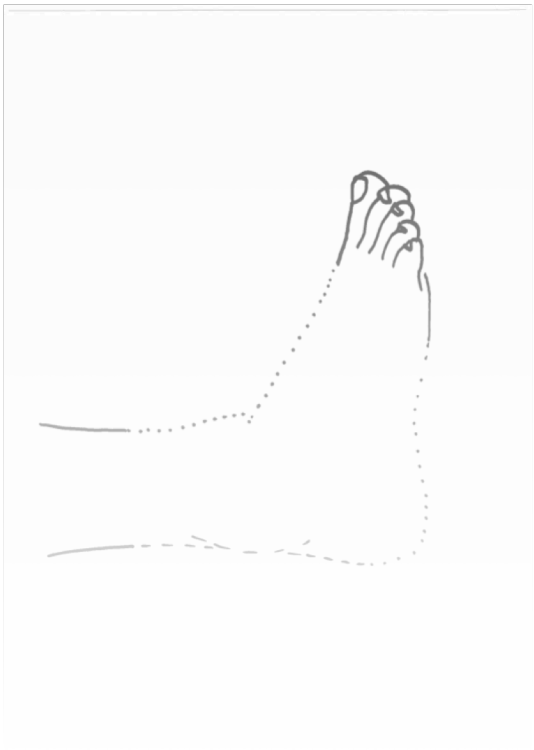
Sum of 7 skinfolds	
Lean body mass	
Predicted% body fat	

APPENDIX VII: DRAWING TEMPLATE

Left Foot



Right Foot



APPENDIX VIII: DRAWING INSTRUCTIONS

''Concentrate on your foot and ankle. Add to this drawing by following the outline of your own foot and ankle as you track it in your mind. Concentrate on where you feel your foot and ankle to be. Also draw in the bones that you can feel. Do this without touching your foot. Your drawing should relate to your own sense of your foot and ankle. Don't draw any part you can't sense. Do not draw what you think your foot looks like – draw what it feels like."