THE RELATIONSHIP BETWEEN ISOKINETIC RATIOS, FUNCTIONAL MOVEMENT SCREENING AND INJURIES IN UNIVERSITY RUGBY PLAYERS:

A RETROSPECTIVE STUDY

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DEDICATION

I would like to dedicate this research report to the memory of my late father who practically sacrificed his whole life for us to become whatever we have and will ever achieve in this world.

ABSTRACT

Background: Rugby is a full contact team sport associated with many injuries. A good understanding of the risk factors that predispose players to injury will help to predict injury adequately and hence, prevent them. Many researchers have studied various isokinetic ratios of the knee, especially the agonist/antagonist (reciprocal) ratio and the bilateral ratio. The Functional Movement Screen (FMS) is another tool that has been extensively studied in predicting injury.

Aim: The aim of this study was to determine the relationship between functional movement screen, isokinetic ratios, and injuries in university rugby players.

Methods: This study was a retrospective study. The data used in this study were from the isokinetic tests, FMS score sheets and injury reporting sheets of forty-two university rugby students from one university rugby season. Isokinetic testing was done at a speed of 60°/sec, CON/CON and INT/EXT bilaterally for the shoulder.

The peak torque (PT), peak torque to body weight (PT/BW), torque at 30°, torque at 0.16sec, bilateral deficit, agonist/antagonist ratio, fatigue ratio and the FMS were compared in players who reported injury in the season and players who did not report an injury in the season. A further multivariate binary logistic regression analysis was made to determine if a combination of the FMS and each of the isokinetic ratios could have predicted injury in the players.

Results: Out of a total of forty-two players included in this study, twenty-two (52.38%) players reported injury in the season under study. A total of twenty-nine reported the previous injury. Out of the 29 players with the previous injury, 18 (62.07%) players reported injury in the season under study while the remaining 11 (39.93%) did not report the injury in the season. Only the agonist/antagonist ratio of the knee above 55.03 (p=0.020) was significantly related to injury in the dominant leg. Other isokinetic indices and ratios were not significantly related with injury in

this study. The FMS ≤14, individually and in combination with each of the isokinetic ratios did not predict injury in this study.

Conclusion: The findings from this study showed that previous injury and agonist/antagonist ratio of the knee were significantly related to injury incidence. However, there was no significant relationship between the injury incidence and each of the FMS, bilateral deficit and fatigue ratio. There was also no significant statistical relationship between injury incidence in this study and each of the bilateral deficit, agonist/antagonist ratio and fatigue ratio when combined with the FMS.

The bilateral ratio, fatigue ratio and the FMS did not predict injury in this study. Combining the FMS with the isokinetic ratios also did not predict injury in this study. Hence, only previous injury and agonist/antagonist ratio were able to predict injury in this study.

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TABLE OF CONTENTS

DECLARATION ii
DEDICATION iii
ABSTRACT iv
ACKNOWLEDGEMENTS vi
TABLE OF CONTENTS vii
LIST OF DEFINITIONS x
ABBREVIATIONS xii
LIST OF FIGURES xiii
LIST OF TABLES xiv
1. CHAPTER ONE – INTRODUCTION 1
  1.1. Background 1
  1.2. Aim of the study 3
  1.3. Objectives of the study 3
  1.4. Motivation for study 3
2. CHAPTER TWO - LITERATURE REVIEW 4
  2.1. Introduction to chapter 4
  2.2. Epidemiology of rugby injuries 4
  2.3. Risk factors 5
    2.3.1. Age 6
    2.3.2. Previous injury 7
    2.3.3. Fatigue and Fitness 8
    2.3.4. Muscle Imbalance 9
    2.3.5. Movement Efficiency 10
  2.4. Predicting injuries in rugby 11
    2.4.1. Isokinetic Testing 11
    2.4.2. The Functional Movement Screen 14
3. CHAPTER THREE - RESEARCH DESIGN AND METHODOLOGY 17
  3.1. Study design 17
  3.2. Site of study 17
  3.3. Sampling 17
  3.4. Study population 17

3.5. Eligibility criteria 17
3.6. Outcome measures..18
3.6.1. Isokinetic Testing 18
3.6.2. Functional Movement Screening..20
3.6.3. Injury Incidence..20
3.7. Data management 21
3.8. Data analysis 21
3.9. Ethical considerations 21
4. CHAPTER FOUR - RESULTS..22
4.1. Demographic characteristics of the participants 22
4.2. Previous and current prevalence of injury 24
4.3. Isokinetic parameters..26
4.4. Relationship between isokinetic indices and limb dominance..28
4.4.1. Isokinetic Indices and Limb Dominance 28
4.4.2. Peak Torque 28
4.4.3. Peak Torque to Body Weight 29
4.4.4. Torque At 30^{o} (Nm)..30
4.4.5. Torque at 0.18 Seconds (Nm)..31
4.4.6. Bilateral Deficit (%) 31
4.4.7. Agonist/Antagonist Ratio (%) 32
4.4.8. Fatigue ratio..33
4.4.9. FMS Score..33
4.5. Relationship between isokinetic indices and the FMS and injury..34
4.5.1. Peak Torque (Nm) 34
4.5.2. Peak Torque to Body Weight (Nm) 35
4.5.3. Torque at 30^{o} (Nm) 35
4.5.4. Torque at 0.18 Seconds (Nm)..36
4.5.5. Bilateral Deficit (%) 37
4.5.6. Agonist/Antagonist Ratio (%) 38
4.5.7. Fatigue Ratio 39
4.5.8. Functional Movement Screen 39
4.6. Multivariate Binary Logistic Regression..40
5. CHAPTER FIVE – DISCUSSION 41
5.1. Introduction to chapter 41
5.2. History of injury..41

5.3. Previous Injury 41
5.4. Isokinetic indices and ratios 42
5.5. FMS...43
5.6. Prediction of injury using the FMS and isokinetic ratios..44
6. CHAPTER SIX: CONCLUSION, LIMITATIONS AND RECOMMENDATIONS...................44
6.1. Conclusion 44
6.2. Limitations and recommendations...44
REFERENCE...46
LIST OF APPENDICES 52
APPENDIX A: EXCEL SPREADSHEET FOR DATA CAPTURE 52
APPENDIX B: THE FUNCTIONAL MOVEMENT SCREEN SCORING SHEET.....................53
APPENDIX C: FMS SCORING AND MEASUREMENT...54
APPENDIX D: INJURY REPORT SHEET 58
APPENDIX E: ETHICS CLEARANCE CERTIFICATE 59
APPENDIX F: LETTER OF PERMISSION TO USE DATA..60

LIST OF DEFINITIONS

Coefficient of variance: This determines if a test is valid or not. Based on the variations between repetitions, the coefficient of variance determines how reproducible the test is[1].

Peak Torque (PT) (Nm): This is the highest output of the muscles during a repetition. It shows the maximum strength capacity of the muscle. However, it is an absolute measure of strength that does not give adequate room for comparison as it is affected by the body weight of the individual[2, 3].

Peak torque to body weight (PT/BW) (Nm): This is the peak torque normalized by bodyweight. The PT is expressed as a percentage of the body weight. As against the PT, PT/BW can be compared to an estimated benchmark. It gives more information on functional activity[2].

Torque at 30˚ (Nm): This is the torque produced at a pre-set angle of 30º in the ROM. This angle is said to be a critical point in knee stabilization[2].

Torque 0.18sec (Nm): This is the torque produced at 0.18 seconds. It represents the amount of tension developed in this time. About 80-90% of the peak torque should be achieved in this time[2].

Bilateral deficit (%): This compares the peak torque between the two limbs. It represents the deficit between the peak torques produced by the dominant and non-dominant hamstrings or quadriceps[2]. A deficit of less than 10 is considered acceptable.

The bilateral deficit (%) is calculated as = $\frac{PT\ of\ dom\ limb - PT\ of\ non{-}dom\ limb}{PT\ of\ dom\ limb}$ X 100 (Stofberg, 2015)

Agonist/antagonist ratio (H/Q ratio) (%): Also known as a reciprocal ratio. It is the ratio of reciprocal muscle groups in percentage (Peak torque produced by the hamstring group by the peak torque produced by the quadriceps group). It compares the peak torque produced by opposing muscle groups. These opposing muscle groups provide joint stability and imbalance predisposes the athlete to injury[2].

The H: Q (%) ratio is calculated as: H: Q $= \frac{PT\ (agonist)}{PT\ (antagonist)}$ X 100[3]

Fatigue ratio (%): This is a measure of how resistant the limb is to fatigue. It compares the work done in the first 1/3 against work done in the last 1/3 of the test. It was calculated by dividing the work done in the first 1/3 by the work done in the last 1/3, multiplied by 100. The closer to 1 or 100%, the more resistant the limb is to fatigue[4].

ABBREVIATIONS

β	Beta coefficient
χ	Chi-squared
º	Degree
%	Percent
Ago/antag ratio	Agonist/antagonist ratio
C.I	Confidence interval
CESSM	Centre for Exercise Science and Sports Medicine
Bil. deficit	Bilateral deficit
Dom	Dominant
E.S	Effect size
FMS	Functional movement screen
FR	Fatigue ratio
G	Gravity
H	Hamstring
H:Q	Hamstring to quadriceps ratio
J	Joules
kg	Kilogram
m	Meter
N	Total number of participants
n	Number of affected participants
Nm	Newton meters
Non-dom	Non-dominant
PT	Peak torque
PT/BW	Peak torque to body weight
p-value or sig	Level of significance
Q	Quadriceps
s or sec	Seconds
SD	Standard deviation
S.E	Standard error

LIST OF FIGURES

Figure 4.1: Flowchart showing the number of total and excluded data. 22
Figure 4.2: FMS categories (n=42)..34
Figure 4.3: Relationship between bilateral deficit and prevalence of injury................................37

LIST OF TABLES

Table 4.1: Demographic characteristics of the participants 23
Table 4.6: Mean peak torque to body weight ratio (Nm) for dominant and non-dominant quadriceps and hamstrings of both legs of 41 university rugby players (n=41). 30
Table 4.7: Mean torque at 30º (Nm) for dominant and non-dominant quadriceps and hamstrings of both legs of 41 university rugby players 30
Table 4.8: Mean torque at 0.18 seconds (Nm) for dominant and non-dominant quadriceps and hamstrings of both legs of university rugby players. 31
Table 4.9: Mean bilateral deficit (%) of the right and left dominant quadriceps and hamstrings. 32
Table 4.10: Correlation between mean bilateral ratios of the quadriceps and the hamstrings....32
Table 4.11: Mean agonist/antagonist ratio (%) for the dominant and non-dominant legs of university rugby players. 32
Table 4.12: Mean fatigue ratio (%) for dominant and non-dominant quadriceps and hamstrings of both legs. 33
Table 4.13: Mean FMS score for right and left leg dominant players. 34
Table 4.14: Relationship between mean peak torque (Nm) and injury incidence in dominant and non-dominant quadriceps and hamstrings...35
Table 4.15: Relationship between mean peak torque to body weight (Nm) and injury incidence in dominant and non-dominant quadriceps and hamstrings...35
Table 4.16: Relationship between mean torque at 30º (Nm) and injury incidence in dominant and non-dominant quadriceps and hamstrings. 36
Table 4.17: Relationship between mean torque at 0.18 seconds (Nm) and injury incidence in dominant and non-dominant quadriceps and hamstrings. 36
Table 4.18: Relationship between mean bilateral deficit (%) and injury prevalence in quadriceps and hamstrings. 37
Table 4.19: Relationship between mean agonist/antagonist ratio (%) and injury prevalence in the dominant and non-dominant lower limb. 38
Table 4.20: The relationship between categories of agonist/antagonist ratio (≤60% and >60%). 38
Table 4.21: Relationship between mean fatigue ratio (%) and injury prevalence in dominant and non-dominant quadriceps and hamstrings...39
Table 4.22: Relationship between mean FMS score and injury incidence. 39
Table 4.23: The relationship between categories of FMS (≤14 and >14). 40

Table 4.24: Multivariate binary logistic regression for injury prediction using a combination of FMS and each of the previous injury, bilateral deficit and agonist/antagonist ratio. 40

1. CHAPTER ONE – INTRODUCTION

1.1. Background

Rugby is a popular high-intensity, fast-paced and exciting contact sport played with an oval ball, which involves collision with opponents and the ground[5]. A game is played between two teams of 18 players each with minimal protective equipment worn[5]. Rugby is a sport associated with a significant number of injuries[6]. Over the years, clinicians and researchers have tried to understand the risk factors for injuries in order to be able to prevent these injuries[7].

The 'Consensus statement on injury definitions and data collection procedures for studies of injuries in Rugby Union' by the Rugby Injury Consensus Group, which was established by the International Rugby Board Medical Advisory Committee, defined injury as any discomfort leading to the inability of the body to maintain its normal structure or function as a result of an energy transfer to the body during a rugby match or during training with or without time-loss from rugby activities or whether there was a need for medical intervention or not[8]. The authors also described any injury that requires one form of treatment or the other as a 'medical attention injury' and any injury that prevents the player from partaking fully in future training or match as a 'time-loss injury'[8].

The World Health Organization (WHO) also defined 'severe functional disability' as loss of over fifty percent of the functional capability of a structure[9] and when the severe functional disability involves a brain or spinal cord injury that results in permanent impairment or lasts more than 12 months, it is known as 'non-fatal catastrophic injury' in Rugby Union[8]. Finally, when a similar injury re-occurs at the same site after the player had returned to full sporting activity following a previous injury, it is termed a 'recurrent injury'[9].

The incidence and prevalence of these injuries in sports, including rugby, have been extensively studied by different researchers[6, 7, 8, 9, 10]. Approximately 30 to 91 injuries per 1000 match hours have been reported in the Rugby Union[10]. The overall rate of sustaining injuries in youth amateur rugby players is 2.7 times higher than in football players[6] in Auckland, New Zealand, and this increases with increasing skill levels[7]. These injuries, especially muscular injuries, are the commonest causes of total or partial cessation of sporting activities[11]. It was also reported that about 70% of injuries sustained occur as a result of contact with another player[12] and a larger percentage of all injuries (30% to 55%) sustained during a match affects the lower limbs[13] and mostly occurred in the knee and thigh[7]. Recurrent injuries are severe than new injuries[5].

Several intrinsic and extrinsic risk factors have been identified to predispose rugby players to injuries[14-16]. The tackling style of the game itself is considered one of the most common causes of injury in rugby[17, 18]. Also, fatigue has been associated with increased injury rates[19]. In sub-elite rugby players, low speed and maximal aerobic power increase the risk of injury[20]. Some major risk factors that increase the risk of injury in rugby include age, previous injury, fatigue, muscle imbalance, fitness, and movement efficiency[21].

Tools such as isokinetic testing and the FMS have been widely studied by many researchers to identify risk factors that predispose athletes to injury, especially rugby players, to prevent these injuries. The Functional Movement Screen (FMS) has been used in sports to identify movement dysfunction and those at risk of musculoskeletal injuries[22, 23]. In experienced rugby players, a pre-season FMS score of ≤ 14 has been said to be associated with increased time loss due to injury compared to players with a score >14[23]. Garrison et al., (2015)[24] made some interesting observations when they combined the FMS with the previous injury to predict injury. There is a need for more studies that combine different tools to identify injury risk factors to increase the sensitivities and specificities of the tools.

1.2. Aim of the study

This study aimed to determine the relationship between the functional movement screen tool, isokinetic ratios, and injuries in university rugby players.

1.3. Objectives of the study

- To determine the relationship between preseason Isokinetic ratios and injury incidence in university rugby players.
- To determine the relationship between preseason Functional Movement Screen (FMS) scores and injury incidence in university rugby players.
- To determine the predictive value of the Functional Movement Screening (FMS) tool and isokinetic ratios on injuries in university rugby players.

1.4. Motivation for study

There is always a need to have more understanding of the factors responsible for rugby injuries. This study hoped to add to the body of knowledge and provide insights for injury prevention specific to the sport of rugby, which in-turn may reduce public health burden, optimise performance and prolong the careers of rugby players.

2. CHAPTER TWO - LITERATURE REVIEW

2.1. Introduction to chapter

This chapter provides current knowledge on the research on isokinetic ratios, functional movement screening and injuries in rugby players. The review discusses the epidemiology of sports injuries especially in rugby players, the risk factors for sports injury and predicting sports injury using the isokinetic testing and the functional movement screen.

The first part addresses what the literature says about the epidemiology of sports injuries, especially in rugby. This part also discussed the epidemiology of injuries concerning contact, during training or the match and the area of the body most affected. The prevalence of injury in rugby was also compared with that of football to give a better understanding of the magnitude of rugby injuries.

Secondly, risk factors predisposing players to injury, as seen in previous studies, are discussed in detail. These were discussed under the headings; age, previous injury, fatigue and fitness, muscle imbalance and movement efficiency. These topics will give an insight into understanding the risk factors for injuries in rugby.

Finally, the last section discusses the prediction of injury in sports, especially rugby, using isokinetic testing and the FMS. The section discussed the coefficient of variance, peak torque, peak torque to body weight, torque at 30 degrees, torque at 0.18 seconds, bilateral deficit, agonist/antagonist ratio and fatigue ratio concerning injuries. It also examines what previous studies say on the use of the functional movement screen in injury prediction.

2.2. Epidemiology of rugby injuries

Rugby is a popular contact sport associated with a significant number of injuries[6]. Over the years, clinicians and researchers have tried to understand the risk factors for injuries to be able to prevent these injuries[7]. Approximately 30 to 91 injuries per 1000 match hours have been reported in the Rugby Union[10]. Similarly, in a study on the epidemiology of adolescent rugby injuries by Bleakley et al., (2011)[25] the authors concluded that the incidence of injuries that needed medical attention was between 27.5 and 129.8 injuries per 1000 match hours[25]. Freitag et al., (2015)[26] also reported that 28% of players below 21 years of age in Rugby Union will likely sustain an injury during a season. The overall rate of sustaining injuries in youth amateur rugby players is 2.7 times higher than in football players[6]. The injury occurs more during matches than during training sessions[7] and the rate of injury also increases with increasing age[25]. These injuries are the commonest cause of total or partial cessation of sporting activities[11]. About eight percent of adolescents stop sporting activities annually as a result of injury[25]. In South Africa, the incidence of injury in professional rugby has been reported to be 55.4 injuries/1,000 player game hours and the most common injury types were ligament sprains (25.8%), and musculo-tendinous strains (24.2%)[27].

It was reported that about 70% of injuries sustained occur as a result of contact with another player[10, 12]. Thirty to fifty-five percent of all injuries sustained during a match affects the lower limbs[13] and mostly occurred in the knee and thigh[7]. A similar observation was made in a study on football players by Frisch et al., (2011)[28], where they concluded that about 87% of injuries sustained by players was in the lower limbs but in contrast to Junge et al., (2004)[6] contact only accounted for a little more than a third of the injuries reported.

2.3. Risk factors

Injuries occur from an interplay of several risk factors and events[15, 29]. Different authors have broadly classified risk factors for sports injuries as intrinsic and extrinsic factors[5, 30]. Intrinsic factors are related to the athlete while extrinsic factors are related to the environment. Intrinsic factors are further subdivided into modifiable and non-modifiable factors.

Modifiable intrinsic risk factors are those factors that can be influenced by the athlete or the team to reduce the incidence and severity of the injury. Examples include strength, flexibility, movement efficiency, muscle imbalance, fitness and fatigue[5, 14, 15, 30].

Non-modifiable intrinsic risk factors are factors related to the athlete but cannot be influenced to prevent injury or reduce its severity. Examples of non-modifiable intrinsic factors include previous injury, race, height and age[5, 14, 15, 30]. Extrinsic factors are the factors related to the environment. They include playing ground conditions and protective equipment[5, 14, 15].

Of these risk factors, the major ones associated with injury in rugby are: age, previous injury, fatigue, muscle imbalance, fitness, and movement efficiency[21]. Apart from age and previous injury, these risk factors can be measured with the use of isokinetic testing and the functional movement screen which were extensively examined in this study.

2.3.1. Age

Many studies have identified increasing age as a risk factor for injuries in rugby[5, 14, 15, 30]. Quarrie et al[30] in a prospective cohort study of injury risk factors in New Zealand Rugby Union players, which involved 258 male players, identified age as a risk factor associated with injury incidence. They observed an increased risk of sustaining injury with increasing age when compared with a reference group (≥17 years). But after correcting for confounding factors, there was no strong association between injury risk and age[30].

In a similar study by Chalmers et al., (2012) involving 704 male rugby players aged 13 years and above, they also observed an increased risk of injury with increasing age but the relationship between age and injury incidence was not consistent across the different age groups[14]. Hrysomallis, (1013)[5] suggested that the reduced injury incidence in the younger players was as a result of the seemingly protective rules, limited body contact, number of players and ground size[5].

2.3.2. Previous injury

Many authors have documented the previous injury as a significant risk factor to sustaining another injury[5, 14, 30-32], although with some inconsistencies. Previous injury is known to be associated with muscle weakness which in turn predisposes the muscle to injury[33].

According to Hrysomallis, (2013)[5], the commonest non-modifiable risk factor for injuries in Australian Rules Football was the previous injury. Players who have had a previous injury were shown to be two to three times more likely to sustain a similar injury in the next season[31]. In a similar study on football players, Kucera et al., (2005)[32] concluded that considering all injuries, football players with a history of injury had a 1.7 to 3.0 times greater risk to sustain a new injury[32].

Quarrie et al., (2001)[30] also reported injuries at the beginning of the season in Rugby Union as a significant risk factor to sustaining another injury. However, they noted that players who sustained injuries in the previous season but without an injury at the start of the current season had no increased risk of sustaining an injury which emphasizes the importance of complete rehabilitation before returning to the field[30].

In a similar study by Chalmers et al., (2012)[14] in the Rugby Union in New Zealand, they agreed with Quarrie et al., (2001)[30]. that there was no evidence of an association between a previous injury in the preceding year and injury incidence in the current season but there was a 46% higher risk of sustaining another injury during the present season in players who started the season with an injury[14].

In contrast to Quarrie et al., (2001)[30] and Chalmers et al., (2012)[14], in a study "to examine the influence of preseason fitness, existing injury and preseason rugby training on subsequent injury" by Lee et al., (2001)[34], the authors reported that there was an association between injury in a previous season and injury incidence in the current season. This is similar to what was observed by Hrysomallis[5] and Kucera et al[32].

Isokinetic testing can be used to assess muscle weakness and muscle imbalance due to the previous injury. However, there is a need to document the previous injury before isokinetic testing as the protocol might need to be adapted. For instance, the injured side becomes the 'involved' side in the presence of injury (discussed under section 3.6.1. – isokinetic testing).

2.3.3. Fatigue and Fitness

The President's Council on Physical Fitness and Sports Research described fitness as the ability to carry out tasks without "undue fatigue"[35]. Kilgore and Rippetoe, (2007)[36] also defined fitness, as "Possession of adequate levels of strength, endurance, and mobility to provide for successful participation in occupational effort, recreational pursuits, familial obligations, and that is consistent with a functional phenotypic expression of the human genotype".

Fatigue and fitness are interrelated and have been reported to be associated with the reduced capacity of the lower limbs to generate strength thereby predisposing the lower limbs to injury[11, 28]. In a study on skilled Rugby League and Australian Rules Football players, Pinniger et al., (2000)[37] reported that fatigue in the hamstrings adversely affects the function of the lower limb muscles and therefore predisposes the player to injury. Reduced 'match fitness' has also been identified as a risk factor to sustaining an injury in rugby especially early in the season[5]. Similarly, Gabbett et al., (2012)[38] suggested in a study to identify risk factors for contact injury in professional rugby league players that increased "aerobic fitness" may reduce "fatigue-related tackling injuries" by reducing the effect of lowered tackling techniques following fatigue. Some other studies have also shown that incidence of injury, both new and recurrent, is increased towards the end of the match and fatigue plays a role in these injuries[11, 15] especially in the dominant leg[11]. Gibson and Edwards, (1985)[39] defined fatigue as the inability to maintain an expected force output. Several epidemiological studies have shown that most injuries in sports occur towards the end of a match[40-44] and fatigue has been implicated in increasing the risk for these injuries[11, 40, 42, 45].

In another study on football players to determine the influence of football-specific fatigue on functional stability, Greig and Walker-Johnson, (2007)[46] observed a change in 'balance strategy' towards the late stages of a match due to fatigue and that could increase injury risk. Several other studies have shown fatigue to diminish proprioceptive sense, which leads to a compromised neurovascular control of the limb and thereby increasing the risk of sustaining injury[47-49].

However, only about 27% of premier league clubs test their players' physical capacities in order to identify any potential risk of sustaining an injury despite the high association of fatigue and fitness with injury incidence[21]. Testing for how resistant a muscle group is to fatigue can be done objectively using the isokinetic fatigue ratio. This compares the work done by a muscle group in the last third of the test and the work done in the first third of the test. Players identified to have reduced resistance to fatigue can thus be rehabilitated to increase their fitness level and thus prevent injury.

2.3.4. Muscle Imbalance

Although muscle imbalance has been identified as an important risk factor for injury in sports[21, 50] and also noted as a major factor in re-injury especially in rugby[51], not many studies have been done on a muscle imbalance in rugby players.

In a prospective study on hamstring injuries in a cohort of sprinters, Yeung et al., (2009) concluded that an imbalance in the quadriceps of sprinters caused by a weakness of up to 0.6 in the peak torque on isokinetic dynamometry at 180º/s is associated with an increased risk of hamstring injury in the weaker hamstring by up to 17 times[52]. In a similar study on football players, Croisier et al., (2008)[50] stated an increased risk of 4 to 6 times in players with muscle imbalance more than those with no imbalance.

In contrast, Bennell et al., (1998)[53] reported in a study on prediction of injuries in 102 Australian Rules Football players using isokinetic testing that deficits in muscle strength as seen on isokinetic testing was not able to predict injury. Viable and reliable ways to measure muscle strength and muscle imbalance include the functional movement screen[54] or isokinetic dynamometry[50]. These are further discussed in later sections of this write-up.

2.3.5. Movement Efficiency

Some athletes participating at high sporting levels have been observed to perform poorly when assessed with simple functional tests. This is because they tend to compensate for the deficiencies in their movement with other muscles or movement leading to reinforcement of poor and inefficient movement patterns. The resultant poor biomechanics predispose the athletes to traumatic injury[55]. A deficiency in movement can be identified with the FMS. Players who have scored ≤14 either by showing complete inability to perform certain tasks or compensating for their deficiency with other muscles have been shown to be predisposed to injury than players who have scored >14[55]. The deficiencies identified should be treated to avoid injuries.

Rosene et al., (2001)[56] described a healthy knee as one with a hamstring to quadriceps (H: Q) or agonist/antagonist ratio between 50% and 80%. Using the functional H: Q ratio (eccentric hamstrings to concentric quadriceps ratio), they explained that the low H: Q ratio may reflect the reduced ability of the hamstring to provide adequate functional stability to the knee while an H: Q ratio that approaches 100% reflects increased ability of the hamstring to provide functional stability to the knee. The stability of the knee reduces the possibility of a knee injury. An H: Q ratio measured at 60 º/s (1.05 rad*s-1) of 60% or less should be treated and rehabilitated to avoid injuries[56].

2.4. Predicting injuries in rugby

To adequately predict injuries in sports, especially rugby, researchers have employed the use of different tools, which include questionnaires, isokinetic testing[47-49] and functional movement screen[24, 57, 58]. This study attempted to further add to such tools by evaluating the effectiveness of the isokinetic ratios and other isokinetic indices and the functional movement screen in predicting injuries in university rugby players.

2.4.1. Isokinetic Testing

Isokinetic movement can be defined as a "movement that occurs at a constant angular velocity with accommodating resistance"[59]. Irrespective of the amount of effort exerted, movement occurs at the same speed throughout the range of motion (ROM).

Isokinetic testing is done with the use of devices called isokinetic dynamometers. These devices provide a resistance that accommodates the torque applied by an individual in order to maintain a constant, preselected angular velocity[3, 60]. Examples of commercially available dynamometers used for testing and training include Biodex Systems 3™, Kin-Kom™ and Cybex NORM™[3].

With isokinetic dynamometers, it is possible to achieve maximal muscle resistance throughout the ROM. It also allows for controlling the stress to muscles, which prevents aggravation of injuries to a healing muscle. Specific muscle groups can be tested or trained separately and results of testing are measurable and reproducible with instant visual feedback which enables adequate monitoring of progress[1, 3, 60]. Isokinetic strength profiles and ratios have been used by many researchers to predict injuries in sports[11, 21, 50, 53, 61, 62]. The agonist/antagonist (H/Q) ratio is the most studied isokinetic parameter used to identify the possible risk of sustaining an injury[63, 64].

Isokinetic parameters and ratios used in this study include thus studies describing these parameters are discussed below:

- Peak torque
- Peak torque to body weight
- Torque at 30^{o}
- Torque at 0.18 seconds
- Bilateral deficit
- Agonist/antagonist ratio
- Fatigue ratio

Many researchers have extensively employed the use of isokinetic testing, especially the strength profile and H/Q ratio in identifying players at risk of injury. Studies on the fatigue ratio in rugby players are very few.

In a study to profile the isokinetic strength by leg preference and position of thirty male academy Rugby Union athletes, Brown et al., (2016)[65] concluded that the strength produced by the dominant lower limb is greater than the strength produced by the non-dominant leg. The authors also observed that the players playing in the forward positions produced more strength than the players playing in the back[65].

Orchard et al., (1997)[61] observed that hamstring injuries recorded in Australian Rules Football players were sustained in limbs that had weaker preseason isokinetic indices (both absolute values and hamstring to quadriceps muscle ratio) irrespective of the limb dominance. The peak torque (injured: 1.75 ± 0.2, uninjured: 2.08 ± 0.31, p-value 0.011), the bilateral ratio (injured: 0.880 ± 0.072, uninjured: 1.005 ± 0.103, p-value 0.005) and the reciprocal ratio (injured: 0.550 ± 0.065, uninjured: 0.662 ± 0.071, p-value 0.000) were all significantly lower in the injured limbs at the preseason isokinetic testing at 60 º/sec, although the bilateral and the reciprocal ratios were more predictive of injury[61].

In another study on hamstring injuries in intercollegiate American Football players, Heiser et al., (1984)[66] concluded that a reciprocal ratio of <0.61 at 60 º/sec and a bilateral ratio of >0.92 at 60 º/sec are associated with significantly increased risk of sustaining a hamstring injury. Yeung et al., (2009)[52] observed a 17 times increased risk of sustaining the injury in forty-four sprinters with a preseason conventional hamstring to quadriceps ratio of less than 0.6 (H: Q < 0.6) at 180 º/sec (p=0.03, HR 17.4, 95% CI 1.31 to 231.4). The authors found no significant difference in the peak torque between the injured and non-injured groups[52].

Croisier et al., (2008)[50], in a study on strength imbalances and prevention of hamstring injury in professional football players, measured the preseason bilateral ratio and agonist/antagonist ratio. Out of the 462 players that were followed up for 9 months, 216 players had preseason muscle imbalance. The frequency of injuries in these players reduced as they received one form of intervention or the other. Out of 91 players who had no intervention for the imbalance, 15 (16.5%) reported injury during the season. On the other hand, out of 70 players who had preseason imbalance but had compensating training until resolution of the isokinetic parameters, only 4 (5.7%) players reported injury. The authors concluded that preseason strength imbalances detected on isokinetic assessment was a risk factor of hamstring injury in football players and restoration of normal strength profiles was associated with reversal of this risk[50].

Aginsky et al., (2014)[4] reported a higher ‘mean relative fatigue ratio’ in the quadriceps of both the dominant and non-dominant (dom: 76.2 ± 6.4, non-dom: 79.3 ± 7.8) for concentric muscle contractions when compared to that of the hamstrings (dom: 70.0 ± 8.8, non-dom: 71.0 ± 13.0) in South African elite football players. This means that the hamstring group is less resistant to fatigue than the quadriceps and this can predispose the players to injury[4].

In summary, the isokinetic strength profiles and ratios, especially the bilateral and agonist/antagonist ratios, have been widely studied and have been shown to predict injury in rugby players.

2.4.2. The Functional Movement Screen

The functional movement screen (FMS) is a screening tool designed by Cook and his colleagues in 1997 in order to assist clinicians with screening for injury risk and "performance-limiting movement patterns" based on principles of proprioception and kinesiology[58]. They described the FMS as a tool, which aims to detect movement and stability imbalances using seven fundamental movement patterns by placing an individual in extreme positions where deficiencies in balance and strength are noticeable due to the absence of appropriate motor control.

In a reliability study on the functional movement screen, Teyhen et al., (2012)[67] demonstrated a moderate to good intra-rater and inter-rater reliability of the functional movement screen among novice raters after a 4-hour training session. Other studies have also shown moderate to excellent inter-rater and intra-rater reliability with regards to the FMS[68-70].

In a study to predict severe injuries in professional Rugby Union players, Tee et al., (2016)[57] observed a significant relationship between a low FMS score and both contact and non-contact injuries. Between the injured (all injuries) and non-injured groups, the composite FMS scores showed significant difference (injured 13.2 ± 1.7 vs. non-injured 14.5 ± 1.5, ES = 0.83, large).

Specifically for contact injuries, there was also a significant difference in the composite FMS scores between the severely injured and non-injured groups (injured 13.1 ± 2.0 vs. non-injured 14.3 ± 1.5, ES = 0.76, medium). The severe injury was defined as the exclusion of an injured player from matches or practice for 28 days or more. For non-contact injuries, despite a p-value of 0.06, a decision to proceed as if there was a 'meaningful difference' between the composite FMS scores between the injured and the non-injured groups was made after considering the closeness of the p-value to significance, similar test values and effect size (ES = medium) as with contact injuries[57].

In a study on male and female Rugby Union players, Armstrong and Greig, (2018)[22] also concluded that FMS can be used to predict injury in both male and female players (p=0.01), even though the individual components of the FMS are more reliable in predicting injuries than the composite FMS scores. However, the cut-off used in this study was 11.5 for both males and females[22].

Kiesel et al., (2007)[71] observed in a study done on professional football players that "dysfunctional basic movement patterns" in players as evidenced by a total FMS score of 14 or less was predictive of serious injury with a sensitivity of 54% and a specificity of 91%[71]. This means that according to Kiesel et al, almost half of the players at risk of sustaining an injury would be missed by employing the use of only the FMS.

In another study on the association between the FMS and injury development in college students, Garrison et al., (2015)[24] observed that after combining the composite FMS score of ≤ 14 with a history of the previous injury, the sensitivity of the FMS in predicting an injury, which required medical attention reduced from 67% to 65% while the specificity increased from 73% to 89%. However, for players who scored 14 or less on the FMS, the odd ratio of 5.61 (2.73, 11.51) demonstrates they are 5 times more likely to sustain injuries than those with an FMS score above 14. The odds ratio increased to 15.11 (6.60, 34.61) when the FMS score was combined with a history of the previous injury. This means that players who scored ≤14 on the FMS with a history of the previous injury are 15 times more likely to sustain injury than those with higher FMS scores and without a history of previous injury[24]. However, this study included males and females of different sports.

With a lower cut-off of 11.5, Armstrong and Greig, (2018)[22] demonstrated a sensitivity and specificity of 0.89 and 0.92 irrespective of the gender of the Rugby Union players. Specifically, the sensitivity and specificity of the FMS at 11.5 for male Rugby Union players were 0.88 and 1.00 respectively and they were 0.90 and 0.86 for the female Rugby Union players respectively[22]. The sensitivity and specificity were much lower when the cut-off of the FMS was set at 14.

With a relatively low sensitivity of 54% and a specificity of 91% of the FMS[71], this means about half of the players who would eventually sustain an injury would have been missed by the FMS alone. Similarly, Bennell et al., (1998)[53] also concluded that when isokinetic testing is used alone, it is not very reliable in predicting injury. Pinto et al., (2018)[62] demonstrated this in the study on the conventional H/Q ratios of 35 professional football players who had isokinetic testing using Cybex Norm dynamometer. The H/Q ratios measured when not fatigued were significantly lower than the H/Q ratios measured in a fatigued state (fatigued H/Q ratio: 1.25-1.38, non-fatigued H/Q ratio 0.70, $P<.01$)[62]. They concluded that more information can be obtained from measuring the H/Q ratio in a fatigued state and may have more potential to adequately predict injury[62].

In summary, the FMS is a validated and reliable tool used to predict injury in rugby players and a score of ≤14 has been shown to be associated with injury by previous researchers. It has also been shown that sensitivity and the specificity of the FMS can be influenced when combined with other injury prediction tools.

3. CHAPTER THREE - RESEARCH DESIGN AND METHODOLOGY

3.1. Study design

This is a retrospective study of the records of injuries sustained by university rugby players during one season (2016), and the preseason functional movement screen and isokinetic testing taken before the commencement of the rugby season.

3.2. Site of study

The data for the functional movement screen and the isokinetic ratios were collected at the Centre for Exercise Science and Sports Medicine (CESSM), University of Witwatersrand, Johannesburg, South Africa before the start of a rugby season. The players were then followed throughout the season and injuries sustained were recorded. The retrospective analysis of the data was done at the Centre for Exercise Science and Sports Medicine, University of Witwatersrand, Johannesburg, South Africa.

3.3. Sampling

All 46 players that registered to play during the university rugby season were screened as requested by Wits Sport, with the FMS and isokinetic testing prior to the commencement of the competition, 42 players were eventually included in the study while four were excluded due to incomplete data.

3.4. Study population

The study population was the rugby players of the University of the Witwatersrand who participated in one university rugby season.

3.5. Eligibility criteria

Inclusion Criteria

- Rugby players of the University of the Witwatersrand who participated in the 2016 university rugby season and whose data were collected by CESSM.

Exclusion Criteria

- Incomplete FMS score sheets (<90% filled)

- Isokinetic dynamometry results with a coefficient of variance >15

3.6. Outcome measures

The researcher collated all of the below information into an excel spreadsheet (Appendix A)

The outcome measures and how they were obtained by previous researchers are presented below.

3.6.1. Isokinetic Testing

Prior to the commencement of the rugby season, isokinetic testing was done on the players at the Centre for Exercise Science and Sports Medicine, University of the Witwatersrand. The isokinetic testing of 15 reps was done at a speed of 60^{o}/sec, CON/CON and INT/EXT bilaterally for the knee.

The researcher extracted the isokinetic indices and ratios from the Biodex dynamometer isokinetic testing result into a spreadsheet (Appendix A). All tests for the various muscle groups had coefficients of variance less than 15 which invariably validates the tests[1, 2]. The dominant leg was extracted from the FMS score sheet. This coincided with the 'uninvolved' leg on the isokinetic recording for players who had no injury or those who reported injury in both legs prior to testing. For those who reported injury in either leg, the 'involved' leg was the injured leg which may or may not be the same as the dominant leg recorded on the FMS score sheet.

The following parameters were included in this study:

a. ***Coefficient of variance***

A value ≤15 is generally acceptable for large muscle groups such as the knee (as used in this study) while a value ≤20 is the acceptable limit for small muscle groups such as the muscles in the hand (Dvir, 2004). All the data used in this study had a coefficient of variance < 15. No data set was excluded on the basis of the coefficient of variance.

b. Peak Torque (PT) (Nm):

The maximum strength produced by the muscle groups (dominant and non-dominant quadriceps and hamstrings) were recorded by the isokinetic dynamometer.

c. Peak torque to body weight (PT/BW) (Nm):

The PT was also automatically normalized by the body weight and presented as the PT/BW by isokinetic dynamometer.

d. Torque at 30º (Nm):

At a pre-set angle of 30º on the dynamometer, the torque produced by the muscle groups at this angle were presented by the dynamometer in Nm.

e. Torque 0.18sec (Nm):

The amount of force generated by the muscle groups at 0.18 seconds was also recorded by the dynamometer in Nm.

f. Bilateral deficit (%):

The dynamometer automatically generated the deficit in the peak torque produced by the muscle groups between dominant and non-dominant limbs.

The peak torque produced by the dominant leg is normally expected to be greater than that produced by the non-dominant leg and a deficit of less than 10% is generally acceptable as higher figures indicate imbalance and may pose a risk to injury[2, 72].

g. Agonist/antagonist ratio (H/Q ratio) (%):

The ratio of the agonist (hamstring) to the antagonist (quadriceps) was electronically generated by the dynamometer from the peak torques of the respective muscle groups and presented in percentages. Generally, a value of the H/Q ratio greater than 60% or 0.6 causes muscle imbalance and this is associated with increased risk of injury as the opposing muscles are responsible for joint stability[2]. Corrections for gravity (G) was done electronically by the dynamometer.

h. Fatigue ratio (%):

To examine fatigue of the knee flexor and extensor muscles, the fatigue ratio was calculated from the work done in the first third (work first third (J)) of the total work and the last third (work last third (J)) of total work as recorded by the isokinetic dynamometer. The researcher calculated the fatigue ratio as follows:

Fatigue ratio (%) = $\frac{work\ first\ third\ (J)}{work\ last\ third\ (J)}$ X 100

3.6.2. Functional Movement Screening

The functional movement screening for this study was performed by an experienced exercise scientist, who carried out the protocol according to the manual, on all participants prior to commencement of the season. The age (years), position played, mass(kg), height (m) and dominant legs were recorded, and they were given clear instructions on how to perform the FMS-specific motions. The scores of the FMS were entered on the FMS score sheet (Appendix B). The FMS was scored as explained in Appendix C.

The researcher captured retrospective results from the FMS score sheets into an excel spreadsheet (Appendix A).

3.6.3. Injury Incidence

Injuries were recorded on the injury report sheet (Appendix D) as reported throughout the season. This included the age, position played by the player, the date the injury was reported, the area of the body injured, type of injury, history of similar injury in the past, cause of injury, time of the match when the injury was sustained and if an injury occurred with contact or not.

The researcher captured the retrospective injury data into the excel spreadsheet (Appendix A).

3.7. Data management

The researcher extracted the above retrospective data from the Biodex dynamometer result sheets, the FMS score sheets, and the injury report sheets and entered them into an excel spreadsheet (Appendix A). The fatigue ratio was manually calculated as above from the work first third and work last third as shown above. Categories were created for the FMS (≤14 and >14), bilateral deficit (≤10 and >10), and the agonist/antagonist ratio (≤60 and >60) as categorized in previous studies.

3.8. Data analysis

Data were summarized and presented using the Statistica (V13) statistical tool. For continuous variables, the distribution of the data was determined by using the Shapiro-Wilk test, parametric statistics of mean and standard deviation and non – parametric statistics of the median and interquartile range were used to describe the population. Categorical variables were summarized using percentages and frequencies. Inferential statistics of the Chi-squared test were used to determine the relationship between the outcome of the functional movement screen and the occurrence of injury. Also, the Chi-squared test was used to determine the relationship between the preseason isokinetic ratios and the occurrence of injury. A level of five percent was accepted as significant (Confidence interval of 95%).

3.9. Ethical considerations

Ethical clearance (certificate number: M190990) for this study was granted by the University of the Witwatersrand Human Research Ethics Committee (Appendix E). Permission to use the data was granted by the custodian, the Director of the Centre for Exercise Science and Sports Medicine (Appendix F).

4. CHAPTER FOUR - RESULTS

This chapter presented the result of this study. This includes the demographic characteristics of the participants, prevalence of injury, isokinetic parameters and relationship between the isokinetic indices and limb dominance.

Furthermore, the various isokinetic indices and the FMS were presented in relation to injury. And this was followed by a multivariate binary logistic regression between the various isokinetic ratios, the FMS and injuries was done.

A total of 46 sets of data were made available to the researcher by the CESSM. Four (4) were eventually excluded due to incomplete data (missing isokinetic test or missing FMS) as per exclusion criteria rules. The remaining 42 sets (n) of data were included in this study (Figure 4.1).

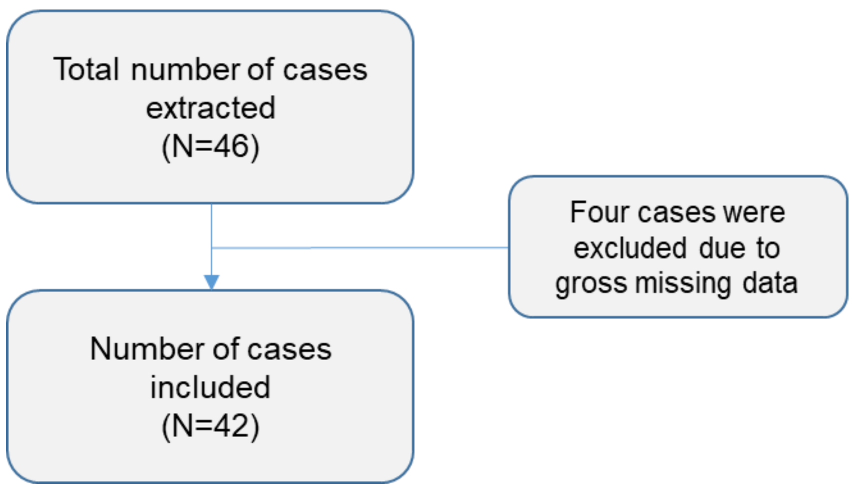

Figure 4.1: Flowchart showing the number of total and excluded data.

4.1. Demographic characteristics of the participants

The demographic distribution of the present study is presented in Table 4.1. Data from forty-two university rugby players were used in this study. The mean age of the players was 21 ± 2 years and the mean weight was 96.65 ± 18.93 kg. Players that were right leg dominant were 31

(75.61%) while 10 (24.39%) were left leg dominant. One player did not report any dominant leg. Of the various positions represented, tight five had the highest frequency (6) while backline had the least (1) (Table 4.1).

Table 4.1: Demographic characteristics of the participants

Age, Mean (SD) in years	21(2)
Weight, Mean (SD) in Kg	96.65(18.93)
Leg dominance	**n(%)**
Right	31(75.61)
Left	10(24.39)
Position	**n(%)**
Full back	3(7.14)
Inside back	4(9.52)
Loose forward	4(9.52)
Tight five	6(14.29)
Backline	1(2.38)
Flank	2(4.76)
Prop	2(4.76)
Eightman	3(7.14)
Wing	3(7.14)
Lock	3(7.14)
Centre	2(4.76)
Flyhalf	3(7.14)
Outside back	2(4.76)
Scrumhalf	3(7.14)
Not reported	1(2.38)

4.2. The previous and current prevalence of injury

A total of 29 (69.05%) players reported previous injuries before the commencement of the season under study. Eighteen (62.07%) players out of the 29 with the previous injury later reported injury in the season under study while the remaining 11 (37.93%) players did not report an injury in the season under study. A total of 22 (52.38%) players reported injuries during the season including training periods and during matches. Out of these 22 players, 18 (81.82%) players had a history of the previous injury, while 4 (18.18%) other players had no history of a previous injury (Table 4.2).

Among the injuries reported during the season, injuries in the left ankle, left knee and right ankle were reported by 4 (18.18%) players each. Five (22.73%) players reported injury in the right thigh. 1 (4.55%) player each reported an injury in the left foot, left hip and groin or right leg. Two (9.09%) players reported injuries in the right knee. Eight (36.36%) injuries were sustained after contact while fourteen (63.64%) were sustained without contact. Half of the injuries were reported to have been caused by overuse while the other half was due to trauma. The injury was reported in the non-dominant leg by 15 (68.18%) players while 6 (27.27%) players reported injury in the dominant leg. Among the players who reported injury during this season (n=22), 14 (63.64%) reported injury once while 8 (36.36%) reported similar injury twice (Table 4.2).

Table 4.2: **Prevalence and causes of injuries and areas of injuries in 42 university rugby players.**

Injury profile (n=42)	**Number of rugby players (n)**	**Percentage of rugby players (%)**
History of previous injury	29	69.05
History of previous injury with new injury	18	62.07
History of previous injury without new injury	11	37.93
New injury reported	22	52.38
New injury with no previous injury	4	18.18
Area of injury (n=22)		
Left ankle	4	18.18
Left foot	1	4.55
Left hip and groin	1	4.55
Left knee	4	18.18
Right thigh	5	22.73
Right ankle	4	18.18
Right knee	2	9.09
Right leg	1	4.55
Leg dominance		
Dominant	15	68.18
Non-dominant	6	27.27
Contact/ no contact		
Contact	8	36.36
No contact	14	63.64
Cause		
Overuse	11	50.00
Trauma	11	50.00
Match/Training		
Match	7	31.82
Training	15	68.18
Recurrence		
Once	14	63.64
Twice	8	36.36

4.3. Isokinetic parameters

The minimum, maximum, mean and standard deviation of the isokinetic indices obtained from the isokinetic tests as well as the functional movement screen results for the group are presented in Table 4.3. Some players recorded zero torque at 30 degrees for the dominant and non-dominant quadriceps and hamstrings. While very little difference was observed in the mean values of the isokinetic indices of both the dominant and non-dominant muscle groups (quadriceps and hamstrings), the mean torque at 30° of both the dominant and non-dominant quadriceps was the same (124.88Nm). The mean of the bilateral deficit for both the quadriceps and hamstrings were below 10%, (Quadriceps=6.97, Hamstrings=8.35), although some players had much higher absolute deficits. Similarly, the mean agonist/antagonist ratios for both the dominant and non-dominant limbs were below 60% (Dom=50.93%, Non-dom=49.92%), although some individual players had much higher values. The minimum FMS score in this study was 11 and the maximum was 19. The mean score was 15.29.

Table 4.3: **Mean isokinetic parameter values and functional movement screen scores of 42 university rugby players.**

Variables	Minimum	Maximum	Mean (SD)
PT Q Dom (Nm)	147.80	401.00	286.04 (49.66)
PT Q Non-Dom (Nm)	141.70	403.50	281.75 (52.65)
PT H Dom (Nm)	91.70	202.40	144.16 (23.69)
PT H Non-Dom (Nm)	79.30	173.40	138.46 (21.26)
PT/BW Dom (Nm)	169.90	419.90	300.81 (49.49)
PT/BW Non-Dom (Nm)	162.30	522.40	297.30 (60.80)
PT/BW H Dom (Nm)	68.80	192.20	151.94 (22.91)
PT/BW H Non-Dom (Nm)	81.50	183.70	145.14 (20.00)
Torque at 30^{o} Q Dom (Nm)	0.00	204.60	124.88 (40.30)
Torque at 30^{o} Q Non-Dom (Nm)	0.00	212.50	124.48 (42.42)
Torque at 30^{o} H Dom (Nm)	0.00	199.50	122.53 (37.06)
Torque at 30^{o} H Non-Dom (Nm)	0.00	161.70	113.70 (36.89)
Torque at 0.18s Q Dom (Nm)	110.00	314.60	219.28 (40.73)
Torque at 0.18s Q Non-Dom (Nm)	141.50	317.10	216.28 (41.42)
Torque at 0.18s H Dom (Nm)	64.40	192.90	126.79 (29.81)
Torque at 0.18s H Non-Dom (Nm)	74.00	158.70	122.48 (21.74)
Bilateral deficit Q (%)	0.60	17.20	6.97 (4.70)
Bilateral deficit H (%)	0.30	19.60	8.35 (5.49)
Ago/Antag Dom (%)	40.20	67.00	50.93 (6.55)
Ago/Antag Non-Dom (%)	31.70	71.20	49.92 (7.20)
FR Dom Q (%)	71	117	90 (10)
FR Non-Dom Q (%)	73	127	90 (12)
FR Dom H (%)	59	113	83 (11)
FR Non-Dom H (%)	70	96	82 (06)
FMS score	11.00	19.00	15.29 (1.72)

PT=Peak Torque; Dom=Dominant; Non-Dom=Non-Dominant; PT/BW=Peak Torque to Body Weight; Q=Quadriceps; H=Hamstring; Ago/Antag=Agonist/Antagonist ratio; FR=Fatigue Ratio; SD=Standard Deviation.

4.4. Relationship between isokinetic indices and limb dominance

4.4.1. Isokinetic Indices and Limb Dominance

Even though there were differences in the absolute mean values of the various isokinetic parameters examined in this study between the dominant and non-dominant muscle groups, none of these differences were significant ($p>0.05$) (Table 4.4).

Table 4.4: Mean isokinetic parameter values and limb dominance of 41 university rugby players

Isokinetic parameters	Mean ± SD		P-value
	Dominance	**Non-Dominance**	
PT Q (Nm)	286.04 ± 49.66	281.75 ± 52.65	0.702
PT H (Nm)	144.16 ± 23.69	138.45 ± 21.26	0.249
PT/BW (Nm)	300.81 ± 49.49	297.30 ± 60.80	0.772
PT/BW H (Nm)	151.94 ± 22.91	145.14 ± 20.00	0.151
Torque at 30^{o} Q (Nm)	124.88 ± 40.30	124.48 ± 42.42	0.965
Torque at 30^{o} H (Nm)	122.53 ± 37.06	113.70 ± 36.89	0.277
Torque at 0.18sec Q (Nm)	219.28 ± 40.73	216.28 ± 41.42	0.739
Torque at 0.18sec H (Nm)	126.79 ± 29.81	122.48 ± 21.74	0.451
Ago/antag ratio (%)	50.93 ± 6.55	49.92 ± 7.20	0.504
FR Q (%)	90 ± 10	90 ± 12	0.920
FR H (%)	83 ± 11	82 ± 06	0.648

PT=Peak Torque; Dom=Dominant; Non-Dom=Non-Dominant; PT/BW=Peak Torque to Body Weight; Q=Quadricep; H=Hamstring; Ago/Antag=Agonist/Antagonist ratio; FR=Fatigue Ratio; SD=Standard Deviation. $P<0.05$=significant

4.4.2. Peak Torque

On further analysis of the study sample, 31 players were right leg dominant while 10 were left leg dominant. The result shows symmetry in the peak torque produced by both the dominant and non-dominant quadriceps (dominant: $p=0.709$, non-dominant: $p=0.318$) and dominant and non-dominant hamstrings (dominant: p=0.322, non-dominant: p=0.864) for both the right leg and left leg dominant players (Table 4.5).

Table 4.5: Mean peak torque (Nm) for dominant and non-dominant quadriceps and hamstrings for both legs of 41 university rugby players.

Muscle group	Peak torque (Nm)		p-value
	Right (n=31) Mean ±SD	Left (n=10) Mean ±SD	
Quadriceps (Dominant), Nm	289.66 ± 51.94	282.94 ± 38.09	0.709
Quadriceps (Non-Dominant), Nm	278.71 ± 50.37	297.92 ± 57.82	0.318
Hamstrings (Dominant), Nm	147.33 ± 23.95	139.01 ± 18.38	0.322
Hamstrings (Non-Dominant), Nm	139.70 ± 21.16	138.39 ± 20.05	0.864

4.4.3. Peak Torque to Body Weight

There was symmetry in the peak torque to body-weight of both the dominant and non-dominant quadriceps (dominant: p=0.093, non-dominant: p=0.058) irrespective of whether it is right dominance or left dominance even though the PT/BW of the non-dominant quadriceps strongly tends towards significance (p=0.058). Similarly. There was no significant difference between the peak torque to body-weight of the dominant hamstrings of the right and left dominant players (p=0.409). However, the peak torque to body weight produced by the non-dominant hamstrings of the left dominant players was 10.6% more than the peak torque to body weight produced by the non-dominant hamstrings of the right dominant players (p=0.025) (Table 4.6). Hence, the peak torque to body weight (Nm) produced by the hamstrings and quadriceps of the non-dominant legs of players with left leg dominance tends to be significantly greater than the peak to body weight (Nm) produced by the hamstrings and quadriceps of the non-dominant legs of the right dominant players respectively (Table 4.6).

Table 4.2: Mean peak torque to body weight ratio (Nm) for dominant and non-dominant quadriceps and hamstrings for both legs of 41 university rugby players.

Muscle group	Peak torque to Body weight (Nm)		p-value
	Right (n=31) Mean ±SD	Left (n=10) Mean ±SD	
Quadriceps (Dominant), Nm	296.21 ± 42.88	325.22 ± 56.15	0.093
Quadriceps (Non-Dominant), Nm	285.38 ± 43.70	343.08 ± 82.37	0.058
Hamstrings (Dominant), Nm	151.74 ± 23.06	158.24 ± 14.67	0.409
Hamstrings (Non-Dominant), Nm	142.60 ± 17.67	157.71 ± 18.35	0.025*

*p=<0.05

4.4.4. Torque At 30^o (Nm)

There was no significant difference between the torques produced at 30^o by both the dominant and non-dominant quadriceps (dominant: p=0.082, non-dominant: p=0.249) and dominant and non-dominant hamstrings (dominant: p=0.247, non-dominant: p=0.552) irrespective of whether it is right or left dominance (Table 4.7).

Table 4.3: Mean torque at 30^o (Nm) for dominant and non-dominant quadriceps and hamstrings for both legs of 41 university rugby players

Muscle group	Torque at 30^o (Nm)		p-value
	Right (n=31) Mean ±SD	Left (n=10) Mean ±SD	
Quadriceps (Dominant), Nm	131.94 ± 39.60	106.34 ± 38.63	0.082
Quadriceps (Non-Dominant), Nm	129.32 ± 42.28	111.16 ± 43.90	0.249
Hamstrings (Dominant), Nm	127.61 ± 38.65	112.08 ± 27.46	0.247
Hamstrings (Non-Dominant), Nm	116.58 ± 37.70	108.47 ± 35.37	0.552

4.4.5. Torque at 0.18 Seconds (Nm)

There was no significant difference between the torques produced at 0.18 seconds by both the dominant and non-dominant quadriceps (dominant: p=0.705, non-dominant: p=0.602) and the dominant and non-dominant hamstrings (dominant: p=0.321, non-dominant: p=0.478) irrespective of whether it is right or left dominance (Table 4.8).

Table 4.4: Mean torque at 0.18 seconds (Nm) for dominant and non-dominant quadriceps and hamstrings of both legs of 41 university rugby players.

Muscle group	**Torque at 18 seconds (Nm)**		**p-value**
	Right (n=31) **Mean ±SD**	**Left (n=10)** **Mean ±SD**	
Quadriceps (Dominant), Nm	221.44 ± 43.50	215.69 ± 33.35	0.705
Quadriceps (Non-Dominant), Nm	215.24 ± 40.92	223.25 ± 44.93	0.602
Hamstrings (Dominant), Nm	130.75 ± 30.91	120.25 ± 19.88	0.321
Hamstrings (Non-Dominant), Nm	124.98 ± 22.25	119.58 ± 14.49	0.478

4.4.6. Bilateral Deficit (%)

This study showed no significant difference in the mean bilateral deficit of right and left dominant quadriceps (p=0.87) and hamstrings (p=0.85) (Table 4.9). Although the correlation test of the bilateral deficit between the quadriceps and hamstrings showed a negative correlation (-0.140), this observation was not significant (p=0.377) (Table 4.10).

Table 4.5: Mean bilateral deficit (%) of the right and left dominant quadriceps and hamstrings of 41 university rugby players.

Muscle group	Bilateral deficit (%)		p-value
	Right (n=31) **Mean ±SD**	**Left (n=10)** **Mean ±SD**	
Quadriceps, %	6.54 ± 4.62	8.54 ± 5.06	0.870
Hamstrings, %	8.00 ± 5.53	9.97 ± 5.37	0.850

Table 4.6: Correlation between mean bilateral ratios of the quadriceps and the hamstrings of 41 university rugby players.

Muscle group	Mean (SD)	Correlation	P-value
Quadriceps, %	6.97 (4.70)	-0.140	0.377
Hamstrings, %	8.35 (5.49)		

4.4.7. Agonist/Antagonist Ratio (%)

There was no significant difference in the mean agonist/antagonist ratio (%) of players who were right dominant (51.5 ± 6.71%) and those who were left dominant (49.5 ± 6.37%) (p=0.21). Similarly, there was also no significant difference in the mean agonist/antagonist ratio of the right (50.83 ± 6.97%) and left (50.83 ± 6.97%) non-dominant legs (p=0.10) (Table 4.11).

Table 4.7: Mean agonist/antagonist ratio (%) for the dominant and non-dominant legs of 41 university rugby players.

Muscle group	Agonist/Antagonist ratio (%)		p-value
	Right (n=31) **Mean ±SD**	**Left (n=10)** **Mean ±SD**	
Dominant, %	51.5 ± 6.71	49.5 ± 6.37	0.210
Non-Dominant, %	50.83 ± 6.97	47.42 ± 7.27	0.100

4.4.8. Fatigue ratio

In absolute values, the hamstrings showed lesser resistance to fatigue in this study, especially the non-dominant hamstrings (Table 4.12). However, there was a significant difference between the right dominant (0.88 ± 0.08) and left dominant (0.96 ± 0.13) quadriceps (p=0.022). The non-dominant quadriceps showed no significant difference between the right and left sides (p=0.895). There was also no significant difference in the dominant and non-dominant hamstrings for both right and left dominant players (dominant: p=0.066, non-dominant: p=0.83) (Table 4.12).

Table 4.8: Mean fatigue ratio for dominant and non-dominant quadriceps and hamstrings of 41 university rugby players.

Muscle group	**Fatigue ratio (%)**		**p-value**
	Right (n=31) Mean ±SD	**Left (n=10) Mean ±SD**	
Quadriceps (Dominant), %	88 ± 8	96 ± 13	0.022*
Quadriceps (Non-Dominant), %	90 ± 13	90 ± 9	0.895
Hamstrings (Dominant), %	81 ± 11	88 ± 11	0.066
Hamstrings (Non-Dominant), %	82 ± 5	82 ± 9	0.830

*p=<0.05

4.4.9. FMS Score

With a cut-off of 14 as in previous studies (Kiesel, Plisky and L, 2007; Garrison *et al.*, 2015; Tee *et al.*, 2016), nine (21.43%) players in this study scored ≤ 14/21 on the FMS score while 33 (78.57%) players scored > 14/21 on the FMS score (Figure 4.2). However, there was no significant difference in the average FMS score of players who were right-dominant (15.39 ± 1.61) and those who were left dominant (15.00 ± 2.16) (p=0.546) (Table 4.13).

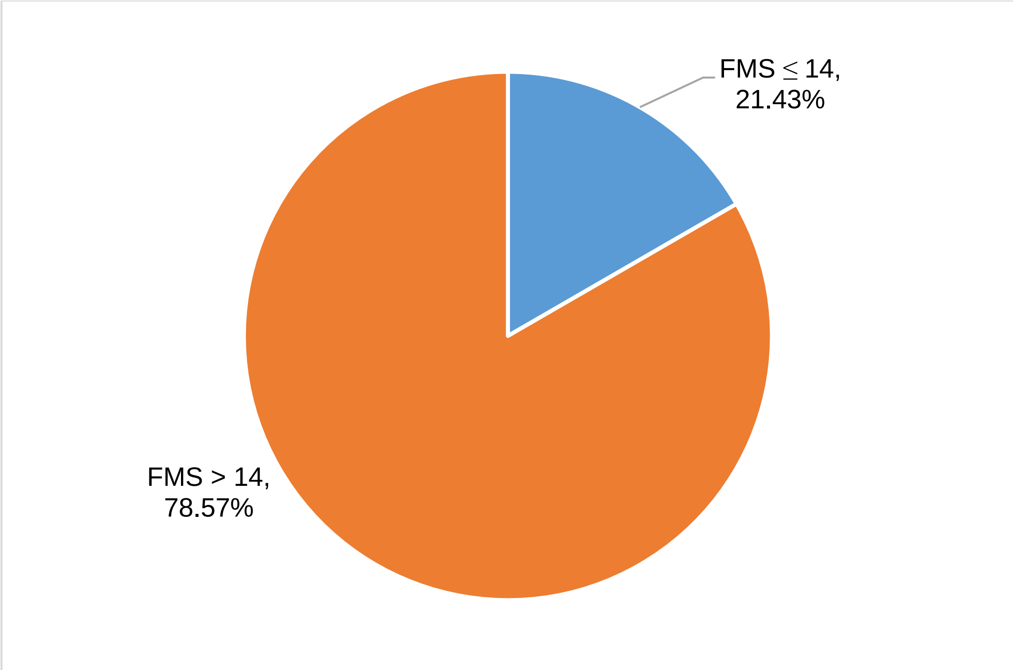

Figure 4.2: FMS categories (N=42)

Table 4.9: Mean FMS score (/21) for right and left leg dominant players of 41 university rugby players.

	FMS score (/21)		p-value
	Right (n=31) **Mean ±SD**	**Left (n=10)** **Mean ±SD**	
Dominance, /21	15.39 ± 1.61	15.00 ± 2.16	0.546

4.5. Relationship between isokinetic indices and the FMS and injury

4.5.1. Peak Torque (Nm)

In this study, there was no significant difference in average peak torque (Nm) produced by all the muscle groups for both the dominant and the non-dominant legs of the players that did not report any injury and those that reported injury ($p>0.050$) (Table 4.14).

Table 4.10: Relationship between mean peak torque (Nm) and injury incidence in dominant and non-dominant quadriceps and hamstrings (N=42).

Muscle group	Peak torque (Nm)		p-value
	No injury (n=20) **Mean ±SD**	**Injury (n=22)** **Mean ±SD**	
Quadriceps (Dominant), Nm	280.07 ± 49.74	291.47 ± 50.11	0.464
Quadriceps (Non-Dominant), Nm	276.63 ± 53.70	286.40 ± 52.49	0.555
Hamstrings (Dominant), Nm	147.10 ± 26.54	141.50 ± 21.03	0.451
Hamstrings (Non-Dominant), Nm	139.89 ± 23.18	137.16 ± 19.82	0.683

4.5.2. Peak Torque to Body Weight (Nm)

The mean peak torque to body weight (Nm) produced by the different muscle groups of the players who did not report injury was not significantly different from the peak torque to body weight (Nm) produced by the players who reported injury in this study for both the quadriceps (dominant: p=0.443, non-dominant: p=0.546) and the hamstrings (dominant: p=0.455, non-dominant: p=0.493) hamstrings (Table 4.15).

Table 4.11: Relationship between mean peak torque to body weight (Nm) and injury incidence in dominant and non-dominant quadriceps and hamstrings (N=42).

Muscle group	Peak torque (Nm)		p-value
	No injury (n=20) **Mean ±SD**	**Injury (n=22)** **Mean ±SD**	
Quadriceps (Dominant), Nm	294.58 ± 40.15	306.49 ± 57.03	0.443
Quadriceps (Non-Dominant), Nm	291.25 ± 49.11	302.79 ± 70.48	0.546
Hamstrings (Dominant), Nm	154.75 ± 17.36	149.38 ± 27.17	0.455
Hamstrings (Non-Dominant), Nm	147.39 ± 17.51	143.09 ± 22.23	0.493

4.5.3. Torque at 30^{o} (Nm)

The relationship between the mean torques at 30^{o} (Nm) and the incidence of injury is shown in Table 4.16. There was no significant difference in the mean torques at 30^{o} (Nm) in the dominant quadriceps (p=0.604) and non-dominant quadriceps (p=0.705) of players who reported injuries and players who did not report injuries. Similarly, there was no significant difference in the mean torques at 30^{o} (Nm) in the dominant hamstrings (p=0.976) and the non-dominant hamstrings (p=0.800) of players who reported injuries and players who did not report injuries.

Table 4.12: Relationship between mean torque at 30^{o} (Nm) and injury incidence in dominant and non-dominant quadriceps and hamstrings (N=42).

Muscle group	Torque at 30^{o} (Nm)		p-value
	No injury (n=20) **Mean ±SD**	**Injury (n=22)** **Mean ±SD**	
Quadriceps (Dominant), Nm	121.44 ± 47.23	128.00 ± 33.63	0.604
Quadriceps (Non-Dominant), Nm	127.12 ± 42.98	122.08 ± 42.76	0.705
Hamstrings (Dominant), Nm	122.71 ± 46.20	122.36 ± 27.41	0.976
Hamstrings (Non-Dominant), Nm	112.17 ± 40.90	115.10 ± 33.76	0.800

4.5.4. Torque at 0.18 Seconds (Nm)

The relationship between the mean torque at 0.18 seconds (Nm) and the prevalence of injury is shown in Table 4.17. There was no significant difference in the average torque at 0.18 seconds (Nm) of the various muscle groups of between players who reported injury and those who did not report injury (p>0.050).

Table 4.13: Relationship between mean torque at 0.18 seconds (Nm) and injury incidence in dominant and non-dominant quadriceps and hamstrings (N=42).

Muscle group	Torque at 0.18 seconds (Nm)		p-value
	No injury (n=20) **Mean ±SD**	**Injury (n=22)** **Mean ±SD**	
Quadriceps (Dominant), Nm	214.27 ± 36.73	223.83 ± 44.42	0.454
Quadriceps (Non-Dominant), Nm	209.77 ± 39.66	222.20 ± 43.01	0.338
Hamstrings (Dominant), Nm	128.43 ± 33.03	125.31 ± 27.25	0.739
Hamstrings (Non-Dominant), Nm	122.63 ± 23.50	122.34 ± 20.56	0.966

4.5.5. Bilateral Deficit (%)

There was no significant difference in the mean bilateral deficit of the quadriceps (p=0.860) and hamstrings (p=0.820) between players that reported injury and those that did not report injury (Table 4.18).

Table 4.14: Relationship between mean bilateral deficit (%) and injury prevalence in quadriceps and hamstrings (N=42).

Muscle group	Bilateral deficit (%)		p-value
	No injury (n=20) Mean ±SD	Injury (n=22) Mean ±SD	
Quadriceps, %	6.11 ± 4.09	7.75 ± 5.17	0.860
Hamstrings, %	7.50 ± 4.91	9.13 ± 5.97	0.820

Further analysis of the categories of bilateral deficit (≤10 and >10) using Chi squared showed that there was no significant association between prevalence of injury and the bilateral deficit categories for the quadriceps (χ^2=1.38. p-value=0.240) and hamstrings (χ^2=0.155. p-value=0.690) (Table 4.18).

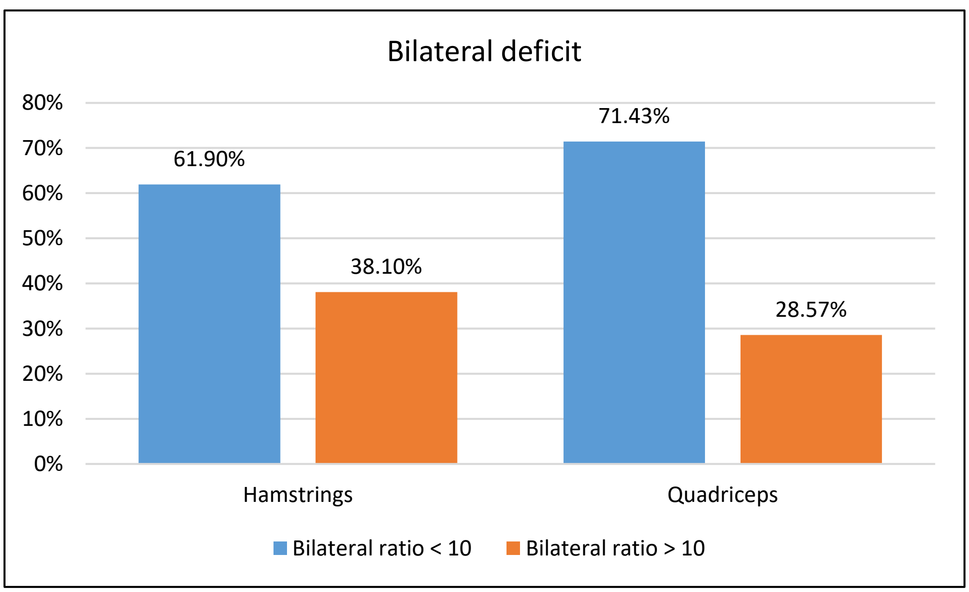

Figure 4.3: Relationship between bilateral deficit and prevalence of injury

4.5.6. Agonist/Antagonist Ratio (%)

Players who reported injury in the current season showed significantly lower agonist/antagonist ratio (%) in the dominant leg (49.02 ± 5.98) than players who did not report injury (55.03 ± 6.66) ($p=0.020$) (Table 4.20). A similar difference was noticed in the non-dominant leg, but the difference was not significant (injured=48.65 ± 7.59; non-injured=51.32 ± 4.91; $p=0.120$) (Table 4.19).

Table 4.15: Relationship between mean agonist/antagonist ratio (%) and injury prevalence in the dominant and non-dominant lower limb (N=42).

Dominance	Agonist/antagonist ratio (%)		p-value
	No injury (n=20) **Mean ±SD**	**Injury (n=22)** **Mean ±SD**	
Dominant, %	55.03 ± 6.66	49.02 ± 5.98	0.020*
Non-Dominant, %	51.32 ± 4.91	48.65 ± 7.59	0.120

*p=<0.05

Further chi-square analysis of the categories of agonist/antagonist ratios (≤60% and >60%) as categorized by Rosene et al., (2001)[56] and Yeung et al., (2009)[52] showed no significant relationship between injury prevalence and the categories for both the dominant ($p=0.199$) and non-dominant legs ($p=0.531$) (Table 4.20).

Table 4.16: The relationship between categories of agonist/antagonist ratio (≤60% and >60%).

Categories	Prevalence of Injury		p-value
	No injury	**Injury**	
Agonist Dominant			0.199
≤60%	17	33	
>60%	3	0	
Agonist Non-Dominant			0.531
≤60%	17	21	
>60%	3	1	

4.5.7. Fatigue Ratio (%)

The mean fatigue ratios of the various muscle groups were not significantly different between players who reported injury and players who did not report injury (p>0.050) (Table 4.21).

Table 4.17: Relationship between mean fatigue ratio and injury prevalence in dominant and non-dominant quadriceps and hamstrings (N=42).

Muscle group	Fatigue ratio (%)		p-value
	No injury (n=20) **Mean ±SD**	**Injury (n=22)** **Mean ±SD**	
Quadriceps (Dominant), %	88.15 ± 8.47	91.61 ± 10.88	0.259
Quadriceps (Non-Dominant), %	87.49 ± 14.73	92.05 ± 9.06	0.229
Hamstrings (Dominant), %	80.04 ± 9.66	85.32 ± 11.35	0.114
Hamstrings (Non-Dominant), %	80.92 ± 6.12	83.28 ± 6.24	0.224

4.5.8. Functional Movement Screen

Although there was a difference between the mean FMS score of players who reported injury (14.91 ± 1.849) and those who did not report injury (15.7 ± 1.49), the observed difference was not significant (p=0.137) (Table 4.22).

There was also no significant association between prevalence of injury and FMS categories (≤14 and >14) on further analysis using Chi-square test (p=0.179) (Table 4.23).

Table 4.18: Relationship between mean FMS score and injury incidence (N=42).

	Functional Movement Screen		p-value
	No injury (n=20) **Mean ±SD**	**Injury (n=22)** **Mean ±SD**	
FMS Score (/21)	15.7 ± 1.49	14.91 ± 1.849	0.137

Table 4.19: The relationship between categories of FMS (≤14 and >14).

FMS Categories	Prevalence of Injury		p-value
	No injury	Injury	
			0.179
≤ 14	2	7	
>14	18	15	

4.6. Multivariate Binary Logistic Regression

A multivariate binary logistic regression was used to predict injury using a combination of two the following parameters which parameters, which include previous injury; bilateral deficit; agonist/antagonist ratio and FMS ≤14; at a 95% confidence interval. The result showed that none of the parameters listed above could significantly predict injury in this study (Table 4.24).

Table 4.20: Multivariate binary logistic regression for injury prediction using a combination of FMS and each of the previous injury, bilateral deficit, and agonist/antagonist ratio.

Outcome measures	β	S.E	Wald test	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
FMS ≤14	0.323	1.027	0.099	1	0.753	1.382	0.185	10.34
Previous injury	-1.45	0.874	2.752	1	0.097	0.234	0.042	1.301
Bil deficit Q ≤10	-1.337	0.901	2.204	1	0.138	0.263	0.045	1.534
Bil deficit H ≤10	-1.073	0.837	1.642	1	0.200	0.342	0.066	1.765
Ago/antag ratio dom <60%	21.844	22809.57	0.000	1	0.999	3.0658E+09	0.000	.
Ago/antag ratio non-dom <60%	0.004	1.982	0.000	1	0.998	1.004	0.021	48.849
Constant	-19.539	22809.57	0.000	1	0.999	0.000		

β=β coefficients, S.E=Standard Error, Sig=significance, C.I=confidence interval, Bil deficit=bilateral deficit, Q=quadriceps, H=hamstrings

5. CHAPTER FIVE – DISCUSSION

5.1. Introduction to chapter

This chapter will discuss the results under the following headings: history of injury, previous injury, isokinetic indices and ratios, FMS and prediction of injury using the FMS and isokinetic ratios.

5.2. History of injury

Out of a total of 42 players, the incidence of injury in this study was 22 (52.38%). This was much higher than what was reported by Freitag et al., (2015)[26] who reported 28% injury incidence in Rugby Union players under 21 years. More injuries occurred in the non-dominant leg than the dominant leg (dom=68.18%, non-dom=27.27%).

There were fewer injuries due to contact in this study when compared to those sustained without contact (contact=36.36, no contact=63.64). This was similar to what was reported by Frisch et al., (2011)[28] in football players but lower than what was reported by Garraway et al., (2000)[12] and Kaux et al., (2015)[10] where contact injuries accounted for about 70% of all injuries reported and a greater number of these injuries were sustained during training as compared to during matches.

5.3. Previous Injury

Twenty-two (52.38%) players reported injuries during the season including training periods and during matches. A total of 29 players (69.05%) out of a total of 42 players had a history of the previous injury. Eighteen (62.07%) players out of these players sustained similar injuries in the season under study while the remaining 11 (37.93%) players who reported injury in the previous season did not report an injury in the season under study. This means that there was a two-times increased risk of sustaining another injury following the history of a previous injury in our study. This observation is similar to what was observed by Quarrie et al., (2001)[30] and

Chalmers et al., (2012)[14] in previous studies on Rugby Union players. This also agrees with findings in football[31, 32]. Since the previous injury has been shown to be significantly associated with injury in this study and in previous studies[5, 14, 30-32], it is important to emphasize the significance of adequate rehabilitation of previous injuries before the commencement of a new season as suggested by Quarrie et al., (2001)[30]. This is to reduce the incidence of new injuries.

5.4. Isokinetic indices and ratios

Unlike what was reported in the Rugby Union by Brown et al., (2016)[65] and Orchard et al., (1997)[61], there was no significant difference in the peak torque, peak torque to body weight, torque at 30^{o} and torque at 0.18sec between the dominant and non-dominant quadriceps and hamstrings in this study for this population. This generally means there was no significant asymmetry between the dominant and non-dominant limbs concerning the isokinetic indices listed above and this probably explains why there was no significant difference in these isokinetic parameters of the dominant and non-dominant muscle groups (quadriceps and hamstrings) of players who reported injury and those who did not report the injury in the season under study. The reason for this is unclear and may include the nature of this squad's pre-season preparation or other factors.

Generally, the mean bilateral deficits recorded in this study in both the hamstrings and the quadriceps were below 10% which is the generally accepted limit, and thus, are less likely to sustain injury[1, 4]. Therefore, players that reported injury did not have significantly higher mean bilateral deficit when compared with players that did not report the injury in this study ($p>0.05$). The findings in this study conform with previous studies, such as Orchard et al., (1997)[61] and Heiser et al., (1984)[66], that show that bilateral deficit greater than 10% was associated with injury while a bilateral deficit less than 10% was not associated with injury.

There was no significant difference in the mean of the agonist/antagonist ratios between the dominant and non-dominant legs but the players who reported injuries showed a significantly lower mean agonist/antagonist ratio (49.02 ± 5.98) in the dominant leg than the players who did not report any injury in the season (55.03 ± 6.66) ($p=0.020$). This shows that increased imbalance in the agonist/antagonist ratio in the dominant limb was associated with injury as seen in previous studies[52, 66]. However, when specifically categorized into ≤ 60% and >60% as in previous studies[52, 66], there was no significant association between the two categories and injury prevalence for both the dominant and non-dominant legs ($p>0.05$) (Table 4.21). Hence, future studies need to examine different cut-off points of the agonist/antagonist ratio in order to adequately risk-stratify players based on the categories of the agonist/antagonist ratio they fall into.

Despite minor differences in absolute values of the mean of the fatigue ratios of all the muscle groups, the observed differences between the players that reported injury and those that did not report injury were not significant in this study ($p>0.05$). Therefore, the fatigue ratio did not predict injury in this study as against what was reported in earlier studies[5, 11, 15, 37, 38].

5.5. FMS

The mean FMS score of players who reported injury in the season under study was lower than the mean FMS score for players who did not report injury (injured=14.91±1.849; non-injured=15.7 ± 1.49). However, unlike previous studies[22, 24, 57, 71], the difference observed was not significant in predicting injury ($p=0.137$). Categories of FMS (≤14 and >14) were also not significant predictors of injury in this study. Since the mean FMS score of players who reported injury was lower than the mean FMS score of players who reported no injury, future studies need to examine various cut-offs of the FMS categories in relation to injury as done by Armstrong et al., (2018). Future researchers can also explore the individual components of the FMS score in addition to the composite score with relation to injury.

5.6. Prediction of injury using the FMS and isokinetic ratios

In contrast to what was reported in the literature[24, 62], combinations involving any of the functional movement screen, previous injury, and isokinetic ratios failed to adequately predict injury in the university rugby players in this study. Hence, the sensitivity and specificity of the functional movement screen were not enhanced by the combination of previous injury and any of the isokinetic ratios.

6. CHAPTER SIX: CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

6.1. Conclusion

The isokinetic ratios and the FMS are well-researched tools used to predict injury in rugby players. This study aimed to examine the association of these parameters individually or in combination with injury in university rugby players. This study showed that history of the previous injury and a lower agonist/antagonist ratio were significant predictors of injury. The bilateral deficits were generally within the acceptable limit. However, combining the FMS with the other parameters did not increase the injury predictive value of either the FMS or the other parameters.

6.2. Limitations and recommendations

This study was a retrospective study on data collected in one university rugby season. Future prospective studies would be able to study the relationship between variables better. Only a total of 46 sets of participant data was available and only 42 participant data fulfilled the inclusion criteria for this study. This number is too small for a regression study, which could have influenced the outcome of this study. Future studies should include more participants.

Analysis of previous injuries in this study only considered injuries present at the time of evaluation at the start of the season under study. No information on injuries sustained in the previous season and had been fully rehabilitated before the start of the season under study. Hence, it was not possible to compare the effect of rehabilitated previous injuries and non-rehabilitated previous injuries on injury incidence in the present season. It is therefore suggested that future studies should put this into consideration, as previous rehabilitated injury could also be a confounding factor, as it has been shown in previous studies, to increase injury risk.

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LIST OF APPENDICES

APPENDIX A: EXCEL SPREADSHEET FOR DATA CAPTURE

	ISOKINETIC TESTING																											FMS SCORE	INJURY						
SN	Dominance	Weight (kg)	Previous injury	Peak torque				Peak TQ/BW				Torque @ 30				Torque @ 0,18				Bil ratio		Ago/Antag ratio		Fatigue ratio											
				Q		H		Q		H		Q		H		Q		H						Q		H									
				DOM	N-D	DOM	N-D	DOM	N-D	DOM	N-D	DOM	N-D	DOM	N-D	DOM	N-D	DOM	N-D	Q	H	DOM	N-D	DOM	N-D	DOM	N-D		Age	Position	Date	Type of injury	Cause	Match/training	Time of injury

APPENDIX B: THE FUNCTIONAL MOVEMENT SCREEN SCORING SHEET

THE FUNCTIONAL MOVEMENT SCREEN

SCORING SHEET

NAME ______________________ DATE ____________ DOB ____________

ADDRESS ____

CITY, STATE, ZIP ______________________ PHONE ____________

SCHOOL/AFFILIATION ______________________________________

SSN ____________ HEIGHT ____________ WEIGHT ____________ AGE ________ GENDER ________

PRIMARY SPORT ______________________ PRIMARY POSITION ______________________

HAND/LEG DOMINANCE ______________________ PREVIOUS TEST SCORE ______________________

TEST		RAW SCORE	FINAL SCORE	COMMENTS
DEEP SQUAT				
HURDLE STEP	L			
	R			
INLINE LUNGE	L			
	R			
SHOULDER MOBILITY	L			
	R			
IMPINGEMENT CLEARING TEST	L			
	R			
ACTIVE STRAIGHT-LEG RAISE	L			
	R			
TRUNK STABILITY PUSHUP				
PRESS-UP CLEARING TEST				
ROTARY STABILITY	L			
	R			
POSTERIOR ROCKING CLEARING TEST				
TOTAL				

Raw Score: This score is used to denote right and left side scoring. The right and left sides are scored in five of the seven tests and both are documented in this space.

Final Score: This score is used to denote the overall score for the test. The lowest score for the raw score (each side) is carried over to give a final score for the test. A person who scores a three on the right and a two on the left would receive a final score of two. The final score is then summarized and used as a total score.

APPENDIX C: FMS SCORING AND MEASUREMENT

The seven movements include a; deep squat; hurdle step; in-line lunge; active straight-leg raise; trunk stability push-up; and rotary and shoulder mobility [54]. Each of the seven movements are scored from 0-3 points, with 0 denoting presence of pain anywhere in the body during the test, 1 given when the individual is unable to assume the required test position or unable to complete the movement pattern, 2 is given when the person is able to complete the movement pattern only with compensation and 3 being the ability of the person to complete the movement pattern correctly without compensation [55]. Cook et al [55] also included some additional screens, graded as either positive or negative, which are meant to identify areas with pain. The sum of the scores ranges from 0 to 21 points [54].

The tests done included the following:

1. Deep squat: This test challenges the mechanics of the whole body when done correctly. It assesses the bilateral and symmetrical mobility and stability of the whole body including the upper and lower extremities and the trunk (Cook *et al.*, 2014). This test is scored as follows;

0 – when not able to assume test position.

1 – tibia and upper torso are not parallel, femur not below horizontal, knees not aligned over feet, lumber flexion noted.

2 – upper torso is parallel with tibia or toward vertical, femur below horizontal, knees or dowel aligned over feet.

3 – upper torso is parallel with tibia or toward vertical, femur below horizontal, knees or dowel aligned over feet.

2. Hurdle step: This test assesses the mobility and stability of the hip, knee and ankle joints. It challenges the proper stride mechanics of the body while stepping employing coordination and stability between the torso and the hips (Cook *et al.*, 2014). The test is scored as follows;

1 – contact with foot and hurdle, loss of balance at any time.

2 – alignment is lost between the hips, knees and ankles, movement in the lumbar spine, dowel and hurdle do not remain parallel.

3 – the hips, knees and ankles remain aligned in the sagittal plane, minimal movement in the lumbar spine, dowel and hurdle remain parallel.

3. In-line lunge (front leg is the side scored); This test assesses the mobility of the hip and ankle joints, knee stability and flexibility of the quadriceps. It simulates a posture that places stress on the trunk and extremities challenging them to resist rotation and alignment. The test is scored as follows;

1 – loss of balance at any time.

2 – movement noted in torso, feet do not remain in sagittal plane on the 2X6, knee does not touch the 2X6 behind the heel of front foot.

3 – minimal to no torso movement, feet remain in sagittal plane on the 2X6, knee touches 2X6 behind the heel of front foot.

4. Shoulder mobility (flexed shoulder is side scored); This test assesses the range of motion of the shoulder joint. It combined internal rotation and adduction of a shoulder and external rotation and abduction of the other shoulder (Cook, Burton and Hoogenboom, 2014). This test is scored as follows;

1 – fists fall greater than one and a half hand lengths.

2 – fists should be within one and a half hand lengths.

3 – fists should be within one hand length.

A shoulder impingement test is done as a clearing test to detect pain. The individual is asked to place one hand over the shoulder of the other limb and attempts to point the elbow upwards. Presence of pain with this movement is recorded as “YES” and absence of pain is scored as “NO”. If there is pain, a score of zero is given to the shoulder mobility test (Cook, Burton and Hoogenboom, 2014).

5. Active straight-leg raise; This test assesses the flexibility of the hamstring and the gastro-soleus muscles without involvement of the pelvis and core. It tests for the

ability to dissociate the lower limbs from the trunk (Cook, Burton and Hoogenboom, 2014).

1 – malleolus resides below mid-patella.

2 – malleolus resides between mid-thigh and mid-patella.

3 - malleolus resides between mid-thigh and ASIS.

6. Trunk stability push-up; This test assesses the stability of the core and the spine when a symmetrical upper body push-up is performed (Cook, Burton and Hoogenboom, 2014). The scores are as follows;

1 – males unable to perform 1 rep with hands in line with chin, female unable to perform 1 rep with thumbs in line with clavicle.

2 – males perform 1 repetition with thumbs in line with the chin, female perform 1 rep with thumbs in line with the clavicle.

3 – males perform 1 repetition with thumbs above head, females perform 1 repetition with thumbs in line with the chin.

A press-up clearing test is done to detect pain and presence of pain is recorded as "YES" while absence of pain is recorded as "NO" (Cook, Burton and Hoogenboom, 2014).

7. Rotary stability; This test assesses the stability of the torso during motion of both the upper and lower extremities. It is a test of neuromuscular coordination and transfer of energy between one segment of the body and the other (Cook, Burton and Hoogenboom, 2014). The rotary stability test is scored as follows;

1 – unable to perform diagonal repetitions.

2 – performs 1 diagonal rep while keeping torso parallel to board, knee and elbow touch in line with the board.

3 – performs 1 unilateral rep while keeping torso parallel to board, knee and elbow touch in line with the board.

A spinal flexion clearing test is done at the end of the rotary stability test to detect pain. The individual assumes a quadruped position with the arms stretched in front of the body. Moving the body back as far as possible with the buttocks touching the heels and the chest touching the thighs. Presence of pain is scored as “YES”. This will automatically give the rotary stability test a core of zero. Absence of pain is recorded as “NO” (Cook, Burton and Hoogenboom, 2014).

APPENDIX D: INJURY REPORT SHEET

Injury Report All History

Date	Athlt	Age	Position	Date of Injury	Injured area and type of injury	Injury history	Onset of injury	Did injury occur during	Injury Other	Time of injury	Type of match	Practice activity	Contact	Contact with	Sports-specific contact	Non-contact activity
27-03-2017		19		27-03-2017	Right Anterior Shoulder SZXX Shoulder Pain/ Injury not otherwise specified	New	Trauma	Match		1st half			Contact	Team mate		
23-03-2017		23	Tight Five	23-03-2017	Right Posterior Thigh TMHX Hamstring strain	Recurrent	Trauma	Wits training session				Team practice	Contact	Team mate		
22-03-2017		22	Inside Back	22-03-2017	Left Hip and Groin GMXX Hip and Groin Muscle Strain/ Tear	New	Trauma	Wits training session				Team practice	Contact			
20-03-2017		23	Loose Forward	20-03-2017	Right Anterior Shoulder SMRX Rotator Cuff muscle injury	Recurrent	Trauma	Match		2nd half			Non-contact			Twisting
13-03-2017		21	Tight Five	13-03-2017	Right Anterior Shoulder SJAX Acromioclavicular joint sprain	Recurrent	Trauma	Match		2nd half			Contact	Opponent		
13-03-2017		24	Tight Five	13-03-2017	Left Anterior Shoulder SHMR Rotator Cuff haematoma	New	Trauma	Match		2nd half			Contact	Ground		
13-03-2017		22	Tight Five	13-03-2017	Right Anterior Shoulder SSAX AC joint stress/ overuse injury	New	Trauma	Match		2nd half			Contact	Opponent		
13-03-2017		20	Outside Back	13-03-2017	Right Posterior Thigh TMHX Hamstring strain	New	Trauma	Match		2nd half			Non-contact			Twisting
06-03-2017		23	Outside Back	06-03-2017	Left Posterior Thigh TMHX Hamstring strain	New	Trauma	Match		1st half			Contact	Opponent		
06-03-2017		20	Loose Forward	06-03-2017	Right Anterior Shoulder SZXX Shoulder Pain/ Injury not otherwise specified	New	Trauma	Match		2nd half			Contact	Opponent		
06-03-2017		24	Tight Five	06-03-2017	Right Anterior Head HNCX Concussion	Recurrent	Trauma	Match		2nd half			Contact	Opponent		
06-03-2017		24	Tight Five	06-03-2017	Right Anterior Shoulder STIX Infraspinatus tendon injury	Recurrent	Trauma	Match		1st half			Contact	Opponent		
27-02-2017		24	Inside Back	27-02-2017	Right Anterior Head HNXX Concussion/ Brain Injury	Recurrent	Trauma	Match		1st half			Contact	Team mate	Collision	
27-02-2017		24	Inside Back	27-02-2017	Right Knee KHXX Knee Soft Tissue Bruising/ Haematoma	New	Overuse	Match		2nd half			Non-contact			Twisting
25-02-2017		19		25-02-2017	Left Anterior Ankle	New	Trauma	Match		2nd			Contact	Opponent		

SPORT

Page 1

APPENDIX E: ETHICS CLEARANCE CERTIFICATE

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Dr AT Amusa

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M190990

NAME: (Principal Investigator)	Dr AT Amusa
DEPARTMENT:	School of Therapetic Sciences Centre for Exercise Science and Sport Medicine Medical School University
PROJECT TITLE:	The relationship between isokinetic ratios, functional movement screening and injuries in University rugby players: a retrospective study
DATE CONSIDERED:	Ad hoc
DECISION:	Aproved unconditionally
CONDITIONS:	
SUPERVISOR:	Professor D Constantinou
APPROVED BY:	CBPenny Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2019/10/01

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary on the 3rd Floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.
I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to submit details to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in **September** and will therefore reports and re-certification will be due early in the month of **September** each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature ____________ Date ____________

PLEASE QUOTE THE CLEARANCE CERTIFICATE NUMBER IN ALL ENQUIRIES

APPENDIX F: LETTER OF PERMISSION TO USE DATA

Centre for Exercise Science and Sports Medicine

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

School of Therapeutic Sciences, Faculty of Health Sciences · Private Bag 3, Wits, 2050, South Africa
Tel: +27 11 717 3372 · Fax : 27 11 86 6363 173 · E-mail: Nadine.petersen@wits.ac.za www.wits.ac.za/cessm

12 April 2019

Human Research Ethics Committee (Medical)

University of the Witwatersrand, Johannesburg

Permission to use data

I hereby support and grant permission for the research that student Abdulrasheed Tunde Amusa (1847712) is proposing. The data of rugby players that we have on file within the Centre for Exercise Science and Sports Medicine, is available for him to analyse as per his protocol.

The research title is "The relationship between isokinetic ratios, functional movement screening and injuries in university rugby players: a retrospective study".

Yours sincerely

Professor D Constantinou

Adjunct Professor: Sports and Exercise Medicine
Director: Centre for Exercise Science and Sports Medicine

CCSM

Exercise is Medicine On Campus