

THE RELATIONSHIP BETWEEN ISOKINETIC KNEE EXTENSOR AND FLEXOR MUSCLE STRENGTH AND VERTICAL JUMP PERFORMANCE IN UNIVERSITY RUGBY UNION PLAYERS OF THE NORTH-WEST UNIVERSITY

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DECLARATION

I, Esti Krüger, hereby declare that the work in this thesis is my own work, all the sources I have used have been referenced and this thesis has not been previously submitted at another university with the aim of obtaining a degree.



Signed

28/03/2014

Date

ABSTRACT

Introduction: Rugby is a professional sport which places emphasises on strength, power, speed and endurance. Therefore the accurate assessment of rugby performance is very important for sports and exercise therapists to enable peak performance for the players. Lower limb strength is often tested by means of isokinetic testing, whilst functional power is tested by means of the vertical jump test. Sophisticated equipment used in the measurement of performance indicators, are often not available in smaller communities and rural areas. A good correlation between laboratory testing and functional testing could be of great value for determining performance in less fortunate communities.

Aim of Study: To determine the relationship between isokinetic strength testing of the quadriceps and hamstring muscle groups and vertical jump performance in rugby players.

Methods: Fifty one male, rugby players who were part of the Varsity Cup Tournament in (2011) participated in this study. Ethical approval was given by the Human Research Ethics Committee (HREC) of the University of Witwatersrand. Height and weight were measured. Isokinetic knee extensor and flexor strength was tested (Biodex system 4 dynamometer TM) at 60°/sec (5 repetitions), 180°/sec (10 repetitions) and 300°/sec (15 repetitions). A single leg vertical jump was done using the Vertec and the performance was assessed as maximal height jump in centimetres. Descriptive statistics (mean and standard deviation) are reported for all outcomes. The SPSS software (IBM. SPSS version 21) was used for analysis. A Pearson's Product Moment Correlation coefficient was calculated between the isokinetic parameters of quadriceps and hamstring muscles and the vertical jump height and power (watts). An independent t-test and a paired t-test were used to calculate the differences between the forward and backline players and the dominant (Dom) and non-dominant (ND) legs.

Results: The mean age of the participants was 21.4 ± 1.2 years; they were 1.83 ± 7.4 m tall and weighed 99.3 ± 13.8 kg. There were 26 forward players (mean height of 1.88 ± 7.2 m and mean weight of 109.9 ± 10.3 kg) and 25 backline players (mean height of 1.80 ± 5.5 m and mean weight of 88.3 ± 6.1 kg). The forwards were significantly taller and heavier than the backline players ($p = 0.0001$). The forwards produced significant greater peak power in the vertical jump than the backline players in both the dominant and non-dominant legs ($p=0.0001$). The PT (Nm) decreased as the angular velocity increased from 60°/sec to 300°/sec. A significant negative correlation ($r = -0.313$; $p = 0.025$) between peak torque (PT) concentric strength from the hamstrings at 60°/sec and the vertical jump height on the non-dominant side were found. Quadriceps PT to vertical power at the higher velocities showed significant correlations at 180°/sec (dominant: $r = 0.294$; $p = 0.011$)

and 300°/sec (dominant: $r = 0.352$; $p = 0.011$; non-dominant: $r = 0.293$; $p = 0.037$). No significant correlations were found between peak torque and vertical jump height when corrected for body weight. When correlating PT and vertical jump power corrected for body weight significant negative correlations was found at 180°/sec (dominant: $r = 0.319$; $p = 0.022$; non-dominant: $r = 0.305$; $p = 0.030$) for the hamstrings.

Conclusion: The findings from the presented study found no significant correlation between lower limb isokinetic knee muscle torque parameters and vertical jump performance in rugby union players. Future research should investigate the relationship between isokinetic testing and vertical jump height by including the parameters of a multi joint mechanism.

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DEFINITIONS OF TERMS

Front-row Players: The forward players who are the loose-head prop, the hooker and the tight-head prop. These players usually wear jerseys No. 1, 2 and 3 respectively. ⁽¹⁾

Scrum Half: A player nominated to throw the ball into a scrum who usually wears jersey No. 9. ⁽¹⁾

Try: Method of scoring: When an attacking player is first to ground the ball in the opponents' in-goal, a try is scored. ⁽¹⁾

Conversion Goal: When a player scores a try it gives the player's team the right to attempt to score a goal by taking a kick at goal; this also applies to a penalty. ⁽¹⁾

Set Piece: It is a means of restarting a game after either a minor infringement or when the ball went out of play e.g. the scrum or lineout. ⁽¹⁾

Scrum: This happens when players from each team come together in scrum formation so that play can be started by throwing the ball into the scrum after stoppage for a minor law infringement. ⁽¹⁾

Ruck: A ruck is a phase of play where one or more players from each team, who are on their feet, in physical contact, close around the ball when the ball is on the ground. ⁽¹⁾

Maul: A maul begins when a player carrying the ball is held by one or more opponents, and one or more of the ball carrier's team mates bind on the ball carrier. A maul therefore consists, when it begins, of at least three players, all on their feet; the ball carrier and one player from each team. ⁽¹⁾

Tackle: A tackle occurs when the ball carrier is held by one or more opponents and is brought to ground. ⁽¹⁾

Lineout: The purpose of the lineout is to restart play, quickly, safely and fairly, after the ball has gone into touch, with a throw-in between two lines of players. ⁽¹⁾

Hinge Joint: A joint that moves in one axis and only permits flexion and extension patterns. ⁽²⁾

Synovial Joint: Is a joint that consists of a joint cavity, articular cartilage and articular capsule. ⁽²⁾

Flexion: Decreasing of the angle between two joints or two body parts. ⁽²⁾

Extension: Increasing the angle between two joints or two body parts.⁽²⁾

Menisci: Is curved shaped fibrocartilage⁽³⁾ that gives joint stability, reduces friction; transmits load and helps with shock absorption in the knee joint.⁽⁴⁾

Concentric: The muscle shortens as the contractile forces are greater than the resistive forces.⁽⁵⁾

Eccentric: The muscle lengthens due to the contractile forces being less than the resistive forces.⁽⁵⁾

Reciprocal Ratio: Is the relationship between the strength of the weaker muscle divided by the strength of the stronger muscle.⁽⁶⁾

LIST OF ABBREVIATIONS

ACL	- Anterior Cruciate Ligament
PCL	- Posterior Cruciate Ligament
MCL	- Medial Collateral Ligament
LCL	- Lateral Collateral Ligament
ROM	- Range of Motion
PT	- Peak Torque
TW	- Total Work
AP	- Average Power
H:Q	- Hamstrings to Quadriceps Reciprocal Ratio
ICC	- Intraclass Correlation Coefficients

CHAPTER 1

1. INTRODUCTION

Accurate assessment of athletic performance has been an objective of sports and exercise therapists for many decades. The purposes of this testing are to assess the effect of a conditioning programme on performance, or the effectiveness of rehabilitation.⁽⁷⁾ Several different testing dynamometry modalities are used to assess for muscle function.⁽⁷⁾ To find well-controlled, laboratory-based tests to predict performance still remains difficult.⁽⁸⁾

With the turn to professionalism of the game of rugby in 1995 there was also a subsequent increase in the demands of the sport with more emphasis being placed on muscle strength, power and speed.^(9,10) These increased demands in conditioning and performance have also been seen at the lower levels of rugby.⁽⁹⁾ Objective testing of strength and power can help the clinician to assess the readiness of a player to return to sport and the progress made by an athlete during rehabilitation.⁽¹¹⁾ Pre-participation screening acts as a health and muscular risk assessment and evaluator for risk in collision sports like rugby⁽¹²⁾ and identifies those at risk for injuries.⁽¹³⁾

Lower limb muscle strength and power are two of these conditioning variables that are important in rugby players. Lower limb strength is often tested by means of isokinetic testing, whilst functional power is tested by means of the vertical jump test.^(8,14) Isokinetic testing is able to quantify isolated muscle strength and has been shown to be a reliable and valid method for testing.⁽¹⁵⁾ Although isokinetic testing is an objective⁽¹⁶⁾ and reliable test it is not considered to be very functional.⁽¹⁷⁾ The vertical jump test is seen to be an example of a functional closed kinetic chain test that is able to measure leg power output⁽¹⁸⁾ in athletes participating in explosive sports codes.⁽¹⁹⁾ The knee joint is one of the main contributors to the vertical jump⁽⁸⁾ and the quadriceps muscles are considered to be one of the most important muscles in vertical jumping performance.⁽⁷⁾

Several studies have investigated the correlation between the isokinetic and vertical jump testing methods with contradicting results.^(7,11,19–21) Augustsson and Thomeé (2000)⁽⁷⁾ found a moderate relationship ($r = 0.57$) between isokinetic muscle testing of the knee joint and the vertical jump height.⁽⁷⁾ Negrete and Brophy (2000)⁽¹¹⁾ found a significant correlation between peak torque isokinetic knee extensor strength and the height from vertical jump test ($r = 0.546 - 0.577$, $p < 0.0001$). No significant correlations were found by Östenberg et al. (1998)⁽²⁰⁾ between isokinetic knee extensor strength at 60°/sec ($r = -0.31$ to 0.31 , $p < 0.05$) and 180°/sec $r = -0.35$ to 0.46 $p < 0.05$) and vertical jump height.

The number of studies investigating the relationship between isokinetic leg strength and functional performance, more specifically the vertical jump test, can be an indication of the popularity of the topic. Isokinetic testing can be used to give valuable information about lower limb musculature and the predisposition of athletes to injury and the readiness to compete because of the detection of muscle imbalances,^(8,15,17) but it is very expensive and time-consuming. It could be of great interest if the single leg vertical jump could predict bilateral differences in isokinetic knee strength,^(16,22) because the vertical jump field test is less expensive and can be easily done in rural areas and smaller communities.

Therefore, based on the above statement it was decided to compare isokinetic knee muscle strength to the single leg vertical jump performance.

1.1 AIM OF THE STUDY

To investigate the relationship between isokinetic strength values of the knee extensor and knee flexor muscles and vertical jump performance in university rugby players.

1.2 OBJECTIVES OF THE STUDY

- To determine the correlation of isokinetic peak torque, relative peak torque and reciprocal ratios of the quadriceps and hamstring muscles at 60°/sec, 180°/sec and 300°/sec to the vertical jump height and power.
- To determine whether a difference exists between the forward and backline players regarding the isokinetic parameters and the vertical jump performance.
- To determine the comparison between the dominant and non-dominant leg of the total group and between the forward and backline players.

1.3 HYPOTHESIS

Lower limb isokinetic knee muscle torque parameters will be correlated with the vertical jump performance.

1.4 NULL HYPOTHESIS

Lower limb isokinetic knee muscle torque parameters will not be correlated with the vertical jump performance.

CHAPTER 2

2. LITERATURE REVIEW

2.1 THE GAME OF RUGBY

Rugby union is a contact sport and played on a field measuring 100m by 70m. It consists of two forty-minute halves, excluding extra time, with a ten minute break in between the two halves. The game is played by fifteen players per team on the field at any given time. The fifteen players are categorized into eight forward players and seven backline players. In addition to the fifteen players, there are an additional seven players who can be substituted only once in a game. The forwards consist of three front row forwards, two locks and two flanks and an eighth man. The flanks and eighth man are also known as the loose forwards. The locks together with the front row are also known as the tight five. The backline consists of a scrumhalf, fly half, two centre players, two wings and a fullback.⁽²³⁾ The scrumhalf and fly half are the link between the forwards and the backline.⁽²⁴⁾

Rugby union is played by millions of people and is considered to be one of the most popular contact professional team sports in the world.^(25,26) After the IRB Rugby World Cup (RWC) in South Africa in 1995 the sport of rugby turned professional and it was expected of the players to become physically stronger and more powerful.⁽⁹⁾ It was found that in the 1999 RWC the teams with taller and heavier players performed better.⁽²⁷⁾ Thus, in rugby the team with the strongest and fastest players are likely to have a better chance to succeed^(10,27) and therefore physical preparation is a core component for success and progression of elite rugby.⁽²⁸⁾ This change to professionalism in rugby has seen an increase in the interest in the sports science aspects of training and competition,⁽²³⁾ with fitness and strength training components perhaps having an effect on success,⁽²⁹⁾ the reduction of the risk of injuries⁽¹²⁾ and aiding in team selection.^(27,30)

Rugby is a complex sport with several aspects of play; the tackle, ruck and maul, set pieces (scrums and lineouts) and open play.⁽²⁶⁾ The turn to professionalism not only effected a change in the physical aspects of the player, but also in the characteristics of rugby itself. There were adjustments in the rules of the game which led to more ball-in-play time, tries, rucks and tackles made with a reduction in scrums, kicks and lineouts.⁽³¹⁾ The physiological demands of rugby are complex. Rugby is an intermittent sport where players need to perform at high intensity efforts on average of five to fifteen seconds with less than forty seconds rest continuously.⁽³²⁾ The average rest periods are up to twenty seconds which usually occur during penalty kicks or conversions, tries and stoppage for injuries.⁽²³⁾ Ninety-

five per cent of work done lasts less than 30 seconds with the rest period being longer than the preceding work done.⁽²³⁾ The average distance covered during a rugby match varies between four to seven kilometres.^(33,34) Rugby requires muscle strength, aerobic and anaerobic endurance with regular bursts of acceleration and deceleration, constant changing of direction, explosive movement with recurrent contact situations, all performed while controlling the ball.⁽²³⁾ Acceleration is an important component for a rugby player⁽³⁴⁾ and rarely takes place from a static standing position.⁽²³⁾ Hence, rugby players need to exert force dynamically and statically; therefore strength and power are important components in rugby.⁽³⁴⁾

The demands between the forwards and backline players are seen to be different with physiological and anthropometric differences also displayed between the groups.⁽²³⁾ The specifications and characteristics for each position are unique and very specific.⁽³²⁾ The forward players tend to be more involved in the physical contact situations and are anthropometrically larger than the backline players. Backline players are smaller, more explosive and faster covering a greater distance on the field.^(23,32,33) Backline players therefore work for short periods (< 4 seconds) at high intensities, but the forward players tend to have more work efforts longer than 12 seconds and thus a higher overall work rate and intensity.⁽³²⁻³⁴⁾ Backline players have prolonged rest periods compared to the forward players who are constantly engaging in physical contact.⁽²³⁾ Furthermore, the forwards are expected to engage in static exertions during set plays like the scrum or lineouts while the backs wait to be involved in the game.^(26,32) Forwards tend to spend less time sprinting (maximum sprint duration 5 seconds) than the backline players, therefore the ability to accelerate is an important factor for forward players.⁽³²⁾

Research has shown that rugby is also associated with high levels of injury.^(12,23,25) The increase in body size, speed and intensity of the game⁽²⁶⁾ together with the nature of rugby with frequent powerful and unprotected collisions at various speeds⁽³⁵⁾ all contributed to the increase in injuries. Holtzhausen et al. (2006)⁽¹²⁾ stated that the higher the level of play, the higher the rate of injury; this finding is also supported by Brooks et al. (2005)⁽²⁵⁾ Jakoet and Noakes (1998)⁽³⁶⁾ stated that as a tournament progresses towards the play-off stages the rate at which injuries occur increases. Bathgate et al. (2002)⁽³⁷⁾ found that the severity of injuries has also increased since the turn to professionalism. There was an increase seen (13%) in the severity of injuries in Australian rugby union players during the period of 1994 to 2000.⁽³⁷⁾

In terms of injury occurrence, the tackle has been found to be the most dangerous part of play and the person being tackled is more often injured than the tackler.⁽³⁸⁾ The head and

face lacerations are the most commonly seen injury, but with a low severity rate.^(24,25) The more severe injuries are associated with muscle strains and ligament sprains being most commonly seen and the lower limbs the most commonly injured body parts.^(12,25) Bathgate et al. (2002)⁽³⁷⁾ reported the locks as the most injured forward playing position overall followed by the eighth man. Of the backline players the fly-half was the most injured player with the scrumhalf sustaining the least number of injuries.⁽³⁷⁾ Brooks et al. (2005)⁽²⁵⁾ found the hooker and fly-half the positions with the most injuries and the locks and open side flanks experienced the most severe injuries. In South African players Holtzhausen et al. (2006)⁽¹²⁾ found that the fullbacks and centres accounted for the most injuries, whereas the most severe injuries were sustained by the wings and centres. Most injuries are sustained to the head and face, but are rarely severe. Forty per cent of knee injuries were severe with the medial collateral ligament being the most commonly injured structure, and at the hamstring muscle (53%) the mostly commonly torn muscle in the thigh area.⁽³⁷⁾

With this high injury incidence in rugby and the increased demands of the professional era of the sport, the return to play of a player back to a competitive level remains problematic. Premature return to competitive play increases the risk of recurrence of injury.⁽³⁵⁾ Currently the challenge still exists to find a standardized testing protocol⁽²³⁾ that can safely replicate the demands of rugby and to evaluate whether the player is ready to compete again.⁽³⁵⁾ This problem is accentuated in the smaller communities and rural areas where equipment and manpower are limited.

2.2 THE BIOMECHANICS OF THE KNEE JOINT

The knee joint is characterized as a synovial joint because it contains synovial fluid together with articular cartilage and an articular capsule.⁽²⁾ It is also described as a modified hinge joint due to the fact that it allows not only for flexion and extension movements, but also rotation.⁽⁴⁾ The knee joint is formed by four bones namely the tibia, fibula, the patella and the femur, together with ligaments, tendons and two oval fibrocartilages (the menisci).⁽³⁹⁾

The knee joint consists of two joints, namely the femorotibial joint (also known as tibiofemoral joint) and the patellofemoral joint.⁽⁴⁾ The femorotibial joint is known as the largest joint and also commonly known as the knee joint.⁽⁴⁾ Thus the knee joint consists of the medial and lateral collateral ligaments, the anterior and posterior cruciate ligaments and the medial and lateral menisci⁽³⁹⁾ and allows for articulation between the femoral condyles and tibial plateaus⁽⁴⁾ The menisci deepens the articular surface of the tibial plateaus⁽²⁾ and transfers loads across the joint. It also acts as a shock absorber and gives stability to the knee joint.⁽⁴⁾ The patella and femoral trochlea forms the patellofemoral joint.⁽⁴⁾ At the superior border of the patella the knee extensor tendons have their insertion which is then

elongated and forms the patellar tendon which crosses over the patella and inserts on the tibial tuberosity.⁽⁴⁰⁾ These anatomical properties ensure that the patella increases the mechanical advantage of the extensor muscles of the knee joint.⁽⁴⁾

The two main muscles groups around the knee joint are the knee extensors (quadriceps femoris muscle group) that consist of four muscles; the rectus femoris, vastus lateralis, vastus intermedius and the vastus medialis muscles.⁽³⁾ The quadriceps muscles are the main knee extensors of the knee. Extension is limited by the tension of the medial and lateral ligaments as well as the ACL.⁽³⁾ The second main muscle group around the knee joint is the hamstring muscle group which includes the semitendinosus, semimembranosus and biceps femoris muscles.⁽³⁾ The hamstring muscles work together to flex the knee joint. Flexion is limited by the soft structures behind the knee.⁽³⁾ Together the quadriceps and hamstring muscle groups work together to optimize the function and dynamic stability of the knee joint.

The knee joint gains its inherent static stability from the ligaments that cross the joint. The anterior cruciate ligament (ACL) prevents anterior translation of the tibia and controls rotational movements.⁽⁴⁾ The ACL is important in the stability of the knee and stabilizes the knee joint especially in pivoting movements.⁽³⁹⁾

The hamstring muscles are synergistic to the ACL and assist in preventing the anterior translation of the tibia on the femur^(41,42) in opposition to the contraction of the quadriceps which pull the tibia anteriorly.⁽⁴³⁾ The posterior cruciate ligament (PCL) prevents the femur from sliding forwards on the tibia during weight bearing movements.⁽⁴⁴⁾

Medial and lateral stability is provided by the two collateral ligaments. The medial collateral ligament (MCL) is divided in a deep and superficial portion.⁽³⁾ The MCL gives restraint to the inside of knee and resists forces from the outside, whereas the lateral collateral ligament (LCL) resists forces from the inside protecting lateral stability of the knee.⁽⁴⁾ Both these two ligaments are tight in extension.⁽³⁾

2.3 FITNESS TESTING FOR RUGBY

Rugby is showing a trend towards physique-based team selection^(27,30) and therefore annual pre-participation testing is done by the exercise specialist or therapist. It is thus important to have a testing protocol that is valid, reliable^(28,45) and which is able to predict performance based on the players skill and conditioning levels.⁽²⁹⁾ Physical performance testing is usually made up of quantitative assessments which are based on normative values to obtain information about the player's physiological abilities to improve overall

performance of the team and the individual.⁽¹⁸⁾ A battery of tests is used to measure components of fitness⁽⁴⁵⁾ and strength and power assessments are often used to monitor the training induced changes in performance or the effectiveness of rehabilitation.⁽⁴⁶⁾

Quantifying muscular capabilities is extremely challenging and to predict a person's muscular performance is difficult.⁽¹⁹⁾ Pre-season testing could give valuable information about a rugby player to a coach and the medical staff.⁽¹³⁾ It establishes a baseline on strength and power^(7,29) and a fitness profile which highlights the strengths and weaknesses of a rugby player and can help with selection and talent identification.⁽¹⁴⁾ Given the complex nature of rugby it makes it difficult to accurately assess for performance.⁽³⁴⁾ It is therefore important to identify the physical elements which are necessary for playing better rugby and selecting those tests more suitable for the rugby performance.⁽⁴⁵⁾ Physical testing can also aid in identification of injury risk factors which is valuable pre-season.^(14,24) The lack of physical conditioning can predispose the player to injuries early in the season⁽¹²⁾ thus the importance of pre-season testing in identifying the weaknesses of players can subsequently help to eliminate the possible injuries.⁽¹³⁾

2.4 LOWER LIMB MUSCLE STRENGTH AND ISOKINETICS

Strength and power are important factors in athletic events.^(47,48) Strength is the ability of a muscle to produce a force⁽⁵⁾ and muscle strength is an important factor for power.⁽⁴⁹⁾ Power production is related to the rapid production of force and therefore an important factor for success in sports.⁽⁵⁰⁾ Strength and power are often assessed to evaluate performance and effectiveness in rehabilitation and conditioning programmes.⁽⁷⁾ Strength and power testing are often restricted to the available equipment and therefore testing the chosen modality is sometimes not appropriate to the sport. There is a contrast seen between sports and laboratory testing for muscle strength and power due to the fact that current isokinetic testing involves isolated muscle strength and movement velocity is kept constant throughout the range of movement which is not true for the dynamic nature of sports.⁽⁴⁷⁾

A variety of testing modalities exist to evaluate the strength of a muscle from simple field tests to expensive advance laboratory tests⁽¹⁷⁾ as well as the differences in terms of the muscle actions and contractility.⁽⁷⁾

An isometric muscle action is a static contraction^(7,51) and testing measures the maximal voluntary contraction against an immovable object with no change in muscle length.⁽⁴⁷⁾ Isometric testing is easily administered and useful when testing large groups, but the main disadvantage is that the testing is specific to that point or angle⁽⁵¹⁾ and it is said not to be

dynamic enough for testing function.^(7,51) Isoinertional (isotonic) muscle action refers to a predetermined resistance/object that is lifted against gravity and the load is constant throughout the range of movement (ROM),^(16,17) but the tension developed is constantly changing throughout the ROM because of changes in the muscle length and deceleration and acceleration of the weight.⁽⁴⁷⁾ A successful one-repetition maximum of a task is used to assess for isoinertional muscle action. This type of assessment can have a high potential for injury, outcome is skill relative and depends on the experience of weight training of the athlete and there exists a lot of variability between the trials and equipment used.⁽⁴⁷⁾ Isoinertional type of muscle action is a combination of concentric and eccentric contractions and therefore more similar to functional activities, but gives more estimated values rather than concrete values of strength.⁽¹⁷⁾

Isokinetic muscle action is where the muscle performs at a constant preselected angular velocity and a computerized programme provides an accommodating resistance throughout the ROM^(15,52) with no initial load to overcome.⁽¹¹⁾ Isokinetics is defined as a dynamic muscle contraction while the velocity of movement is controlled.^(53,54) This implies that the resistance of the dynamometer is continuously changing and adapting to the muscular torque produced at different joint angles.⁽⁵⁵⁾

The Biodex system fulfils the criteria established by the American Academy of Orthopaedic Surgeons. These criteria take into consideration the safety, the reliability and validity of the apparatus as well as the appropriateness and the educational support of the manufacturer.⁽⁵⁶⁾ Drouin et al. (2004)⁽⁵⁷⁾ found an interclass correlation coefficient (ICC) of 0.99 for trial-to-trial reliability and day-to-day reliability as well as validity in the Biodex System 3 dynamometer. Isokinetic testing is a widely used,⁽⁵⁸⁾ reliable,⁽¹⁹⁾ objective,⁽⁵²⁾ reproducible,^(59,60) and a valid assessment tool.⁽⁵⁷⁾ The use of Isokinetic equipment does limit measurement errors that can be made by testers. Keskula et al. (1995)⁽⁶¹⁾ found that there is an interrater reliability (ICC 0.90 – 0.96) with isokinetic testing. The value of isokinetics is that it yields comparable results,⁽⁶⁰⁾ and it is a popular method to assess muscular function.⁽⁴⁶⁾ It is also valuable to be used in pre-season screening, to evaluate the effect of training and for insurance reimbursements.⁽⁵⁷⁾ One error that can be made is that the axis of rotation of a limb is not aligned with the mechanical axis of the machine and that could cause inaccurate assessment.^(53,62)

Isokinetic devices allow the individuals to exert as much force as they are able to generate up to a predetermined velocity,⁽⁶³⁾ therefore isokinetic's is dependent on the subject's effort.⁽¹⁷⁾ Isokinetic dynamometers are often used to test for dynamic strength in specific

muscle groups,^(16,17) are very useful in rehabilitation⁽⁸⁾ and are often used to evaluate the effects of conventional isotonic strength training.⁽¹⁷⁾

Isokinetic testing is a valid, commonly used method to evaluate for isolated muscle group strength in a standardized way,^(8,17,20,64,65) however, due to the nature of isokinetic movement it also tests for muscle performance.⁽⁶¹⁾ Most of the isokinetic testing is done in a non-weight bearing,⁽¹⁶⁾ single-joint isolated movement assessing the muscles' maximal strength^(7,17) which bears little resemblance to functional performance.⁽⁷⁾ However, objective isokinetic testing provides strength and power data that can guide with the rehabilitation process.⁽¹¹⁾ Furthermore, isokinetic testing is important for clinicians to assess the progression of the patient during the rehabilitation period^(7,8,20) and the results can be used to help with return to play decisions, but it should be used with caution.^(17,53) Holmes and Alderink (1984)⁽⁶⁴⁾ argued that normative isokinetic strength data are needed to aid in the assessment of injured players. Wilk (1991)⁽⁵⁶⁾ stated that isokinetics cannot be used alone and should include other clinical and functional factors when making a clinical interpretation regarding the rehabilitation outcomes and progression of a patient.

The most common parameters that are assessed during isokinetic muscle strength testing are peak torque (PT), total work (TW) and average power (AP). PT, measured in Newton metres, is the maximum amount of angular force that can be produced anywhere in the ROM in the muscle during a single repetition⁽¹⁵⁾ and is identified as the peak of the force curve in relation to the ROM.⁽⁵¹⁾ and it is also the most common measurement used for interpretation.⁽¹¹⁾

Work is defined as the product of torque and distance travelled and is established by the area under the torque curve.⁽⁵⁶⁾ It reveals the subject's ability to produce torque throughout the movement. TW is the total amount of work done with each repetition regardless of speed, ROM or time.⁽¹⁵⁾ Torque and work are inversely related to velocity.

Power is defined as the work/time equation and shows a parabolic relationship with velocity.⁽⁵¹⁾ Power may be described as the ability to express explosive strength. AP is the total amount of work done in a certain amount of time.⁽¹⁵⁾

Isokinetic testing can be done at several angular velocities ranging from 30°/sec up to 500°/sec depending on the isokinetic device. With slower speeds fewer trials are needed for reliability⁽⁶⁶⁾

Two other commonly used parameters of isokinetics are the relationship between antagonist and agonist muscles known as the reciprocal concentric ratio⁽⁶⁷⁾ and the relative PT. The reciprocal concentric ratio is the relationship between the strength of the weaker muscle group divided by the strength of the stronger muscle group.⁽⁶⁾ The normative PT is to correct for body weight and therefore take the build of a player into consideration.⁽⁶⁷⁾ A significant correlation exists between PT and body weight.⁽⁶⁴⁾

2.5 ISOKINETICS AND THE KNEE JOINT

The knee is the most common joint tested^(42,64) and is tested in extension and flexion patterns. The knee extensor PT has been found to be a reliable measurement.^(58,59) The extension-flexion motions are given through the concentric hamstring to quadriceps (H:Q) ratio.⁽⁴¹⁾ The H:Q ratio is calculated by dividing the PT of the hamstring muscle group by the PT of the quadriceps muscle group.⁽⁶⁸⁾ The H:Q ratio ranges from 0.5 – 0.8 (50 to 80%)^(13,41,42) and gives valuable data on knee stability, functional performance and muscle imbalances.^(55,67) The H:Q ratio increases as the angular velocities increases.^(41,64) A low H:Q ratio can predispose the player to certain injuries^(13,69) especially ACL injuries⁽⁴¹⁾ and therefore preseason assessment on the H:Q ratios can be of great value.⁽⁴²⁾ This is in contrast to Rothstein et al.⁽⁵³⁾ who argued that the ratios generated from isokinetic data should not be used to make clinical decisions.

Lategan (2011)⁽⁶³⁾ recently found that mean peak torque knee flexion values in South African men between 16 and 26 years old was 158.5Nm and for knee extension 235.9Nm. He stated that young South African men had higher PT knee extension/flexion values than their international counterparts when tested at an angular velocity of 60°/sec.⁽⁶³⁾ In another study done by Lategan (2012)⁽⁷⁰⁾ he found mean PT values for men (21 years) of 204.3Nm during extension at an angular velocity of 60°/sec and 107.8Nm for knee flexion at the same velocity. At 180°/sec angular velocity he found mean PT values for knee extension of 147.2Nm and flexion 81.4Nm.⁽⁷⁰⁾ This is consistent with the fact that PT knee extensor strength will decrease with increased testing velocity.⁽⁵⁸⁾

2.6 LOWER LIMB MUSCLE POWER AND VERTICAL JUMP

Power is the ability of the neuromuscular system to overcome resistance at a high speed contraction⁽⁴⁸⁾ and thus it is the rate at which the force is produced.⁽⁵⁾ Power can be assessed where either the velocity or the load is kept constant, but this is not a true assessment of the sporting environment where the velocity and load constantly change.⁽⁴⁷⁾ Power is therefore dependent on strength and the velocity of the moving limb.⁽⁷¹⁾ The vertical jump test is an effective indirect measurement of power.^(19,72) Muscle power is the

basis of physical effort in rugby and the vertical jump is commonly used to assess for explosive leg power in rugby.^(28,45,49)

Vertical jumping is a gross-locomotor skill which results from maximal effort from sequential summed moments of several muscles.⁽¹⁹⁾ The vertical jump test is a functional closed kinetic chain test, easily measured which assesses the power output of the legs and can be used as a laboratory or field tests.^(18,65,72,73) For the field test the maximum jump height is most commonly assessed during the vertical jump.⁽⁷²⁾ The Vertec (Sports Imports, Hilliard, OH) is mostly used for the field testing instead of the older method of the Sargent jump using a board and chalk dust.⁽⁷⁴⁾ The Vertec is a metal pole with colour plastic vanes attached to the pole in 0.0127m increments.⁽⁷⁵⁾ The metal pole is adjusted according the standing reaching height of the person. The maximum jump height reached is determined with the highest swivel touched during the jump.⁽⁷⁵⁾ The drawback of the Vertec is that the results could be depended on the shoulder ROM of the athlete or the ability of touch the vane at the highest point.^(72,75) The maximum jump height in centimetres is calculated by subtracting the standing reaching height from the jump height reached.⁽⁷²⁾ Laboratory vertical jump testing today makes use of the force plates (Just Jump Systems) and motion analysis systems.^(74,75) These systems do not allow for human error as the Vertec does but it is more expensive and requires also personnel that are trained in using the equipment.⁽⁷⁵⁾

There are two forms of the vertical jump commonly tested namely the squat jump and the counter movement jump.⁽⁵¹⁾ In the squat jump the player lowers himself into a squat position (not past 90° of knee flexion) and jumps up after a pause as high as possible. The squat position is therefore the starting position and thus the squat jump only requires concentric activation.^(73,76) The take-off phase is considered to be a concentric action leading to extension of the hip and knee joints which are produced by the hamstring, quadriceps and gluteal muscle groups. This is followed by plantar flexion of the ankle joint caused by the soleus and gastronemius muscles.^(77,78) The counter-movement jump on the other hand allows for a countering movement with knees bending as far as each participant feels comfortable (dropping down) and immediately jumps upwards.⁽⁵¹⁾ The counter-movement jump requires moderate eccentric activation followed by high concentric activation.^(73,76) Both tests can be either with or without arm movement. The arm swing is better for the jumping height.⁽⁷⁹⁾

The amount of force needed in a vertical jump depends on a subject's body weight⁽⁷³⁾ and therefore body weight needs to be corrected for by converting the results to mechanical work or power. A heavier person will need greater extension strength to overcome the higher external resistance during jumping.⁽⁷⁹⁾ When a heavier subject jumps the same

height/distance than a lighter subject the heavier one will generate more force.⁽¹⁶⁾ The inclusion of body mass reflecting better results was also found by English et al.⁽¹⁶⁾ and Genuario and Dolgener (1980)⁽⁷¹⁾. Several power prediction formulae were developed to estimate average power⁽⁷²⁾ and total work.⁽⁸⁰⁾ One of the first power calculations was the Lewis formula where body mass was included in the calculation, but did not account for gravitation.⁽⁷⁹⁾ Harman and colleagues (1991)⁽⁸¹⁾ developed prediction equations for peak and average power taking gravity into consideration.

In general the backline players perform better with the vertical jump than the forwards, but Quarrie et al.⁽³⁰⁾ also stated that the body mass of the players needs to be taken into consideration when comparing backline players to forwards.

A few questions still remain uncertain. Can vertical jumping power truly predict muscular explosive power⁽⁷⁹⁾ and what physical characteristics all predict vertical jump performance?⁽⁸²⁾ The knee extensors of the thigh contribute most to the vertical power during the jump⁽⁷⁾ but Anderson et al. (1991)⁽²¹⁾ found no correlation in quadriceps and hamstring strength to the vertical jump. They stated that other factors besides leg strength, like neuromuscular adaptations will improve performance and must be considered for prediction of performance in the vertical jump in a trained athlete.⁽²¹⁾ Lieberman and Katz (2003)⁽¹⁹⁾ on the other hand are of the meaning that lower limb power measured from the vertical jump test could be an indication to the performance of the knee extensor muscles but it all depends on the calculation method used. Also the jumping movement requires the activation of all lower limb muscle groups which can influence the jumping ability.⁽⁸⁾

2.7 ISOKINETICS AND VERTICAL JUMP

The relationship between isokinetics and vertical jump can be of importance due to isokinetic testing being expensive and most schools and colleges not having this sophisticated equipment to measure strength and power characteristics of the legs. It is important to consider the phase of training and the level of the athlete when correlation is done between these two tests.⁽¹⁸⁾ It is still not clear whether isokinetics can provide valid measurements for assessing muscular power.⁽⁴⁸⁾ Research has been done regarding the relationship between isokinetic testing and vertical jump however, with contradictory results.^(7,8,11,14,18-22,58,60,73,82) There exists a better correlation between isokinetic testing and the vertical squat jump and counter movement jump height at higher angular velocities.⁽⁷¹⁾ Moderate correlations were found between PT knee extension and the squat jump height at 180°/sec ($r = 0.546 - 0.691$),^(11,18,60) but other studies also found a moderate correlation at 60°/sec ($r = 0.629 - r = 0.760$).^(18,83) Testing done with the counter movement jump also shows this tendency ($r = 0.515 - 0.642$),^(18,60,73) but Osterberg et al. (1998)⁽²⁰⁾ found a low

correlation between vertical counter movement jump height and isokinetic PT knee extension at 180°/sec ($r = 0.23$) and stated that these two tests cannot be used in the place of the other.

Augustsson and Thomeé (2000)⁽⁷⁾ found a moderate relationship between the counter movement vertical jump height and peak torque knee extension done at 60°/sec ($r = 0.57$) whereas Osterberg et al. (1998)⁽²⁰⁾ found no correlation. Male university students do not show any correlation between countermovement jump height and isokinetic testing done at angular velocities of 60°/sec or 180°/sec.^(21,22) The same results were found in first division basketball players.⁽¹⁴⁾

There seems to be a better correlation when there is a correction for body weight regarding the height reached in the vertical jump. A better correlation with isokinetic strength values and functional hopping tests for distance are attained by including the subject's body mass into the equation and rather to use the work done in power instead of the absolute jumping height, and thus English et al. (2006)⁽¹⁶⁾ recommend the inclusion of body weight. A better trend exists for correlation between faster isokinetic angular velocities ($r = 0.91$ at 300°/sec $p < 0.05$) using peak power measurements of the knee extensors and the squat vertical jump peak power compared to the slower velocities where they found no correlation ($r = 0.31$ at 30°/sec).⁽⁸⁾ Moderate to strong correlations are found in counter-movement jump work to PT knee extensors at various speeds ($r = 0.599 - 0.848$).^(19,60,84) Out of these findings it can be seen that the testing velocity of isokinetic testing does influence the results. Tsiokanos et al. (2002)⁽⁶⁰⁾ found a stronger correlation to squat jump work to knee PT extensors at different speeds ($r = 0.739 - 0.778$).

Jameson et al. (1997)⁽⁶⁵⁾ tested student participants who were divided into categories of sedentary, active and trained. The total group had a moderate correlation ($r = 0.57$) to peak torque of the quadriceps at 180°/sec and one leg vertical jump peak force (using the ground reaction force method for peak force generation). The trained subjects had a higher correlation to the vertical jump ($r = 0.85$).⁽⁶⁵⁾

The above mentioned contradictions can be due to different angular velocities selected (60, 120, 180, 240 or 300 degrees/second) or the different calculation methods applied in calculating the vertical jump for comparing work done. Different types of testing equipment were also used.^(65,73) In addition previous studies investigated sporting codes such as volleyball, basketball and soccer and included both genders. Therefore it is difficult to draw correlations from the available literature. The only studies applying isokinetics and vertical jump in a similar fashion were the two studies of Genuario and Dolgener (1980)⁽⁷¹⁾ and Tsiokanos et al. (2002)⁽⁶⁰⁾, but the testing was done on females and males respectively.

CHAPTER 3

3. METHODOLOGY

3.1 METHODS OF STUDY

In this chapter the researcher will describe the methods and procedures undertaken during the experimental work of this study.

3.2 STUDY DESIGN

This was a cross-sectional study design using retrospective data from 2011/2012 to describe the association between vertical jump performance and isokinetic knee joint muscle strength. All participants had to give consent prior to the routine rugby testing.

3.3 SITE OF STUDY

The data were gathered by the researcher at the Biokinetics Institute of the North-West University, Potchefstroom Campus (Appendix A). Permission to use this data was granted by North-West University (Appendix B).

3.4 STUDY POPULATION AND SELECTION

The sample group comprised 51 male rugby players from the Rugby Institute at the North-West University, Potchefstroom Campus who were members of the 2011/2012 pre-season Varsity Cup squad. The rugby players were between 20 and 25 years old. The selection of the pre-season team was made by the coach and all squad members took part in the pre-season physiological testing. The players who participated in the testing did not have any current injuries or had been fully rehabilitated from previous injuries and had played in the last six rugby games of the previous season. The testing was performed at the end of the 2011 season and prior to the start of the 2012 season.

3.5 MEASURING TOOLS AND INSTRUMENTATION

3.5.1 Anthropometry

The height and weight measuring was done according to the international standards for anthropometric assessment 2011.⁽³⁰⁾ For the height a stadiometer was used in combination with the stretch method where the subject had to stand with heels together and the heels, buttocks and upper part of the back touching the stadiometer. The head was put in the Frankfort plane. The subject was instructed to inhale and the measurement was taken before the subject exhaled.⁽⁸⁵⁾ Height was measured in meters (m) to the nearest 0.1m.

The weight was measured with an electronic scale (Micro electronic platform T3, C.o.m.i.r., SA), the subject stood on the scale for 3 sec and the weight was taken. The subject was

barefoot and wore only shorts for these measurements. Weight was measured in kilograms (kg) to the nearest 0.1kg.

3.5.2 Isokinetic Testing

A Biodex System 4 Isokinetic Dynamometer[™] (Shirley, New York) was used to determine the strength of the quadriceps and hamstring muscle groups. Prior to testing the subject completed a five minute warm up on a cycle ergometer and performed 15 repetitions of dynamic stretching of the lower limb muscles.

The subject was then placed in a seated position on the Biodex chair with the back seat in an upright angle (85°). The upper thigh, shoulders and hips were stabilized with straps in order to isolate the limb being tested. The subject's lateral femoral condyle was aligned with the central axis of the dynamometer. The subject was instructed to take hold of the handles next to his sides. The anatomical zero was set at 90° of knee flexion and full extension was the end point.

A gravity torque correction was performed at 30° of knee extension according to the manufacturer's prescription (Biodex multi-joint system pro, operational manual).⁽⁸⁶⁾ A gravitational correction is done when testing knee extension – flexion in the vertical plane to rule out gravitational error.⁽⁵⁵⁾ Correcting for the effect of gravity increases the quadriceps torque value and decreases the hamstrings torque value.⁽¹⁵⁾

The player was given five warm-up repetitions at 60°/sec and then five maximal efforts were performed by the subject for the test. There was a two minute rest and again a warm-up of five repetitions at 180°/sec and ten maximal efforts were performed for the tests. Another rest period of two minutes was given and again the player had five warm-up repetitions at 300°/sec followed by fifteen repetitions of maximal effort for the test. This was done bilaterally with the dominant limb tested first followed by the non-dominant limb. It was important to increase the repetitions with higher speeds to ensure for better accuracy.⁽⁶⁶⁾ The highest peak torque was documented together with the relative peak torque and reciprocal ratio's at every speed. Verbal motivation was given to the players. Dominance was established by asking the players which leg they would prefer to kick the ball with.

3.5.3 Single Leg Vertical Jump

This test was done on a separate day from the isokinetic testing. A Vertec (sports imports, Hilliard, OH) vertical jump apparatus was used according to the methods described by Klavara.⁽⁷²⁾ The subject warmed up for five minutes on a cycle ergometer and did 15 repetitions of dynamic stretches of the lower limb muscles. The subject's standing height

was measured with his one arm fully extended upward and reached to the highest possible vane. This mark was taken as the zero starting position. The subject was instructed to stand on one leg and to place his hands on his hips and bend down and start from a squat position (not further than 90° of knee flexion) and hold the position for a few seconds. From there they were instructed to jump-up from one leg and touch the vane at the highest possible point without any other countermovement of the legs or arms.

The jump height was measured from the difference between standing height and jumping height. The subject had three trail repetitions followed by three test repetitions. The measurement of the best of three test repetitions in centimetres was taken and documented. This was done bilaterally with the dominant leg tested first followed by the non-dominant leg. The formula used for the peak power produced was the formula proposed by Haman et al.(81): Peak power (W) = 61.9 • jump height (cm) + 36.0 • body mass (kg) + 1822.

3.6 STATISTICAL ANALYSIS

Data analysis was done with the SPSS software (IBM. SPSS version 21).

3.6.1 Descriptive Statistics

Means and standard deviations were reported to descriptively characterize participants and variables measured. The sample size was larger than 30 and therefore by the central limit theorem of normality can be assumed.⁽⁸⁷⁾

3.6.2 Exploratory Analysis

3.6.2.1 Pearson's product moment correlation coefficient

The relationship between isokinetic knee extensor and flexor strength and vertical jump performance were determined by means of Pearson's correlations. Statistical significance was set at $p \leq 0.05$ (95%) and the correlation coefficient (r) was used as a measure of practical significance or effect, with values between 0.3 and 0.5 indicating a practically visible relationship and values of 0.5 and higher indicating a practically significant relationship.

3.6.2.2 Independent T-test

The independent T-test was used where equal variances were not assumed to assess for any differences between forward and backline players for the peak torque (Nm), peak torque to bodyweight percentage (PT/BW) and reciprocal ratio's (%).

3.6.2.3 Paired T-test

A paired T-test was performed to assess if any bilateral differences existed between the means of each testing parameter.

3.7 ETHICAL ASPECTS

A letter of approval from the research focus area, Physical Activity Sport and Recreation (PhASRec) of the North West University for the use of data has been given (Appendix B). Ethical clearance was applied for and granted (M130232) by the University of the Witwatersrand Human Research Ethics Committee (HREC) (Appendix C). All participants signed informed consent forms prior to being tested (Appendix D).

CHAPTER 4

4. RESULTS

4.1 DEMOGRAPHIC INFORMATION

Fifty one rugby players from the Rugby Institute at the North-West University, Potchefstroom campus who were members of the 2011/2012 pre-season Varsity Cup squad were tested. The group had a mean age of 21.4 ± 1.2 years; weighed 99.3 ± 13.8 kg and were 1.83 ± 7.4 m tall (Table 4.1). There were 26 forward players (mean height of 1.88 ± 7.2 m and mean weight of 109.9 ± 10.3 kg) and 25 backline players (mean height of 1.80 ± 5.5 m and mean weight of 88.3 ± 6.1 kg). The forward players were found to be significantly taller ($p = 0.0001$) and weighed significantly ($p = 0.0001$) more than the backline players. All players were reported as being right dominant.

Table 4.1: Demographic Information for the Total Group (n=51) of Rugby Players

	Backline players (n=25)	Forward players (n=26)	Total group (n=51)
Age (years)	21.6 ± 1.2	21.3 ± 1.2	21.4 ± 1.2
Height (m)	1.80 ± 5.5 *	1.88 ± 7.2	1.83 ± 7.4
Weight (kg)	88.3 ± 6.1 #	109.9 ± 10.3	99.3 ± 13.8

* Backline height vs. forward height: $p = 0.0001$

Backline weight vs. forward weight: $p = 0.0001$

4.2 VERTICAL JUMP MEASUREMENTS

Figure 4.2 below shows the mean vertical jump height for the total group of rugby players and comparing the forward and backline players. There was no difference between the non-dominant (37.3 ± 7.0 cm) and dominant (36.3 ± 5.7 cm; $p = 0.432$) sides when comparing the total group of rugby players. However, when comparing the backline and forward players, the backline players were able to jump higher when using the non-dominant leg (39.5 ± 6.7 cm) compared to the forward players (35.2 ± 6.8 cm) ($p = 0.028$). There was no difference in jump height between the forward (35.0 ± 5.1 cm) and backline (37.6 ± 6.0 cm) players when analysing the dominant side ($p = 0.96$).

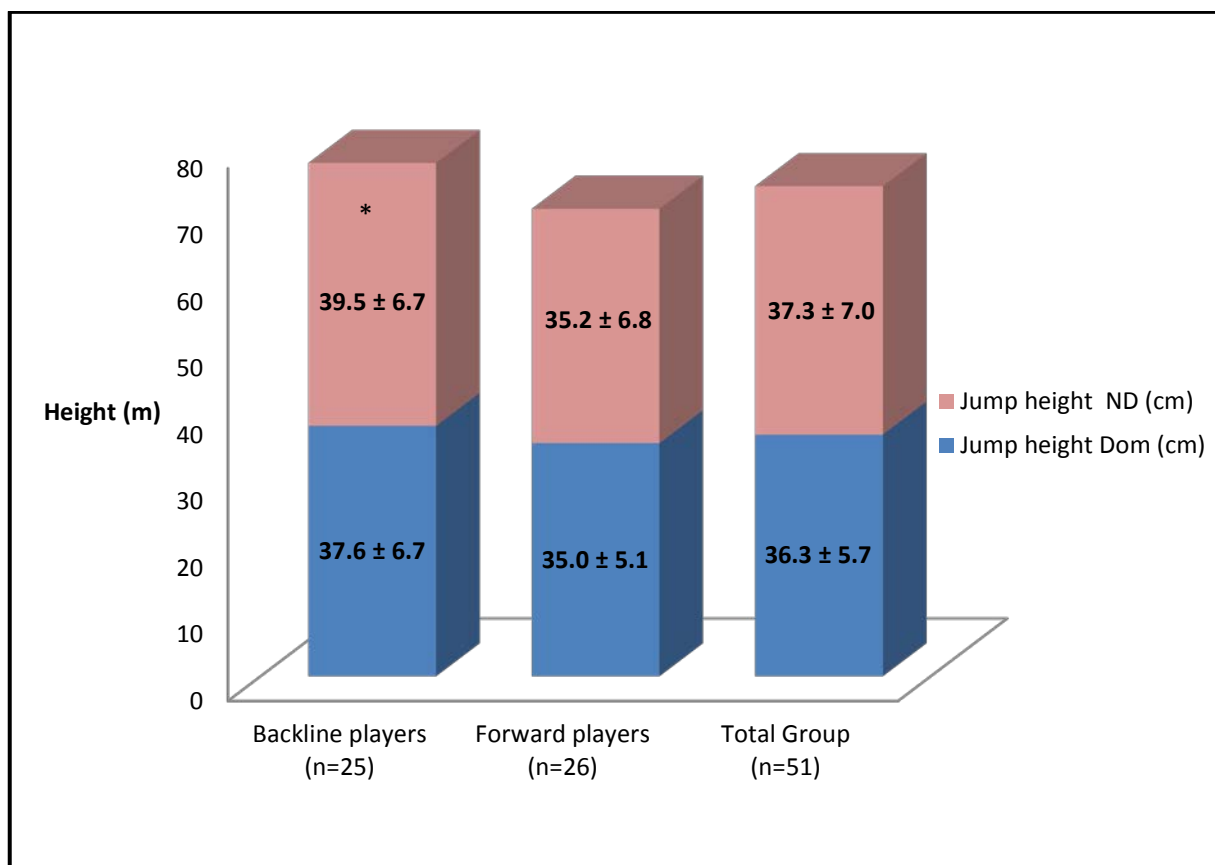


Figure 4.1: Mean Vertical Jump Height for the Total Group of Rugby Players (n=51) and Comparing the Backline (n=25) and Forward Players (n=26)

** Backline vs Forward players Jump height ND $p = 0.028$*

Figure 4.2 below shows the mean peak power output during the vertical jump tests for the total group of rugby players and comparing the backline to the forward players. The peak power output in the total group showed no difference when assessing differences between the dominant and non-dominant legs (D: 7645.4 ± 507.2watts vs. ND: 7707.2 ± 492.3watts: $p = 0.534$). When comparing the forward to the backline players, the forward players were found to have a significantly greater peak power output compared to the backline players on both the dominant (Forwards: 7946.0 ± 396.5watts vs. Backline: 7332.7 ± 415.3watts: $p=0.0001$) and non-dominant sides (Forwards: 7958.4 ± 404.0watts v Backline: 7445.9 ± 442.2watts: $p=0.0001$).

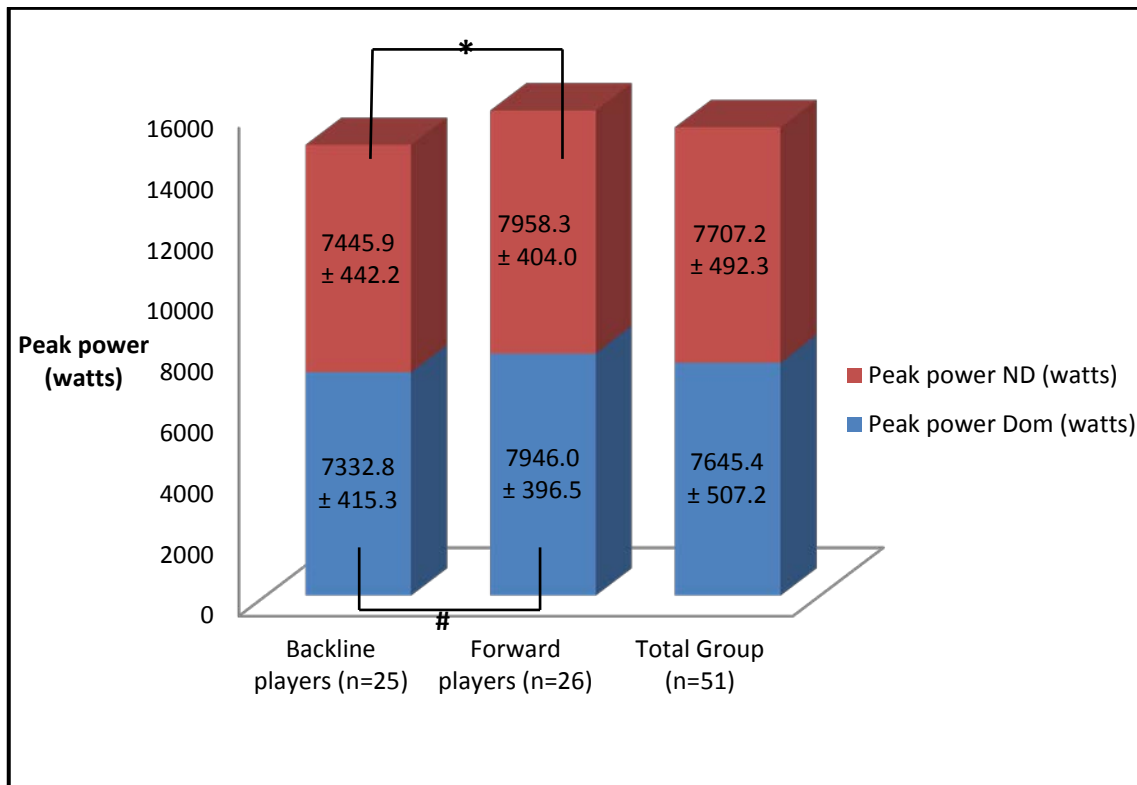


Figure 4.2: Mean Vertical Jump Peak Power for the Total Group of Rugby Players (n=51) and Comparing the Backline (n=25) and Forward Players (n=26)

* Forward vs backline players peak power ND $p = 0.0001$

Forward vs backline players peak power Dom $p = 0.0001$

4.3 ISOKINETIC PARAMETERS

4.3.1 Quadriceps Peak Torque (Nm)

Table 4.2 below shows the mean quadriceps peak torque for the total group of rugby players and comparing the forward and backline playing positions. For the total group, the quadriceps peak torque on the dominant side was found to have a trend of being stronger than the non-dominant side; however there were no significant differences at the different velocities.

When comparing the forward to the backline players, the forward players had a significantly greater quadriceps muscle peak torque on the dominant leg at 60°/sec (forwards: $288.4 \pm 60.4\text{Nm}$ vs. backline $253.3 \pm 45.4\text{Nm}$) ($p = 0.024$) and at 180°/sec (D: forwards: $207.3 \pm 37.9\text{Nm}$ vs. backline: $183.1 \pm 26.0\text{Nm}$) ($p = 0.011$). There were no differences in the quadriceps peak torque on the non-dominant side between the forward ($274.3 \pm 76.1\text{Nm}$) and backline players ($248.8 \pm 44.0\text{Nm}$) ($p = 0.152$) at 60°/sec and at 180°/sec (ND: forwards: $195.1 \pm 41.6\text{Nm}$ vs. backline: $177.2 \pm 29.5\text{Nm}$) ($p = 0.083$). However, at the fastest speed of 300°/sec, the quadriceps peak torque was greater in the forward players

on both the dominant (forwards $159.4 \pm 30.5\text{Nm}$, backline $137.6 \pm 24.6\text{Nm}$) ($p=0.007$) and non-dominant sides (forwards $153.5 \pm 28.4\text{Nm}$, backline $134.9 \pm 21.4\text{Nm}$) ($p=0.011$).

Table 4.2: Mean Quadriceps Muscle Peak Torque Values at 60°/sec, 180°/sec and 300°/sec for the Rugby Players (n=51) and Comparing Forward (n=26) and Backline (n=25) players

Variable	Backline players (n=25)	Forward players (n=26)	Total Group (n=51)
PT60 Quadriceps Dom (Nm)	253.5 ± 45.4	$288.4 \pm 60.4^*$	271.3 ± 55.9
PT60 Quadriceps ND (Nm)	248.8 ± 44.0	274.3 ± 76.1	261.8 ± 63.1
PT180 Quadriceps Dom (Nm)	183.1 ± 26.0	207.3 ± 37.9	195.4 ± 34.6
PT180 Quadriceps ND (Nm)	177.2 ± 29.5	195.1 ± 41.6	186.3 ± 36.9
PT300 Quadriceps Dom (Nm)	137.6 ± 24.6	$159.4 \pm 30.5^\#$	148.7 ± 29.6
PT300 Quadriceps ND (Nm)	134.9 ± 21.4	$153.5 \pm 28.4^\&$	144.4 ± 26.7

Abbreviations: Dom: dominant; ND: non-dominant

** Forward vs Backline players PT60 Quadriceps Dom: $p = 0.024$*

^\# Forwards vs Backline players PT300 Quadriceps Dom: $p = 0.007$

^\& Forwards vs Backline players PT300 Quadriceps ND: $p = 0.011$

4.3.2 Quadriceps Peak Torque/Body Weight Ratio (%)

Table 4.3 below shows the mean quadriceps muscle peak torque to body weight (PT/BW) ratios (%) for the total group of rugby players and the group split into their forward and backline playing positions. When analysing the total group, the PT/BW ratio between the dominant and non-dominant sides were not different at 60°/sec (D: $274.8 \pm 54.8\%$ vs. ND: $265.2 \pm 60.3\%$: $p = 0.398$), 180°/sec (D: $198.4 \pm 34.8\%$ vs. ND: $189.1 \pm 37.4\%$: $p = 0.198$) and 300°/sec (D: $150.7 \pm 28.7\%$ vs. ND: $146.5 \pm 26.6\%$: $p = 0.441$) speeds.

When comparing the groups the backline players had a significantly larger PT/BW ratio for the quadriceps muscle on the non-dominant leg (backline: $200.2 \pm 32.4\%$ vs. forwards: $178.4 \pm 39.3\%$) ($p=0.035$) at 180°/sec. There were no differences between the players on either the dominant (backline: $286.0 \pm 47.1\%$ vs. forwards: $264.1 \pm 60.2\%$) ($p=0.155$) or non-dominant (backline: $280.9 \pm 46.4\%$ vs. forwards: $250.0 \pm 68.7\%$) ($p=0.067$) sides for the slower speed; the dominant side at 180°/sec (backline: $207.0 \pm 29.2\%$ vs. forwards: $190.0 \pm 38.2\%$) ($p=0.081$); or the dominant (backline: $155.6 \pm 27.6\%$ vs. forwards: $146.0 \pm 29.6\%$) ($p=0.241$) and non-dominant (backline: $152.5 \pm 25.1\%$ vs. forwards: $140.6 \pm 27.2\%$) ($p=0.111$) sides for the faster speed of 300°/sec.

Table 4.3: Mean Quadriceps Muscle Peak Torque to Body Weight Ratios (%) at 60°/sec, 180°/sec and 300°/sec for the Rugby Players (n=51) and Comparing Forward (n=26) and Backline (n=25) Players

Variable	Backline players (n=25)	Forward players (n=26)	Total Group (n=51)
PT/BW 60 Quadriceps Dom (%)	286.0 ± 47.2	264.1 ± 60.2	274.9 ± 54.8
PT/BW 60 Quadriceps ND (%)	280.9 ± 46.4	250.0 ± 68.6	265.2 ± 60.3
PT/BW 180 Quadriceps Dom (%)	207.0 ± 29.2	190.0 ± 38.2	198.4 ± 34.8
PT/BW 180 Quadriceps ND (%)	200.2 ± 32.4 *	178.4 ± 39.3	189.1 ± 37.4
PT/BW 300 Quadriceps Dom (%)	155.6 ± 27.6	146.0 ± 29.6	150.7 ± 28.7
PT/BW 300 Quadriceps ND (%)	152.5 ± 25.1	140.6 ± 27.2	146.5 ± 26.6

Abbreviations: Dom: dominant; ND: non-dominant

** Backline vs Forward players PT/BW 180 Quadriceps ND = $p=0.035$*

4.3.3 Hamstring Peak Torque (Nm)

Table 4.4 below shows the mean hamstring muscle peak torque for the total group of rugby players and the group split into their forward and backline playing positions. For the total group, the mean hamstring muscle peak torque did not show any statistical significance between the dominant and non-dominant sides

The forward players showed a significantly larger peak torque hamstring strength on the dominant leg at 60°/sec (forwards: $151.4 \pm 28.5\text{Nm}$, backline: $127.6 \pm 23.6\text{Nm}$; $p = 0.002$), however no significance was seen on the non-dominant leg (forwards: $138.5 \pm 29.3\text{Nm}$ vs. backline: $127.2 \pm 22.3\text{Nm}$; $p = 0.128$). The forwards also showed a larger hamstring muscle peak torque strength at 300°/sec on the non-dominant side for the forwards ($90.9 \pm 23.5\text{Nm}$) compared to the backline ($80.0 \pm 12.5\text{Nm}$; $p=0.045$) and no significant difference in the dominant side (forwards: $94.9 \pm 22.6\text{Nm}$ vs. backline: $86.0 \pm 16.9\text{Nm}$; $p = 0.119$). At the medium speed of 180°/sec no significance was seen on the non-dominant side or the dominant side.

Table 4.4: Mean Hamstring Muscle Peak Torque Values at 60°/sec, 180°/sec and 300°/sec for the Rugby Players (n=51) and Comparing Forward (n=26) and Backline (n=25) Players

Variable	Backline players (n=25)	Forward players (n=26)	Total Group (n=51)
PT60 Hamstring Dom (Nm)	127.6 ± 23.6	151.4 ± 28.5 *	139.7 ± 28.3
PT60 Hamstring ND (Nm)	127.2 ± 22.3	138.5 ± 29.3	133.0 ± 26.5
PT180 Hamstring Dom (Nm)	102.4 ± 21.0	114.5 ± 23.1	108.6 ± 22.7
PT180 Hamstring ND (Nm)	100.0 ± 18.9	108.3 ± 26.3	104.2 ± 23.1
PT300 Hamstring Dom (Nm)	86.0 ± 16.9	94.9 ± 22.6	90.6 ± 20.3
PT300 Hamstring ND (Nm)	80.0 ± 12.5	90.9 ± 23.5 #	85.5 ± 19.5

Abbreviations: Dom: dominant; ND: non-dominant

** Forward vs Backline players PT60 Hamstring Dom $p = 0.002$*

Forward vs Backline players PT300 Hamstring ND $p=0.045$

4.3.4 Hamstring Peak Torque/Body Weight Ratio (%)

Table 4.5 below shows the mean quadriceps muscle peak torque to body weight (PT/BW) ratios (%) for the total group of rugby players and the group split into their forward and backline playing positions. When analysing the total group, the PT/BW ratio at all the speeds did not show any difference between the dominant and non-dominant sides

The backline players showed a significantly larger peak torque to body weight ratio at 60°/sec on the non-dominant leg (forwards: 127.1 ± 30.5% vs. backline: 143.8 ± 25.2%) ($p = 0.038$), and no difference on the dominant side (forwards: 138.7 ± 28.1% vs. backline: 144.1 ± 26.2%) ($p = 0.483$). Furthermore, at the higher speeds there were also no difference found at 180°/sec and 300°/sec on the dominant and non-dominant side.

Table 4.5: Mean Hamstring Muscle Peak Torque to Body Weight Ratios (%) at 60°/sec, 180°/sec and 300°/sec for the Rugby Players (n=51) and Comparing Forward (n=26) and Backline (n=25) Players

Variable	Backline players (n=25)	Forward players (n=24)	Total Group (n=51)
PT/BW 60 Hamstring Dom (%)	144.1 ± 26.2	138.7 ± 28.1	141.3 ± 27.0
PT/BW 60 Hamstring ND (%)	143.8 ± 25.2*	127.1 ± 30.5	135.3 ± 29.0
PT/BW 180 Hamstring Dom (%)	115.8 ± 24.1	105.3 ± 24.7	110.4 ± 24.8
PT/BW 180 Hamstring ND (%)	113.0 ± 21.3	99.6 ± 27.5	106.2 ± 25.3
PT/BW 300 Hamstring Dom (%)	97.3 ± 19.4	87.3 ± 23.4	92.2 ± 21.9
PT/BW 300 Hamstring ND (%)	90.7 ± 16.3	83.4 ± 22.4	87.0 ± 19.8

Abbreviations: Dom: dominant; ND: non-dominant

** Backline vs Forward players PT/BW 60 Hamstring ND (%) $p = 0.038$*

4.3.5 Unilateral Hamstring/Quadriceps Reciprocal Ratio (%)

Figure 4.3 shows below the unilateral hamstring/quadriceps reciprocal ratio (%) for the total group of rugby players and comparing the forward and backline playing positions. When analysing the total group no statistical differences were seen between the dominant and non-dominant legs.

Furthermore, there were no differences found between the forward and backline players on the dominant side and on the non-dominant side at all three speeds.

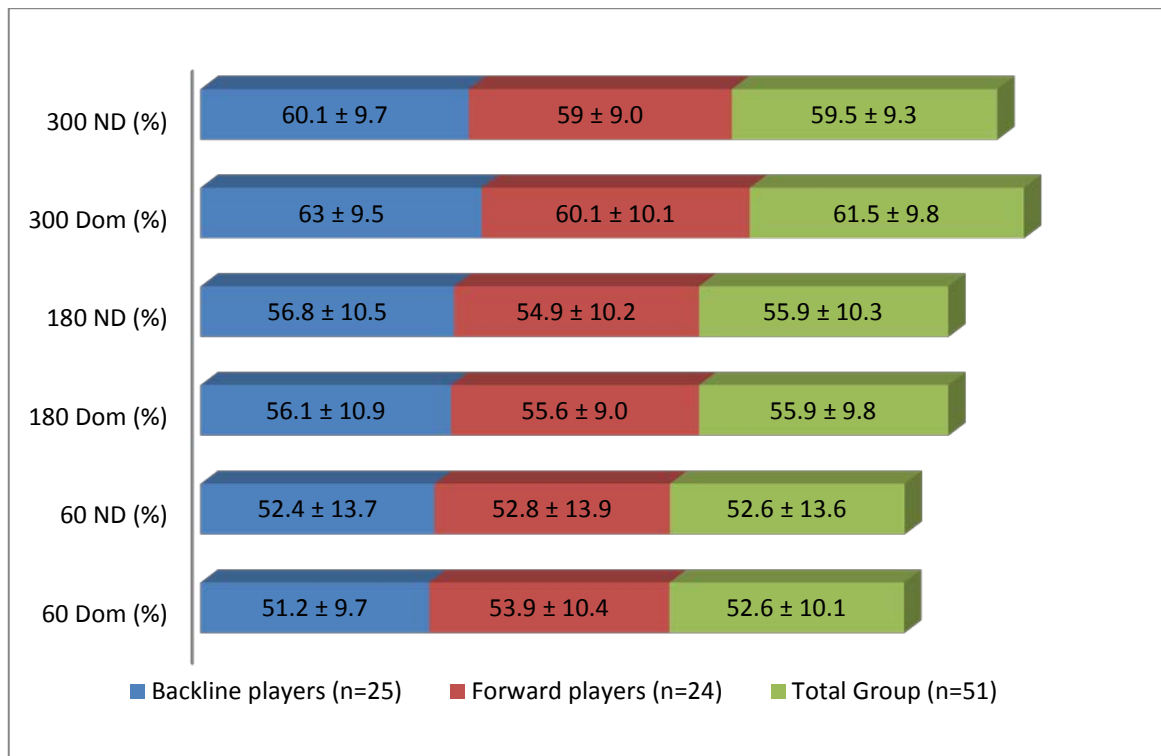


Figure 4.3: Mean Unilateral Reciprocal Ratio (%) at 60°/sec, 180°/sec and 300°/sec for the Rugby Players (n=51) and Comparing Forward (n=26) and Backline (n=25) Players

Abbreviations: Dom: dominant; ND: non-dominant

4.4 CORRELATIONS

Table 4.6 and Figure 4.4 below shows the correlations between the vertical jump height (cm) and PT of the hamstring and quadriceps muscle groups at three speeds for the total group of rugby players. The only significant correlation found was a negative correlation between the non-dominant hamstring muscle PT at 60°/sec and the vertical jump height on the non-dominant side ($r = -0.313$; $p=0.025$) (Figure 4.4). All other correlations between vertical jump height and hamstring and quadriceps PT were not significant (Table 4.6).

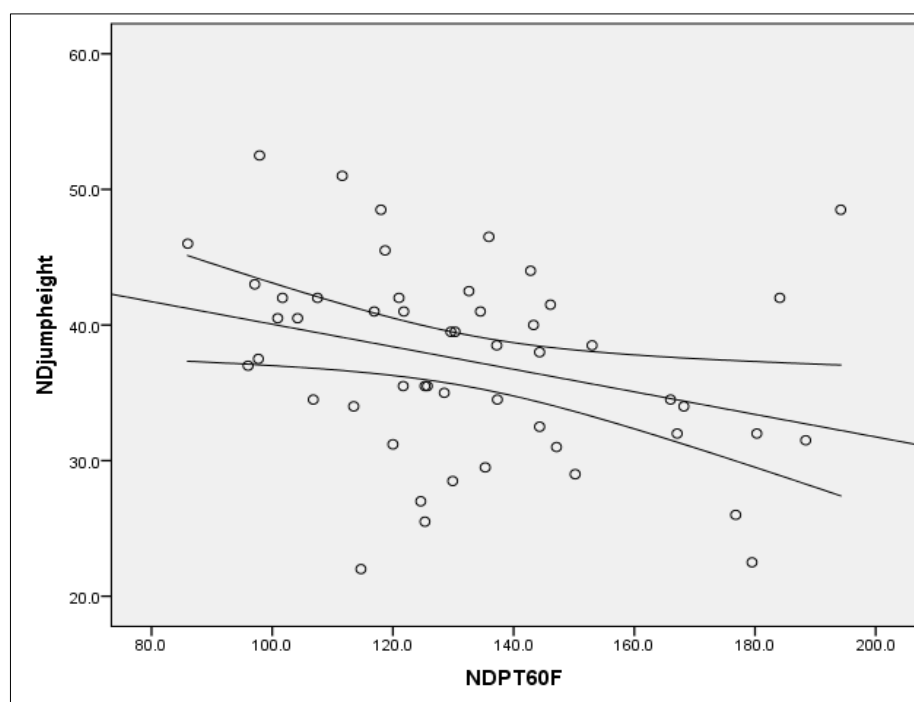


Figure 4.4: Correlation between Vertical Jump Height (cm) and Hamstring Peak Torque (Nm) at 60°/sec on the Non-Dominant Side for the Rugby Players (n=51) $r = -0.313$, $p = 0.025$ [95%CI]

Abbreviations: NDPT60F: non-dominant peak torque at 60°/sec flexion; ND: non-dominant

Table 4.6: Correlation Between Vertical Jump Height (cm) And Quadriceps And Hamstring Peak Torque (Nm) at 60°/sec, 180°/sec and 300°/sec for the Rugby Players (n=51)

Variable	Dom jump height r (p)	ND jump height r (p)
PT 60 quadriceps	-0.230 (0.105)	- 0.212 (0.134)
PT 180 quadriceps	-0.081 (0.572)	- 0.162 (0.257)
PT 300 quadriceps	-0.026 (0.857)	- 0.098 (0.492)
PT 60 hamstrings	-0.115 (0.420)	- 0.313 (0.025)*
PT 180 hamstrings	-0.085 (0.551)	- 0.125 (0.384)
PT 300 hamstrings	0.096 (0.503)	- 0.112 (0.434)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque

**PT 60 hamstring muscle strength vs ND jump height*

Table 4.7 and Table 4.8 below show the correlations within the backline and forward player groups for the vertical jump height (cm) and PT (Nm) of the hamstring and quadriceps muscle groups at the three different speeds. No correlations were found between the vertical jump height and isokinetic peak torque parameters in either the backline or forward players.

Table 4.7: Correlation between Vertical Jump Height (cm) and Quadriceps and Hamstring Peak Torque (Nm) at 60°/sec, 180°/sec and 300°/sec for the Backline Players (n=25)

Variable	Dom jump height r (p)	ND jump height r (p)
PT 60 quadriceps	-0.205 (0.325)	- 0.199 (0.341)
PT 180 quadriceps	-0.064 (0.761)	- 0.010 (0.961)
PT 300 quadriceps	-0.025 (0.904)	- 0.123 (0.557)
PT 60 hamstrings	-0.081 (0.699)	- 0.324 (0.114)
PT 180 hamstrings	-0.255 (0.218)	- 0.139 (0.507)
PT 300 hamstrings	0.089 (0.673)	- 0.173 (0.408)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque

Table 4.8: Correlation between Vertical Jump Height (cm) and Quadriceps and Hamstring Peak Torque (Nm) at 60°/sec, 180°/sec and 300°/sec for the Forward Players (n=26)

Variable	Dom jump height r (p)	ND jump height r (p)
PT 60 quadriceps	-0.145 (0.478)	- 0.148 (0.470)
PT 180 quadriceps	-0.054 (0.792)	- 0.165 (0.420)
PT 300 quadriceps	-0.156 (0.448)	- 0.108 (0.600)
PT 60 hamstrings	-0.039 (0.848)	- 0.227 (0.265)
PT 180 hamstrings	-0.213 (0.296)	- 0.030 (0.884)
PT 300 hamstrings	0.220 (0.281)	- 0.043 (0.833)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque

Table 4.9 and Figures 4.5 to 4.8 below show the correlations between quadriceps and hamstring muscle PT and the vertical jump peak power (watts) in both the dominant and non-dominant legs for the total group of rugby players at three speeds. In the total group the dominant leg showed significant correlations between quadriceps muscle PT at 180°/sec and peak power output ($r = 0.294$; $p = 0.036$) (Figure 4.5), the quadriceps muscle PT at 300°/sec and the vertical jump peak power ($r = 0.352$, $p = 0.011$) (Figure 4.6) and the hamstring muscle PT at 60°/sec and peak power output ($r = 0.353$, $p = 0.011$) (Figure 4.7). On the non-dominant side a significant correlation was seen between the quadriceps muscle PT at 300°/sec and the vertical jump peak power ($r = 0.293$, $p = 0.037$) (Figure 4.8). There were no other significant correlations between quadriceps and hamstring muscle PT and peak power output during the vertical jump test (Table 4.9).

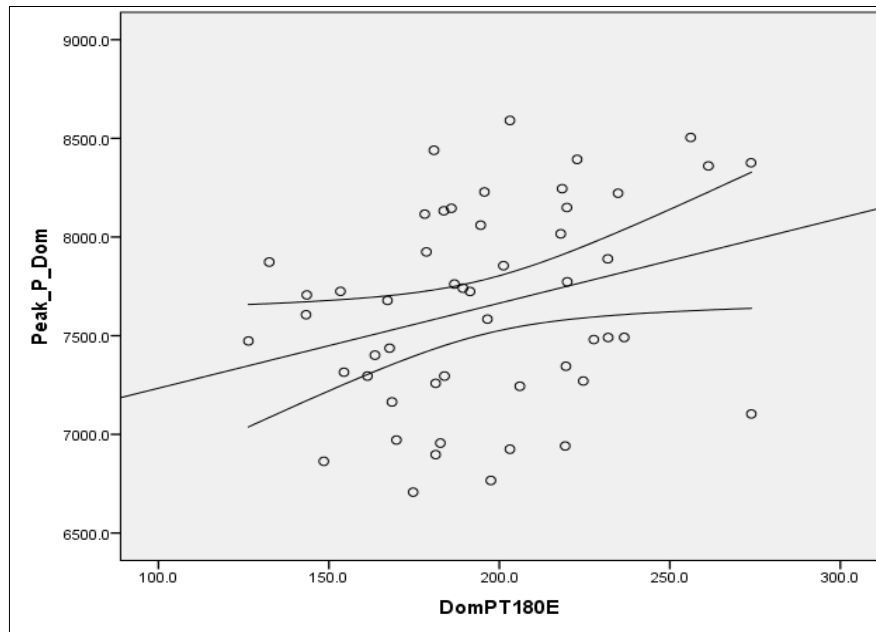


Figure 4.5: Correlation between Vertical Jump Peak Power (watts) and Quadriceps Peak Torque (Nm) 180°/sec on the Dominant Side for the Rugby Players (n=51) $r = 0.294$, $p = 0.036$ [95%CI]

Abbreviations: DomPT180E: dominant peak torque at 180°/sec extension; Peak_P_Dom: Peak power dominant

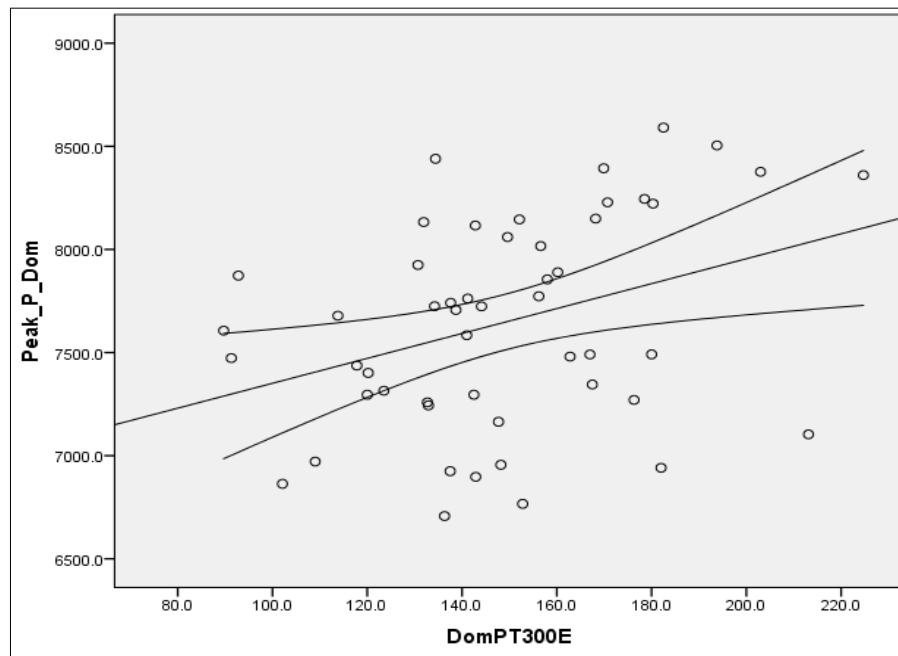


Figure 4.6: Correlation between Vertical Jump Peak Power (watts) and Quadriceps Peak Torque (Nm) 300°/sec on the Dominant Side for the Rugby Players (n=51) $r = 0.352$, $p = 0.011$ [95%CI]

Abbreviations: DomPT300E: dominant peak torque at 300°/sec extension; Peak_P_Dom: Peak power dominant

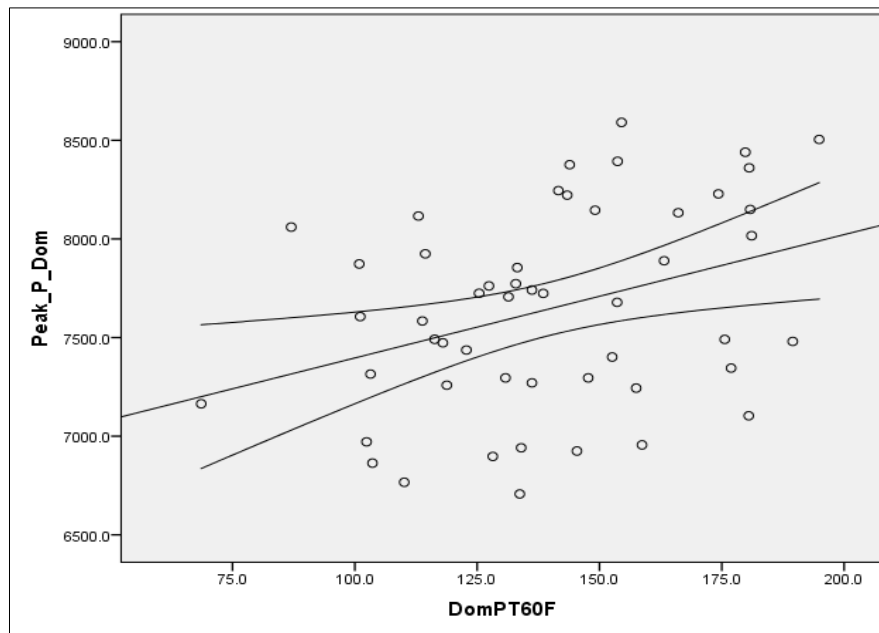


Figure 4.7: Correlation between Vertical Jump Peak Power (watts) and Hamstring Peak Torque (Nm) 60°/sec on the Dominant Side for the Rugby Players (n=51) $r = 0.353$, $p = 0.011$ [95%CI]

Abbreviations: DomPT60F: dominant peak torque at 60°/sec flexion; Peak_P_Dom: Peak power dominant

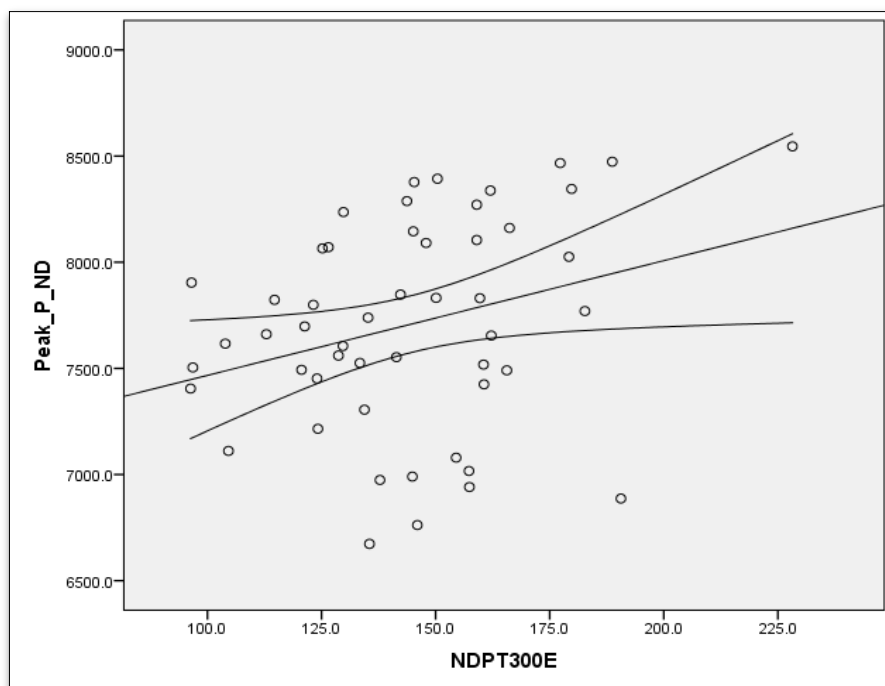


Figure 4.8: Correlation between Vertical Jump Peak Power (watts) and Quadriceps Peak Torque (Nm) 300°/sec on the Non-Dominant Side for the Rugby Players (n=51) $r = 0.293$, $p = 0.037$ [95%CI]

Abbreviations: NDPT300F: non-dominant peak torque at 300°/sec flexion; Peak_P_ND: Peak power non-dominant

Table 4.9: Correlation between Vertical Jump Peak Power (watts) and Quadriceps and Hamstring Peak Torque (Nm) at 60°/sec, 180°/sec and 300°/sec for the Rugby Players (n=51)

Variable	DOM Peak Power r (p)	ND Peak Power- r (p)
PT 60 quadriceps	0.209 (0.140)	0.167 (0.241)
PT 180 quadriceps	0.294 (0.036)*	0.203 (0.153)
PT 300 quadriceps	0.352 (0.011)#	0.293 (0.037)\$
PT 60 hamstrings	0.353 (0.011)&	- 0.038 (0.791)
PT 180 hamstrings	0.162 (0.255)	0.058 (0.638)
PT 300 hamstrings	0.158 (0.268)	0.152 (0.286)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque

**PT 180 quadriceps vs DOM peak power*

#PT 300 quadriceps vs DOM peak power

\$PT 300 quadriceps vs ND peak power

&PT60 hamstrings vs DOM peak power

Tables 4.10 and 4.11 below show the correlations between quadriceps and hamstring muscle PT and the vertical jump peak power (watts) within the forward (Table 4.10) and backline (Table 4.11) players. There were no significant correlations between these variables.

Table 4.10: Correlation between Vertical Jump Peak Power (watts) and Quadriceps and Hamstring Peak Torque (Nm) at 60°/sec, 180°/sec and 300°/sec for the Forward Players (n=26)

Variable	DOM Peak Power r (p)	ND Peak Power- r (p)
PT 60 quadriceps	0.006 (0.975)	0.138 (0.502)
PT 180 quadriceps	0.111(0.590)	0.040 (0.845)
PT 300 quadriceps	0.215 (0.292)	0.238 (0.241)
PT 60 hamstrings	0.154 (0.451)	-0.186 (0.364)
PT 180 hamstrings	0.086 (0.678)	-0.075 (0.714)
PT 300 hamstrings	0.104(0.612)	0.090 (0.661)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque

Table 4.11: Correlation between Vertical Jump Peak Power (watts) and Quadriceps and Hamstring Peak Torque (Nm) at 60°/sec, 180°/sec and 300°/sec for the Backline Players (n=25)

Variable	DOM Peak Power r (p)	ND Peak Power- r (p)
PT 60 quadriceps	0.045 (0.829)	- 0.026 (0.901)
PT 180 quadriceps	0.103 (0.626)	0.162(0.439)
PT 300 quadriceps	0.119 (0.572)	0.008 (0.970)
PT 60 hamstrings	0.113 (0.592)	- 0.184 (0.378)
PT 180 hamstrings	- 0.100 (0.634)	- 0.008 (0.968)
PT 300 hamstrings	0.188 (0.367)	- 0.147 (0.483)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque

Tables 4.12 to 4.14 show the correlations for the quadriceps and hamstring muscle PT/BW ratios (%) and the vertical jump height (cm) in the dominant and non-dominant legs for the total group of rugby players (Table 4.12) and within the forward (Table 4.13) and backline (Table 4.14) players. There were no significant correlations found between the PT/BW and the vertical jump height in the group of rugby players and within the forward and backline players.

Table 4.12: Correlation between Quadriceps and Hamstring Muscle Peak Torque to Body Weight (PT/BW) Ratios (%) and Vertical Jump Height (cm) at 60°/sec, 180°/sec and 300°/sec for the Rugby Players (n=51)

Variable	Dom Jump Height r (p)	ND Jump Height r (p)
PT/BW quadriceps 60	- 0.023 (0.873)	0.049 (0.735)
PT/BW quadriceps 180	0.153 (0.283)	0.146 (0.306)
PT/BW quadriceps 300	0.183 (0.198)	0.214 (0.132)
PT/BW hamstrings 60	0.087 (0.542)	-0.002 (0.990)
PT/BW hamstrings 180	0.075 (0.603)	0.124 (0.385)
PT/BW hamstrings 300	0.251 (0.075)	0.142 (0.322)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque; BW: body weight

Table 4.13: Correlation between Quadriceps and Hamstring Muscle Peak Torque to Body Weight (PT/BW) ratios (%) and Vertical Jump Height (cm) at 60°/sec, 180°/sec and 300°/sec for the Forward Players (n=25)

Variable	Dom jump height r (p)	ND jump height r (p)
PT/BW quadriceps 60	-0.012 (0.955)	0.015 (0.940)
PT/BW quadriceps 180	0.176 (0.389)	0.034 (0.871)
PT/BW quadriceps 300	0.265 (0.191)	0.320 (0.112)
PT/BW hamstrings 60	0.164 (0.424)	0.002 (0.992)
PT/BW hamstrings 180	0.283 (0.161)	0.136 (0.507)
PT/BW hamstrings 300	0.278 (0.168)	0.198 (0.332)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque; BW: body weight

Table 4.14: Correlation between Quadriceps and Hamstring Muscle Peak Torque to Body Weight (PT/BW) Ratios (%) and Vertical Jump Height (cm) at 60°/sec, 180°/sec and 300°/sec for the Backline Players (n=26)

Variable	Dom jump height r (p)	ND jump height r (p)
PT/BW quadriceps 60	-0.149 (0.477)	-0.111 (0.596)
PT/BW quadriceps 180	0.018 (0.933)	0.097 (0.645)
PT/BW quadriceps 300	0.042 (0.842)	-0.032 (0.878)
PT/BW hamstrings 60	-0.027 (0.898)	-0.232 (0.264)
PT/BW hamstrings 180	-0.211 (0.312)	-0.078 (0.710)
PT/BW hamstrings 300	0.139 (0.507)	-0.064 (0.762)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque; BW: body weight

Table 4.15 and Figures 4.9 to 4.13 shows below the correlations of the quadriceps and hamstring muscle PT/BW ratios (%) and the vertical jump peak power (watts) in both the dominant and non-dominant legs for the total group and Table 4.16 to Table 4.17 within the forward (Table 4.16) and backline (Table 4.17) players. In the total group when PT was corrected for body weight significant negative correlations were found between the dominant and non-dominant PT/BW ratios and vertical peak power. The quadriceps PT/BW ratio on the dominant side showed a moderate negative correlation with peak power output at 60°/sec ($r = -0.295$, $p = 0.036$) (Figure 4.9) and at 180°/sec ($r = -0.295$, $p = 0.036$) (Figure 4.10). On the dominant side the hamstring muscle PT/BW had a moderate negative correlation with peak power output at 180°/sec ($r = -0.319$, $p = 0.22$) (Figure 4.11). On the non-dominant side a moderate negative correlation was found between the hamstrings and peak power output at 60°/sec ($r = 0.422$, $p = 0.002$) (Figure 4.12) and a moderate correlation at 180°/sec to peak power ($r = 0.305$, $p = 0.030$) (Figure 4.13). There were no significant correlations within the forward or backline groups between PT/BW ratios and peak power output.

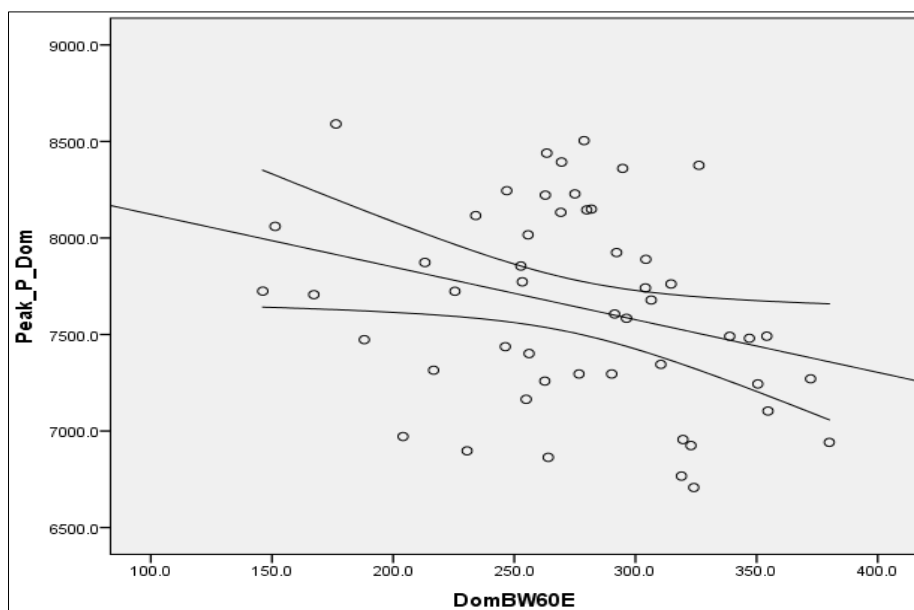


Figure 4.9: Correlation between Vertical Jump Peak Power and Quadriceps Muscle Peak Torque to Body Weight (PT/BW) Ratios (%) at 60°/sec on the Dominant Side for the Rugby Players (n=51) $r = - 0.295$, $p = 0.036$ [95%CI]

Abbreviations: DomBW60E: dominant PT/BW ratio 60°/sec extension; Peak_P_ND: Peak power dominant

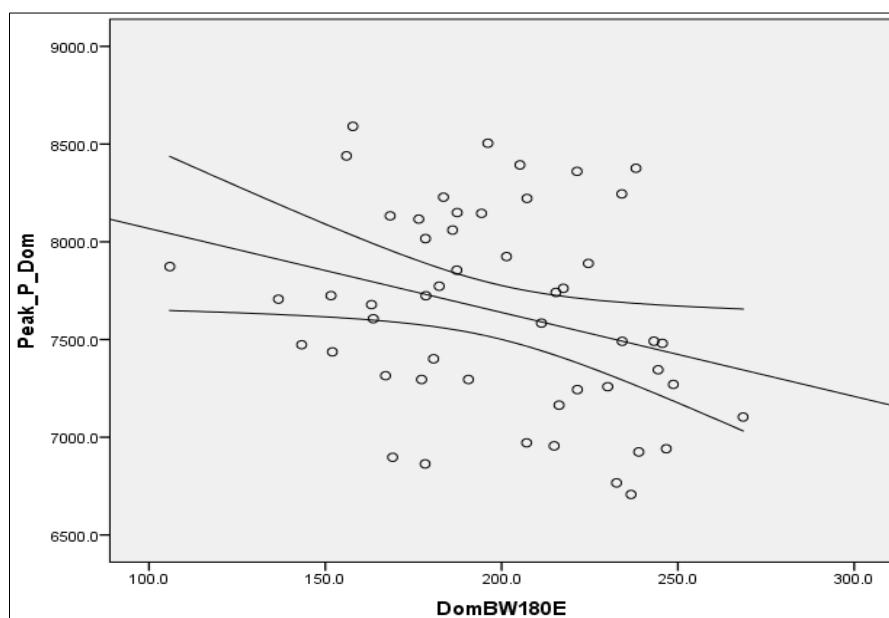


Figure 4.10: Correlation between Vertical Jump Peak Power and Quadriceps Muscle Peak Torque to Body Weight (PT/BW) ratios (%) at 180°/sec on the Dominant Side for the Rugby Players (n=51) $r = - 0.295$, $p = 0.036$ [95%CI]

Abbreviations: DomBW180E: dominant PT/BW ratio 180°/sec extension; Peak_P_ND: Peak power dominant

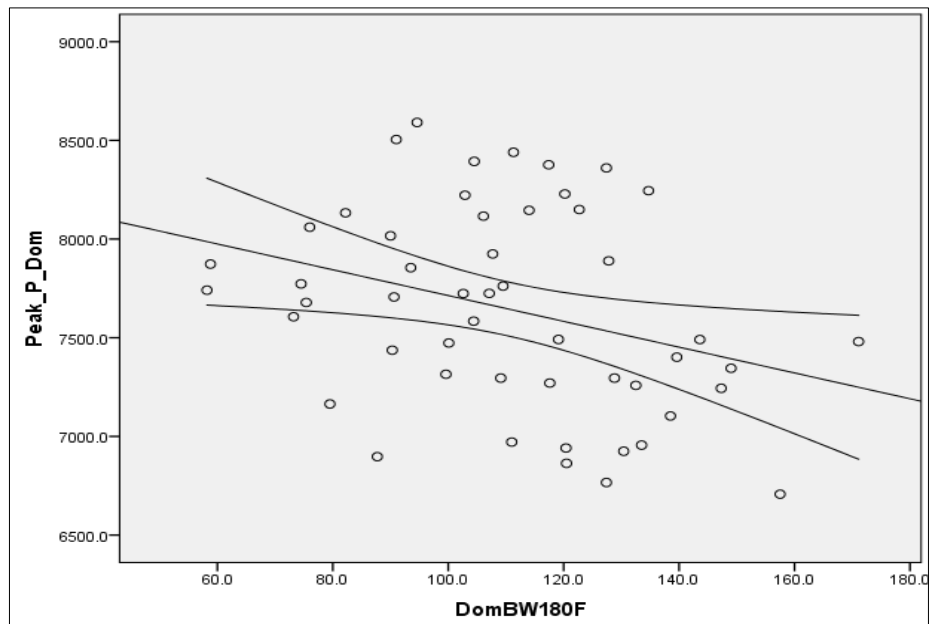


Figure 4.11: Correlation between Vertical Jump Peak Power and Hamstring Muscle Peak Torque to Body Weight (PT/BW) ratios (%) at 180°/sec on the Dominant Side for the Rugby Players (n=51) $r = - 0.319$, $p = 0.022$ [95%CI]

Abbreviations: DomBW180F: dominant PT/BW ratio 180°/sec flexion; Peak_P_Dom: Peak power dominant

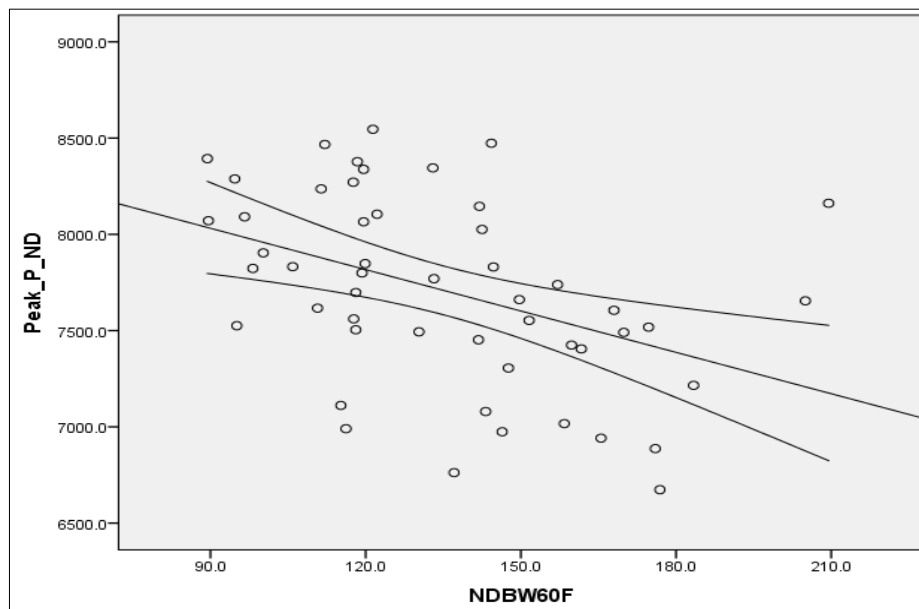


Figure 4.12: Correlation between Vertical Jump Peak Power and Hamstring Muscle Peak Torque to Body Weight (PT/BW) Ratios (%) at 60°/sec on the Non-Dominant Side for the Rugby Players (n=51) $r = - 0.422$, $p = 0.002$ [95%CI]

Abbreviations: NDBW60F: non-dominant PT/BW ratio 60°/sec flexion; Peak_P_ND: Peak power non-dominant

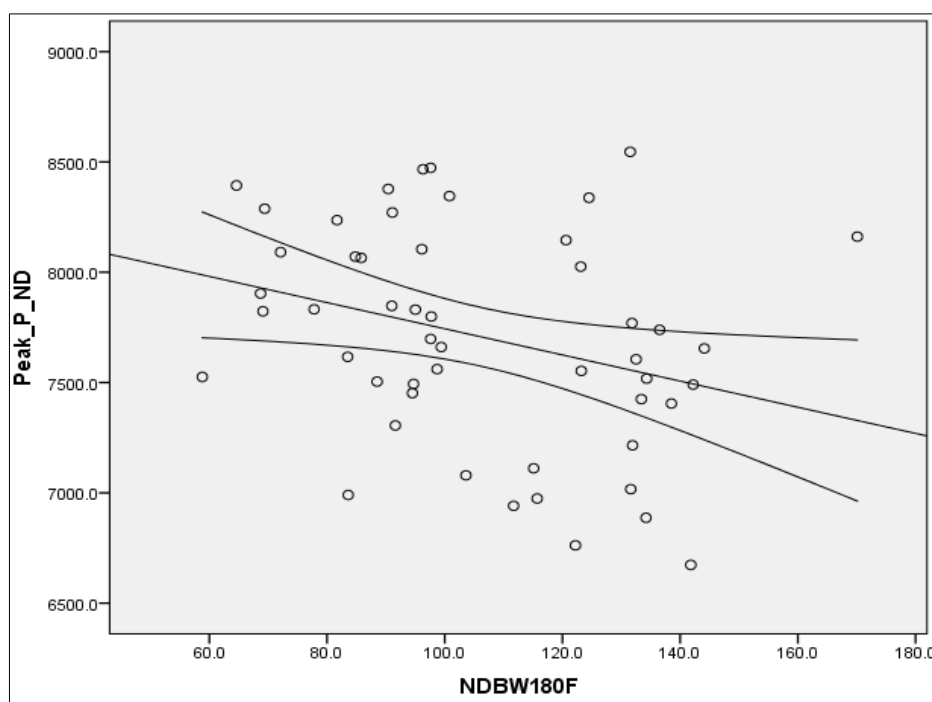


Figure 4.13: Correlation between Vertical Jump Peak Power and Hamstring Muscle Peak Torque to Body Weight (PT/BW) ratios (%) at 180°/sec on the Non-Dominant Side for the Rugby Players (n=51) $r = -0.305$, $p = 0.030$ [95%CI]

Abbreviations: NDBW180F: non-dominant PT/BW ratio 180°/sec flexion;
Peak_P_ND: Peak power dominant

Table 4.15: Correlation between Quadriceps and Hamstring Muscle Peak Torque to Body Weight (PT/BW) ratios (%) and Vertical Jump Peak Power (watts) at 60°/sec, 180°/sec and 300°/sec for the Rugby Players (n=51)

Variable	Dom Peak Power r (p)	ND Peak Power r (p)
PT/BW quadriceps 60	-0.295 (0.036)*	-0.212 (0.135)
PT/BW quadriceps 180	-0.295 (0.036)\$	-0.235 (0.097)
PT/BW quadriceps 300	-0.185 (0.193)	-0.188 (0.185)
PT/BW hamstrings 60	-0.164 (0.250)	-0.422 (0.002)&
PT/BW hamstrings 180	-0.319 (0.022)#	-0.305 (0.030)@
PT/BW hamstring 300	-0.205 (0.148)	-0.238 (0.093)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque; BW: body weight

*PT/BW quadriceps 60 vs DOM peak power

\$PT/BW quadriceps 180 vs DOM peak power

&PT/BW hamstrings 60 vs ND peak power

#PT/BW hamstrings 180 vs ND peak power

@PT/BW hamstrings 180 vs ND peak power

Table 4.16: Correlation between Quadriceps and Hamstring Muscle Peak Torque to Body Weight (PT/BW) Ratios (%) and Vertical Jump Peak Power (watts) at 60°/sec, 180°/sec and 300°/sec for the Forward Players (n=26)

Variable	Dom Peak Power r (p)	ND Peak Power r (p)
PT/BW quadriceps 60	-0.302 (0.133)	-0.045 (0.826)
PT/BW quadriceps 180	-0.250 (0.219)	-0.186 (0.362)
PT/BW quadriceps 300	-0.152 (0.458)	-0.012 (0.953)
PT/BW hamstrings 60	-0.205 (0.315)	-0.355 (0.075)
PT/BW hamstrings 180	-0.228 (0.263)	-0.242 (0.233)
PT/BW hamstrings 300	-0.176 (0.390)	-0.093 (0.653)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque; BW: body weight

Table 4.17: Correlation between Quadriceps and Hamstring Muscle Peak Torque to Body Weight (PT/BW) Ratios (%) and Vertical Jump Peak Power (watts) at 60°/sec, 180°/sec and 300°/sec for the Backline Players (n=25)

Variable	Dom Peak Power r (p)	ND Peak Power r (p)
PT/BW quadriceps 60	-0.124 (0.556)	-0.166 (0.428)
PT/BW quadriceps 180	-0.114 (0.588)	0.000 (0.999)
PT/BW quadriceps 300	-0.059 (0.778)	-0.159 (0.448)
PT/BW hamstrings 60	-0.051 (0.807)	-0.308 (0.134)
PT/BW hamstrings 180	-0.260 (0.209)	-0.154 (0.462)
PT/BW hamstrings 300	0.024 (0.911)	-0.273 (0.187)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque; BW: body weight

Tables 4.18 to 4.20 below shows the correlations of the reciprocal ratio (%) and the vertical jump height (cm) and peak power (watts) for both the dominant and non-dominant legs in the total group of rugby (table 4.18) players and within the forward (table 4.19) and backline (table 4.20) players. There were no significant correlations found when comparing the hamstring to quadriceps ratio and the vertical jump height or peak power output.

Table 4.18: Correlations of the Reciprocal Ratio (%) and the Vertical Jump Height (cm) and Peak Power (watts) in Both the Dominant and Non-Dominant Legs in the Total Group of Rugby Players (n=51)

Variable	Dom Jump Height (cm) r (p)	ND Jump Height (cm) r (p)
H:Q 60	0.118 (0.410)	- 0.053 (0.712)
H:Q 180	- 0.045 (0.755)	- 0.040 (0.782)
H:Q 300	0.164 (0.250)	- 0.052 (0.716)
	Dom Peak Power	ND Peak Power
H:Q60	0.160 (0.261)	- 0.164(0.251)
H:Q 180	- 0.103 (0.473)	- 0.239 (0.092)
H:Q 300	- 0.076 (0.596)	- 0.174 (0.221)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque; BW: body weight

Table 4.19: Correlations of the Reciprocal Ratio (%) and the Vertical Jump Height (cm) and Peak Power (watts) in Both the Dominant and Non-Dominant Legs in the Total Group of Forward Players (n=26)

Variable	Dom Jump Height (cm) r (p)	ND Jump Height (cm) r (p)
H:Q 60	0.225 (0.268)	0.25 (0.902)
H:Q 180	0.186 (0.364)	0.046 (0.822)
H:Q 300	0.132 (0.520)	- 0.094(0.649)
	Dom Peak Power	ND Peak Power
H:Q 60	0.118 (0.567)	- 0.264 (0.192)
H:Q 180	- 0.018 (0.930)	- 0.254 (0.210)
H:Q 300	- 0.066 (0.747)	- 0.178 (0.384)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque; BW: body weight

Table 4.20: Correlations of the Reciprocal Ratio (%) and the Vertical Jump Height (cm) and Peak Power (watts) in Both the Dominant and Non-Dominant Legs in the Total Group of Backline Players (n=25)

Variable	Dom Jump Height (cm) r (p)	ND Jump Height (cm) r (p)
H:Q 60	0.094 (0.657)	- 0.133 (0.526)
H:Q 180	- 0.228 (0.273)	- 0.193 (0.354)
H:Q 300	0.137 (0.514)	- 0.057 (0.785)
	Dom Peak Power	ND Peak Power
H:Q 60	0.073 (0.730)	- 0.141 (0.501)
H:Q 180	- 0.186 (0.374)	- 0.198 (0.343)
H:Q 300	0.111 (0.598)	- 0.157 (0.455)

Abbreviations: Dom: dominant; ND: non-dominant; PT: Peak torque; BW: body weight

CHAPTER 5

5. DISCUSSION

The objective assessment of muscle performance for the evaluation of conditioning programmes, talent identification, and the establishment for normative values, therapeutic rehabilitation progression and identification for predisposing factors to injury are the interest of many studies.^(6,7,13,14,17,20,21,46,58,60,65) The purpose of this study was to assess whether there was a correlation between isokinetic knee torque and vertical jump testing results, in order to assess muscle function in a group of rugby players.

5.1 DEMOGRAPHIC INFORMATION

The demands of the sport of rugby have increased due to the turning to professionalization of the game. Furthermore, research has shown that the stature of a rugby player is also important for success and performance during the professional era^(9,10,23,27–30) and there has been an increase in the weight and the height of rugby players in the last century.^(88,89) In this current study the forward players were found to be taller compared to the backline players. This finding is similar to that of Quarrie and Hopkins (2007)⁽³¹⁾ and Duthie et al. (2003)⁽²³⁾ These differences in height and weight are necessary for the positional demands placed on the forwards, especially during the set pieces.^(23,30,33) The nature of the game needs the locks and flankers to be taller than the rest to compete and contest in lineouts. In addition, the higher body mass of the forwards found in this study allows them to reach greater momentum⁽³⁰⁾ during tackles and produce larger force in the scrum.⁽⁹⁰⁾ Furthermore, the backline players are known as the ball carriers⁽²³⁾ and therefore need to be more agile and have the ability to evade their opponents.

5.2 VERTICAL JUMP HEIGHT AND PEAK POWER

The two most common testing techniques for the vertical jump test are the squat jump and the counter-movement jump.⁽⁵¹⁾ The squat jump was preferred in this study, due to there being a lesser chance for variability in the squat jump technique compared to the countermovement jump.⁽⁵¹⁾

The backline players showed the tendency to be able to jump higher than the forward players when starting on either the dominant or non-dominant leg; however, only the non-dominant leg showed a significant difference ($39.5 \pm 6.7\text{cm}$ vs. $35.2 \pm 6.8\text{cm}$). Previous research also found that the backline players were able to jump higher (means ranged from $51.4\text{cm} - 65.3\text{cm}$) during the vertical jump test compared to the forward players (mean ranged from $49.9\text{cm} - 62.3\text{cm}$).^(30,49,91) Although, the findings of the current study are

comparable to previous research, the previous studies assessed a bilateral vertical squat jump method and the current study assessed a unilateral squat jump method. Why the backline players significantly jumped higher from their non-dominant leg could be a misinterpretation of what in fact is their dominant leg seeing it was established only by questioning the players as to which leg they preferred to kick the ball with. Backline players are also involved more in kicking in the team and the kicking leg is sometimes presumed to be the dominant leg,⁽⁹²⁾ although all the stability during the kick is placed on the non-dominant leg and therefore they could be more used to stabilize on the non-dominant leg compare to the forward players. This could perhaps cause some error when interpreting which leg indeed is the dominant side.

When analysing the total group, there also was a trend for the players to achieve a better jump height using the non-dominant side; however, these results were not significantly different from the dominant jump height. The reason for the non-dominant side having a greater jump height is unclear; however, it could be due to the fact that the non-dominant leg is used mostly to stabilize the player during kicking activities and the player could therefore be more stable on this leg prior to the jump.⁽⁹²⁾ Furthermore highly trained athletes train their dominant and non-dominant sides evenly during practice sessions.⁽⁹³⁾ Recent studies showed that the dominance factor is not applicable to highly trained athletes^(6,92) and Swearingen et al. (2011)⁽⁹⁴⁾ found that non-athletes performed better in a single leg vertical jump test using the non-dominant leg compared to the dominant leg. This finding, however, is in contrast to a study by Kobayashi et al. (2013)⁽²²⁾ who found in non-athlete males the dominant leg performed better in the single leg vertical jump compared to the non-dominant side ($19.2 \pm 3.9\text{cm}$ vs. $17.0 \pm 3.5\text{cm}$, $p = 0.001$). De Ruiter et al. (2010)⁽⁹²⁾ stated that there is no clear difference in dominant versus non-dominant legs in leg extension torque or muscle stimulation.⁽⁹²⁾ The reason why there is contradiction to the above mentioned literature could be due to different equipment used. Kobayashi et al. (2013)⁽²²⁾ used a Kistler force platform compared to the Vertec used in the study of Swearingen et al. (2011)⁽⁹⁴⁾. Additionally the testing participants was conducting in male and females participants mixed between students and working class with a mean age of 23.9 ± 2.0 years⁽⁹⁴⁾ and Kobayashi et al. (2013)⁽²²⁾ used only male physical activity students with a mean age of 23 ± 1 years.

In order to assess the peak power output during the vertical jump test, the player's body weight is taken into consideration. The forwards (D: $7946.0 \pm 396.5\text{watts}$, ND: $7958.4 \pm 404.0\text{watts}$) were found to have a significantly greater peak power output compared to the backline players (D: $7332.7 \pm 415.3\text{watts}$, ND: $7445.9 \pm 442.2\text{watts}$) on both the dominant and non-dominant sides. As the forward players were found to weigh more than the

backline players, this indicates that the heavier the player the greater amount of power they are able to generate during a vertical jump test. Therefore this concurs with previous research suggesting that heavier players will produce greater power to reach a similar jump height when compared to a lighter person^(17,60,72,80) due to the fact that they need to overcome higher resistance before the jump.

5.2.1 Isokinetic Parameters

In order to compare our study with other previous studies the peak torque (Nm) was assessed in the rugby players, but for comparisons between the backline and the forward players the peak torque to body weight ratio (PT/BW) will be used for that discussion. The reason for this is that it is necessary to normalize for body weight when groups are being assessed and in order to compare individuals to each other.

5.3 QUADRICEPS PEAK TORQUE (NM) AND PEAK TORQUE TO BODY WEIGHT RATIO (%)

Functional and sporting activities are accompanied by high torque generated at the joints and therefore testing at higher velocities could have a better indication to sporting activities^(6,41) and the assumption could be made that different muscle properties are being assessed at the different speeds and therefore it is important to include the different angular velocities.⁽⁶⁾ This is in fact contradictory to findings of Olmo and Castilla (2005)⁽⁴⁸⁾ which confirms a strong correlation of peak torque extension between 60°/sec and 300°/sec and both parameters produce similar information regarding muscle strength. Researchers⁽⁵³⁾ argue that the assumption that strength is tested at slower velocities (below 60°/sec), power during higher velocities (180°/sec - 300°/sec) and functional testing (above 300°/sec) cannot be confirmed and therefore do not agree with Davies (1992).⁽¹⁵⁾

When assessing the groups' quadriceps muscle strength at the varying speeds, the quadriceps muscle peak torque was found to be the highest at the slowest velocity and to decrease as the velocity increased. This is a common phenomenon found in isokinetic testing.^(55,58,60) This phenomenon is known as Hill's equation and stipulates that during concentric muscle action the time for cross bridge formation between actin and myosin filaments reduces with the increase in velocity of contraction.⁽⁹⁵⁾

For the total group of rugby players, the quadriceps muscle peak torque (Nm) ranged from 144.4 ± 26.7Nm at 300°/sec to 271.3 ± 55.9Nm at 60°/sec. In this study the PT on the dominant side had a trend of being stronger than the non-dominant side at all speeds. The forwards showed a trend to have a higher quadriceps absolute muscle peak torque (Nm)

compared to the backline players on both the dominant and non-dominant sides; however this was only significant when assessing the dominant side at 60°/sec and on both sides at 300°/sec. Cheung et al. (2013)⁽⁶⁷⁾ found similar findings but with no significant difference between the dominant and non-dominant quadriceps peak torque in soccer players.

The PT/BW values ranged from $146.5 \pm 27.2\%$ to $274.9 \pm 54.8\%$ at 300°/sec and 60°/sec respectively. In contrast to a study done by Siqueira et al. (2002)⁽⁶⁾ the PT/BW ratio knee extension values are considerably lower than the jumping and running athletes found in their study. Knee extension PT/BW ratio ranged from 347.1% to 373.9% at 60°/sec.⁽⁶⁾ In the same study the non-athletes were also found to have higher values than in this current study with PT/BW values ranging from 311.5% - 315.1%. In a further study done by Orchard et al. (1997)⁽¹³⁾ in Australian footballers showed higher values at the three velocities at 60°/sec, 180°/sec and 300°/sec, with ranges from $314 \pm 33\%$ to $188 \pm 26\%$. The possible cause for the lower values in this current study could be the fact that the testing was done after their off-season period and therefore deconditioning might have taken place during the rest phase. The other studies did not mention the phase their testing was done in.

The PT/BW ratio (%) on the dominant side also showed the trend of being stronger than the non-dominant side at all speeds. This concurs with other studies.^(6,67) Siqueira et al. (2002)⁽⁶⁾ found a tendency of the dominant leg to be stronger than the non-dominant leg in running and jumping athletes but with no significant difference. In non-athletes there was a significant difference between the dominant and the non-dominant sides at 60°/sec and 240°/sec ($p = 0.009$ in both speeds). The dominant side is considered to be stronger than the non-dominant side⁽⁶⁾, however a difference of more than 10% may indicate signs of pathology.⁽⁵⁶⁾

In order to compare the force production in the forward and backline groups the relative peak torque should rather be taken into consideration, especially in the weight bearing limbs. Normalisation of strength compared to body weight allows for individual and group comparisons.⁽¹⁵⁾ When corrected for body weight, the backline players, being lighter than the forward players, showed a higher percentage of peak torque relative to body weight. The backline players produced a significantly higher percentage peak torque on their non-dominant side at 180°/sec ($200.2 \pm 32.4\text{Nm/kg}$ vs. 178.4 ± 39.3 , $p = 0.035$) compared to the forward players.

5.4 **HAMSTRING PEAK TORQUE (NM) AND PEAK TORQUE TO BODY WEIGHT RATIO (%)**

Hamstring strength is an important factor in normal biomechanics and injury prevention. The hamstring muscle acts as a synergist to the anterior cruciate ligament (ACL) and therefore helps to prevent anterior translation of the tibia on the femur.^(41,42) Furthermore, weak hamstrings muscles relative to the quadriceps muscle strength could predispose the player to possible hamstring injuries.⁽¹³⁾

The total group showed a PT range of $85.5 \pm 19.5\text{Nm}$ to $137.7 \pm 28.3\text{Nm}$ from $300^\circ/\text{sec}$ to $60^\circ/\text{sec}$ and a relative strength (PT/BW) of $87.0 \pm 19.8\%$ to $141.3 \pm 27.0\%$. These values are also lower than what was found in the Australian footballers who produced PT/BW values of $127 \pm 25\%$ - $206 \pm 31\%$ at $300^\circ/\text{sec}$ to $60^\circ/\text{sec}$.⁽¹³⁾ These lower values from this current study could indicate a limitation in the conditioning program where the players might focus more on the quadriceps strength and not too much on hamstring strength.

For the total group the dominant side also showed a trend of producing higher values than the non-dominant side, but with no statistical significance. The forwards again show a higher absolute peak torque compared to the backline players with a significant difference at $60^\circ/\text{sec}$ on the dominant side ($151 \pm 28.5\text{Nm}$ vs. $127.6 \pm 23.6\text{Nm}$, $p = 0.002$) and on the non-dominant side at $300^\circ/\text{sec}$ (90 ± 23.5 vs. $80.0 \pm 12.5\text{Nm}$, $p = 0.045$). However, when corrected for body weight, the backline players produced a higher percentage of peak torque to body weight ratio at all three velocities. The backline players also produced a significantly higher PT/BW ratio at $60^\circ/\text{sec}$ on the non-dominant side ($143.8 \pm 25.2\%$ vs. $127.1 \pm 30.5\%$, $p = 0.038$). These findings are along the same trend as found for the quadriceps muscle strength results.

5.5 **UNILATERAL HAMSTRING/QUADRICEPS (H:Q) RECIPROCAL RATIO (%)**

Co-activation of hamstring and quadriceps muscles protects the knee joint against faulty lower limb biomechanics.⁽⁴¹⁾ This concentric ratio is established when the strength of the weaker muscle group (hamstring muscle group) is divided by the strength of the stronger muscle group (quadriceps muscle group).⁽⁶⁾ During movement the hamstring muscles are the antagonist to the quadriceps muscles and act eccentrically to the concentric quadriceps, therefore this ratio is seen not to be very functional, although this ratio will give an idea of the relationship between muscles around the knee joint.⁽⁶⁾

In this study the unilateral ratio increased with an increase in velocity. This phenomenon is expected during isokinetic testing.^(42,56) For the total group the H/Q ratio ranged from $52.6 \pm 10.1\%$ to $61.5 \pm 9.8\%$. According to established guidelines⁽⁵⁶⁾ the rugby players in this study are below the acceptable values, indicating hamstring muscle weakness compared to the quadriceps muscles. Orchard et al. (1997)⁽¹³⁾ stated that a hamstring to quadriceps ratio

below 61% could place a player at an increased risk for hamstring injuries. For 60°/sec the ratio range is 60% – 69%, the 180°/sec is 70% - 79% and at 300°/se the ratio is 80% - 89%.⁽⁵⁶⁾ In this study there was no clear difference between forwards and backline which concurs with Rosene et al. (2001)⁽⁴²⁾ who argued that athletes can maintain similar strength on both sides. In the current study both groups fall below the acceptable ranges in the H:Q ratio's. This could have significant implications in the whole study because this, in fact, means that the hamstring muscle group of all the players is weak and could possibly not perform optimally during functional testing.

CORRELATIONS

5.6 PEAK TORQUE TO VERTICAL JUMP HEIGHT AND PEAK POWER

There was a trend for the peak torque values of the quadriceps and the hamstring muscle groups to be negatively correlated to the vertical jump height in the total group as well as in the forwards and backline players. Even though there was this trend, the only significant correlation to the vertical jump height was for the hamstring muscle PT at 60°/sec on the non-dominant side in the total group ($r = -0.313$, $p = 0.025$). This small contribution of the concentric hamstring muscles during the squat jump may indicate that the hamstrings are more involved eccentrically, and further studies are needed to test eccentric torque and jump height to support this hypothesis.

In the literature it is also found that higher isokinetic speeds have a closer relationship to functional performance.⁽⁸⁾ This was seen in a positive correlation between the PT hamstrings strength at 300°/sec and vertical jump height on the dominant side, indicating that faster speeds may translate to increased functionality. In addition, Iossifidou et al. (2005)⁽⁸⁾ found a stronger correlation between higher angular velocities and the squat vertical jump. Isokinetic testing done in the current study went up to 300°/sec, but functional performance like a jump exceeds this velocity.⁽⁴⁸⁾

The quadriceps muscle group is seen as the muscle group that makes the biggest contribution to the squat jump. ⁽⁷⁾ Augustsson and Thomeé (2000)⁽⁷⁾ found that knee extensor peak torque at 60°/sec had a good correlation with vertical jump height ($r = 0.57$, $p = 0.022$) in healthy male subjects. However, contradictory to literature, the current study unexpectedly found that the strength of the quadriceps did not relate to better jump performance. Malliou et al. (2003)⁽¹⁸⁾ found a significant correlation to the squat jump and isokinetic peak torque knee extension testing at 60°/sec and 180°/sec with r -values ranging from 0.595 to 0.783 ($p = 0.05$ and 0.01 respectively) which concurs with a study from Tsiokanos et al. (2005)⁽⁶⁰⁾ In the study from Malliou et al. (2003)⁽¹⁸⁾ the subjects were

considerably lighter ($80.2 \pm 6.3\text{kg}$) than the current study. Other studies found contradictory results with no relationship to isokinetic peak torque.^(14,21,22,65) Alemdaroğlu (2012)⁽¹⁴⁾ found no significant relationship between isokinetic quadriceps and hamstring muscle strength and the squat vertical jump in first division basketball players at $60^\circ/\text{sec}$ and $180^\circ/\text{sec}$. Furthermore, Anderson et al. (1991)⁽²¹⁾ found no correlation with concentric knee extension testing in a supine position at $60^\circ/\text{sec}$ and $180^\circ/\text{sec}$. This contradiction in the literature between isokinetic strength and vertical jump might mean that one test cannot be used in place of the other.^(7,11)

When assessing the peak torque of the quadriceps and hamstring muscles to the peak power of the vertical jump positive relationships were found in the total group except in the non-dominant side of the hamstring muscles at $60^\circ/\text{sec}$. The quadriceps on the dominant side at $180^\circ/\text{sec}$ ($r = 0.294$, $p = 0.036$) and both the quadriceps on the dominant ($r = 0.352$, $p = 0.01$) and non-dominant ($r = 0.293$, $p = 0.037$) side at $300^\circ/\text{sec}$ showed significant positive correlations to the vertical jump peak power. This suggests that jumping performance correlates better at higher angular velocities of isokinetic testing, indicating that as the speed becomes closer to a functional speed the performance correlation improves. Furthermore, body weight may have an effect on performance testing, and should be taken into account when interpreting these relationships.⁽⁶⁰⁾ In addition, the dominant hamstring peak torque at $60^\circ/\text{sec}$ showed a positive correlation to peak power of the total group of rugby players ($r = 0.353$, $p = 0.011$). This indicates that concentric hamstring muscle strength does contribute, by a small percentage, to the power produced during the squat jump.

5.7 PEAK TORQUE TO BODY WEIGHT RATIO'S TO VERTICAL JUMP HEIGHT AND PEAK POWER

The positive correlations between peak torque to body weight ratio's and vertical jump height at all speeds except for $60^\circ/\text{sec}$ indicates that an increase in jump height was obtained with an increase in peak torque ratio and are in support of research performed by Negrete and Brophy (2000).⁽¹¹⁾ Negrete and Brophy (2000)⁽¹¹⁾ found a significant correlation ($r = 0.546$, $p = 0.0001$) between a single leg vertical jump height and knee extensor PT and percentage PT/BW at $180^\circ/\text{sec}$ in college male and female students.

This is expected, as during a squat jump the player needs to overcome his body mass and thus isokinetic parameters corrected to body weight becomes more relevant to consider in this setting.

In contrast, the opposite was found when analysing the relationship between relative peak torque and vertical jump power in the current study. The majority of quadriceps and hamstring muscle strength tests were found to have negative correlations to the vertical jump peak power. Therefore, despite correcting for body weight when addressing the relationship between strength and power, an inconsistent finding emerged in this study. The fact that isokinetic torque measurements are divided into phases of acceleration, load range and deceleration^(51,55) Rothstein et al. (1987)⁽⁵³⁾ argued that in the initial part when the muscle produces a force to move the limb up to the pre-selected velocity it is in fact not recorded, thus ratios or percentages are not accurate and cannot account for clinical reasoning.

5.8 RECIPROCAL RATIOS TO VERTICAL JUMP HEIGHT AND PEAK POWER

The reciprocal ratios are an indication of agonist-antagonist function. In this study there are more negative relationships than positive relationships to the vertical jump height and the peak power in the total group. The non-dominant side showed more negative correlations than the dominant side. None of the correlations were found to be significant. It is worth noting that the pattern of movement for the hamstring muscle group is different in the isokinetic action when compared to the jump. The isokinetic test is an open chain movement⁽⁵⁰⁾ from a fixed position at a less than functional velocity.⁽⁶⁰⁾ In contrast, the squat jump is a functional movement which incorporate multi-joints⁽⁵⁰⁾ initiated from a closed chain position.⁽⁶⁰⁾ Thus, the differences between the two tests, coupled with the fact that the hamstring muscle does not act in a true concentric manner during the squat jump could explain why no relationship was found to exist. This study further reinforces the gap between isokinetic testing and functional performance which is mentioned in the literature. Therefore, clinicians and coaches are encouraged to incorporate both isokinetic and power measurements to ensure a comprehensive assessment of their players.

CHAPTER 6

6. SUMMARY, CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

6.1 SUMMARY

The aim of the study was to investigate the correlation between isokinetic peak torque parameters and the vertical squat jump test in rugby union players. According to the current literature there is a tendency to correlate absolute tests with functional test to guide clinicians working in low resource facilities to optimise progression in rehabilitation and training in the absence of sophisticated and expensive equipment. The literature, however indicate contradictory results with regards to the relationship between isokinetic peak torque parameters and vertical jump tests. The differences observed might be due to different testing procedures, different equipment used, sporting population investigated and different gender. Similar methodologies were applied in a limited number of studies. These studies were however not performed on a rugby playing population. In South Africa rugby is one of the most popular sport with a high injury incidence rate and many players from areas with limited access to expensive equipment increasing the need for reliable functional testing as substitute lower limb strength.

Single leg vertical jump normative data could be of value for the rehabilitation team when assessing for function after an injury and to the conditioning specialist to assess for any bilateral functional differences. A single leg jump test could predict bilateral muscle differences. Therefore the research question to be answered was: Is there a correlation between isokinetic testing and the single leg vertical squat jump in rugby union players?

In order to answer the posed question, a cross-sectional study design was performed on university rugby players. Isokinetic testing was performed at different speeds for hamstring and quadriceps to determine the ratio's. A single leg vertical squat jump was also performed by the same participants. The results indicated a significant negative correlation between PT concentric strength from the hamstrings at 60°/sec and the vertical jump height on the non-dominant side. Positive correlations was seen in both quadriceps torque and hamstring torque when comparing PT to vertical power at the higher velocities showed significant correlations at 180°/sec and 300°/sec. No significant correlations was found when peak torque was corrected for body weight and compared to vertical jump height. When comparing PT to vertical jump power corrected for body weight negative correlations was seen and significant correlations at the slower velocities in the both the quadriceps and hamstrings. The reciprocal ratio's showed no correlations to the vertical jump height or power. The present study did highlight that the participating rugby players were slightly

weaker than their overseas counterparts and could be valuable information to the conditioning staff

6.2 **CONCLUSION**

In conclusion, the presented study showed no clear correlation between lower limb isokinetic knee muscle torque parameters and the vertical jump performance in the tested rugby players. Isokinetic strength might not be a factor in predicting jump performance. Therefore the rugby testing battery should be designed according to the specific need of the rugby coach, and may need to address strength and power parameters independently and test batteries should rather be established specific to the coach and rehabilitation experts' need. Findings from this study contribute to the controversy of the gap between isokinetic testing and functional performance as mentioned in the literature.

6.3 **LIMITATIONS AND RECOMMENDATIONS**

The findings of this study should be interpreted considering some limitations that were present. Players were tested at the end of the off-season and were tested prior to being conditioned for the new season. Players were requested to indicate dominance; they might have indicated dominance on the dominant hand for writing, which could be different from the dominant leg. A limb symmetry index could have been included in the results that could have given more clarity on the difference between left and right.

The familiarization of a player to the test could have had an impact. Most of the players are very familiar to vertical jump, but not to isokinetics. Training on isokinetic more than once could make the testing more reliable. Also randomly assign testing order rather than selecting the limb sequence to cancel out any familiarization it could have on the testing procedure. A larger sample size and randomization of participants could also give more reliability to future studies.

Recommendations for future studies should include studies that focus on including the plantar flexion torque to compare to the vertical jump. Some studies stated to include the hip or ankle joint as the vertical jump is a multi-joint movement. Strength is not the only factor involved in function and it is also important to look at other factors contributing to a jump such as flexibility, balance and neuromuscular control. Also other isokinetic parameters like average power and peak torque in the first third of the ROM could be related better to function as well as eccentric torque. Coordination and timing are also important during the vertical jump and to touch the vane at the highest possible point in time is related to skill and balance and this therefore predisposes this manner of testing to a margin of error.

REFERENCES

1. IRB rugby union laws of the game 2013. International rugby board 2013.[document on the internet]. Dublin; 2013. Available from: <http://www.irb.com>
2. Moore KL. Clinical orientated anatomy. 3rd ed. Baltimore: Williams & Wilkins; 1992.
3. Last RJ. Some anatomical details of the knee joint. *Journal of Bone and Joint Surgery*. 1948;30 (B4):683–8.
4. Goldblatt JP, Richmond JC. Anatomy and biomechanics of the knee. *Operative Techniques in Sports Medicine*. 2003;11(3):172–86.
5. Kuttgen HW, Kraemer WJ, Knuttgen H. Terminology and measurement in exercise performance. *Journal of Applied Sport Science Research*. 1987;1(1):1–10.
6. Siqueira CM, Pelegrini FRMM, Fontana MF, Greve JMD. Isokinetic dynamometry of knee flexors and extensors: comparative study among non-athletes, jumper athletes and runner athletes. *Revista do Hospital das Clínicas Faculty Medicine Saou Paulo*. 2002;57(1):19–24
7. Augustsson J, Thomeé R. Ability of closed and open kinetic chain tests of muscular strength to assess functional performance. *Scandinavian Journal of Medicine & Science in Sports*. 2000;10(3):164–8.
8. Iossifidou A, Baltzopoulos V, Giakas G. Isokinetic knee extension and vertical jumping: are they related? *Journal of Sports Sciences*. 2005 Oct;23(10):1121–7.
9. Garraway WM, Lee AJ, Hutton SJ, Russel EBAW, Macleod DAD. Impact of professionalism on injuries in rugby union. *British Journal of Sports Medicine*. 2000;34(5):348–51.
10. Lambert MI, Durandt J. Long-term player development in rugby – how are we doing in South Africa ? *South African Journal of Sports Medicine*. 2010;22(3):67–8.
11. Negrete R, Brophy J. The Relationship between isokinetic open and closed chain lower extremity strength and functional performance. *Journal of Sport Rehabilitation*. 2000;9:46–61.
12. Holtzhausen LJ, Schwellnus MP, Jakoet I, Pretorius AL. The incidence and nature of injuries in South African rugby players in the rugby Super 12 competition. *South African Medical Journal*. 2006;96(12):1260–5.
13. Orchard J, Marsden J, Lord S, Garlick D. Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. *The American Journal of Sports Medicine*. 1997;25(1):81–5.
14. Alemdaroğlu U. The relationship between muscle strength, anaerobic performance, agility, sprint ability and vertical jump performance in professional basketball players. *Journal of Human Kinetics*. 2012;31(March):149–58
15. Davies GJ. A compendium of isokinetics in clinical usage and rehabilitation techniques. 4th ed. S & S Publishers; 1992. p. 9 – 68.
16. English R, Brannock M, Chik WT, Eastwood LS, Uhl T. The relationship between lower extremity isokinetic work and single-leg functional hop-work test. *Journal of Sport Rehabilitation*. 2006;15(2):95–104.

17. Söderman K, Lindström B. The relevance of using isokinetic measures to evaluate strength. *Advances in Physiotherapy*. 2010;12(4):194–200.
18. Malliou P, Ispirlidis I, Beneka A, Taxildaris K, Godolias G. Vertical jump and knee extensors isokinetic performance in professional soccer players related to the phase of the training period. *Isokinetic and Exercise Science*. 2003;11(3):165–9.
19. Liebermann D, Katz L. On the assessment of lower-limb muscular power capability. *Isokinetics and Exercise Science*. 2003;11:87–94.
20. Ostenberg A, Roos E, Ekdahl C, Roos H. Isokinetic knee extensor strength and functional performance in healthy female soccer players. *Scandinavian Journal of Medicine & Science in Sports*. 1998;8:257–64.
21. Anderson M, Gieck J, Perrin D, Weltman A, Rutt R, Denegar C. The Relationships among isometric, isotonic, and isokinetic concentric and eccentric quadriceps and hamstring force and three components of athletic performance. *The Journal of Orthopaedic and Sports Physical Therapy*. 1991;14(3):114–20.
22. Kobayashi Y, Kubo J, Matsubayashi T, Matsuo A, Kobayashi K, Ishii N. Relationship between bilateral differences in single-leg jumps and asymmetry in isokinetic knee strength. *Journal of Applied Biomechanics*. 2013;29(1):61–7.
23. Duthie G, Pyne D, Hooper S. Applied physiology and game analysis of rugby union. *Sports Medicine (Auckland, N.Z.)*. 2003;33(13):973–91.
24. MacQueen AE, Dexter WW. Injury trends and prevention in rugby union football. *Current Sports Medicine Reports*. 2010;9(3):139–43.
25. Brooks JHM, Fuller CW, Kemp SPT, Reddin DB. Epidemiology of injuries in English professional rugby union: part 1 match injuries. *British Journal of Sports Medicine*. 2005;39(10):767–75.
26. Kaplan KM, Goodwillie A, Strauss EJ, Rosen JE. Rugby injuries. A review of concepts and current literature. *Bulletin of NYU Hospital for Joint Disease*. 2008;66(2):86–93.
27. Olds T. The evolution of physique in male rugby union players in the twentieth century. *Journal of Sports Sciences*. 2001;19(4):253–62.
28. Duthie GM. A framework for the physical development of elite rugby union players. *International Journal of Sports Physiology and Performance*. 2006;1(1):2–13.
29. Green, B, Blake C, Caulfield B. Field testing to predict performance in rugby union players. *International symposium on biomechanics in sports: Conference proceedings archive*. 2009;1(1). ISSN: 1999-4168
30. Quarrie KL, Handcock P, Waller AE, Chalmers DJ, Toomey MJ, Wilson BD. The New Zealand rugby injury and performance project. III. Anthropometric and physical characteristics of players. *British Journal of Sports Medicine*. 1995;29(4):263–70.
31. Quarrie KL, Hopkins WG. Changes in player characteristics and match activities in Bledisloe Cup rugby union from 1972 to 2004. *Journal of Sports Sciences*. 2007;25(8):895–903.
32. Duthie G, Pyne D, Hooper S. Time motion analysis of 2001 and 2002 super 12 rugby. *Journal of Sports Sciences*. 2005;23(5):523–30.

33. Deutsch MU, Maw GJ, Jenkins D, Reaburn P. Heart rate, blood lactate and kinematic data of elite colts (under-19) rugby union players during competition. *Journal of Sports Sciences*. 1998;16(6):561–70.
34. Cunniffe B, Proctor W, Baker JS, Davies B. An evaluation of the physiological demands of elite rugby union using global positioning system tracking software. *Journal of Strength and Conditioning Research*. 2009;23(4):1195–203.
35. Beardmore AL, Handcock PJ, Rehrer NJ. Return-to-play after injury: practices in New Zealand rugby union. *Physical Therapy in Sport*. 2005;6(1):24–30.
36. Jakoet I, Noakes TD. A high rate of injury during the 1995 rugby world cup. *South African Medicine Journal*. 1998;88(1):1–3.
37. Bathgate A, Best JP, Craig G, Jamieson M. A prospective study of injuries to elite Australian rugby union players. *British Journal of Sports Medicine*. 2002;36(4):265–9; discussion 269.
38. Brooks JHM, Fuller CW, Kemp SPT, Reddin DB. A prospective study of injuries and training amongst the England 2003 Rugby World Cup squad. *British Journal of Sports Medicine*. 2005;39(5):288–93.
39. Brukner P, Khan K. Brukner & Khan's Clinical Sports Medicine. 4th ed. McGraw-Hill Australia Pty Ltd; 2012. p. 626 – 627.
40. Mason JJ, Leszko F, Johnson T, Komistek RD. Patellofemoral joint forces. *Journal of Biomechanics*. 2008;41(11):2337–48.
41. Hewett TE, Myer GD, Zazulak BT. Hamstrings to quadriceps peak torque ratios diverge between sexes with increasing isokinetic angular velocity. *Journal of Science and Medicine in Sport*. 2008;11(5):452–9.
42. Rosene JM, Fogarty TD, Mahaffey BL. Isokinetic hamstrings:quadriceps ratios in Iintercollegiate athletes. *Journal of Athletic Training*. 2001;36(4):378–83.
43. DeMorat G, Weinhon P, Blackburn T, Chudik S, Garret W. Aggressive quadriceps loading can induce noncontact anterior cruciate ligament injury. *American Journal of Sports Medicine*. 2000;32(2):477–83.
44. Bowman KF, Sekiya JK. Anatomy and biomechanics of the posterior cruciate ligament and other ligaments of the knee. *Operative Techniques in Sports Medicine*. 2009;17(3):126–34.
45. Evans EG. Basic fitness testing of rugby football players. *British Journal of Sports Medicine*. 1973;7:384–8.
46. Murphy AJ, Wilson GJ. The ability of tests of muscular function to reflect training-induced changes in performance. *Journal of Sports Sciences*. 1997;15(2):191–200.
47. Abernethy P, Wilson G, Logan P. Strength and power assessment. Issues, controversies and challenges. *Sports Medicine (Auckland, N.Z.)*.1995;19(6):401–17.
48. Olmo J, Castilla N. Explosive strength-related isokinetic parameters in high-level sprinters and long-distance runners: The relative power index. *Isokinetics and Exercise Science*. 2005;13:243–9.
49. Nicholas CW. Anthropometric and physiological characteristics of rugby union football players. *Sports Medicine (Auckland, N.Z.)*. 1997;23(6):375–96.

50. Stone MH, Moir G, Glaister M, Sanders R. How much strength is necessary? *Physical Therapy in Sport*. 2002;3(2):88–96.
51. Brown L, Weir J. ASEP procedures recommendation 1: Accurate assessment of muscular strength and power. *Journal of Exercise Physiology*. 2001;4(3):1–21.
52. Kannus P, Järvinen M. Prediction of torque acceleration energy and power of thigh muscles from peak torque. *Medicine and Science in Sports and Exercise*. 1989;21(3):304–7.
53. Rothstein JM, Lamb RL, Mayhew TP. Clinical uses of isokinetic measurements. *Critical Issues. Physical Therapy*. 1987;67(12):1840–4.
54. Thistle HG, Hislop HJ, Moffroid M, Lowman EW. Isokinetic contraction: a new concept of resistive exercise. *Archives of Physical Medicine and Rehabilitation*. 1967;48(6):279–82.
55. Baltzopoulos V, Brodie DA. Isokinetic dynamometry. Applications and limitations. *Sports Medicine (Auckland, N.Z.)*. 1989;8(2):101–16.
56. Wilk, K. E. Isokinetic testing: goals, standards and knee test interpretation. *Biodex Medical System. Biodex System 3* (1991).
57. Drouin JM, Valovich-mcLeod TC, Shultz SJ, Gansneder BM, Perrin DH. Reliability and validity of the Biodex system 3 pro isokinetic dynamometer velocity, torque and position measurements. *European Journal of Applied Physiology*. 2004;91(1):22–9.
58. Saliba L, Hrysomallis C. Isokinetic strength related to jumping but not kicking performance of Australian footballers. *Journal of Science and Medicine in Sport*. 2001;4(3):336–47.
59. Feiring DC, Ellenbecker TS, Derscheid GL. Test-retest reliability of the biodex isokinetic dynamometer. *The Journal of Orthopaedic and Sports Physical Therapy*. 1990;11(7):298–300.
60. Tsiokanos A, Kellis E, Jamurtas A, Kellis S. The relationship between jumping performance and isokinetic strength of hip and knee extensors and ankle plantar flexors. *Isokinetics and Exercise Science*. 2002;10:107–15.
61. Keskula DR, Dowling JS, Davis VL, Finley PW, Dell'omo DL. Interrater reliability of isokinetic measures of knee flexion and extension. *Journal of Athletic Training*. 1995;30(2):167–70.
62. Houweling TAW, Hamzeh MA. Does knee joint alignment with the axis of the isokinetic dynamometer affect peak torque? *Isokinetics and Exercise Science*. 2010;18:217–21.
63. Lategan L. Isokinetic norms for ankle, knee, shoulder and forearm muscles in young South African men. *Isokinetics and Exercise Science*. 2011;19(1):23–32.
64. Holmes JR, Alderink GJ. Isokinetic strength characteristics of the quadriceps femoris and hamstring muscles in high school students. *Physical Therapy*. 1984;64(6):914–8.
65. Jameson T, Knight K, Ingersol C, Edwards J. Correlation of isokinetic, isometric, isotonic strength measurements with a one-leg vertical jump.pdf. *Isokinetics and Exercise Science*. 1997;6:203–8.
66. Osternig LR. Isokinetic dynamometry: implications for muscle testing and rehabilitation. *Exercise and Sport Sciences Reviews*. 1986;14:45–80.
67. Cheung RTH, Smith AW, Wong DP. H:q ratios and bilateral leg strength in college field and court sports players. *Journal of Human. Journal of Human Kinetics*. 2012;33(1):63–71

68. Aagaard P, Simonsen EB, Magnusson P, Larsson B, Dyhre-Poulsen P. A new concept for isokinetic hamstring: quadriceps muscle strength ratio. *The American Journal of Sports Medicine*. 1998;26(2):231–7.
69. Andrade MDS, De Lira CAB, Koffes FDC, Mascarin NC, Benedito-Silva AA, Da Silva AC. Isokinetic hamstrings-to-quadriceps peak torque ratio: the influence of sport modality, gender, and angular velocity. *Journal of Sports Sciences*. 2012;30(6):547–53.
70. Lategan L. Comparison of isokinetic knee flexion and extension between men and women. *African Journal for Physical, Health Education, Recreation and Dance*. 2012;18(4):841–51.
71. Genuario SE, Dolgener FA. The relationship of isokinetic torque at two speeds to the vertical jump. *Research Quarterly for Exercise and Sport*. 1980;51(4):593–8.
72. Klavora P. Vertical-jump Tests: A Critical Review. *Strength and Conditioning Journal*. 2000;22(5):70.
73. Atabek HÇ, Sönmez GA, Yilmaz İ. The relationship between isokinetic strength of knee extensors/flexors, jumping and anaerobic performance. *Isokinetics and Exercise Science*. 2009;17(2):79–83.
74. Isaacs L, Isaacs D. Comparison of the Vertec and Just Jump Systems for measuring height of vertical jump by young children. *Perceptual and Motor Skills*. 1998;86(2):659–61.
75. Leard JS, Cirillo MA, Katsnelson E, Kimiatek DA, Miller TW, Trebinčević K, Garbalosa JC. Validity of two alternative systems for measuring vertical jump height. *Journal of Strength and Conditioning Research*. 2007;21(4):1296–9.
76. Markovic G, Jaric S. Is vertical jump height a body size-independent measure of muscle power? *Journal of Sports Sciences*. 2007;25(12):1355–63.
77. Spägle T, Kistner A, Gollhofer A. Modelling, simulation and optimisation of a human vertical jump. *Journal of Biomechanics*. 1999;32(5):521–30.
78. Umberger B. Mechanics of the vertical jump and two-joint muscles: Implications for training. *Journal of Strength and Conditioning Research*. 1998;20(5):70–4.
79. Johnson DL, Bahamonde R. Power output estimate in university athletes. *Journal of Strength and Conditioning*. 1996;10(3):161–6.
80. Bosco C, Luhtanen P, Komi PV. A simple method for measurement of mechanical power in jumping. *European Journal of Applied Physiology*. 1983;50:273–82.
81. Harman EA, Rosenstein MT, Fykman PN, Rosenstein RM, Kraemer WJ. Estimation of human power output from vertical jump. *The journal of strength conditioning research*. 1991;5(3):116–20.
82. Davis DS, Briscoe DA, Markowski CT, Saville SE, Taylor CJ. Physical characteristics that predict vertical jump performance in recreational male athletes. *Physical Therapy in Sport*. 2003;4(4):167–74.
83. Tomioka M, Owings TM, Grabiner MD. Lower extremity strength and coordination are independent contributors to maximum vertical jump height. *Journal of Applied Biomechanics*. 2000;17(3):181–8.
84. Kovačević E, Abazović E, Bradić J, Vrcić M. The predictive value of isokinetic assessment on the explosive strength of the lower extremities. *Homo Sporticus*. 2012;1(1):1–8.

85. Stewart A, Marfell-Jones M, Olds T, De Ridder H. International Standards for anthropometric assessment (2011). The International Society for the Advancement of Kinanthropometry; 2011. p. 1–115.
86. Biodex multi-joint system – pro setup/operational manual.
87. Steyn AG, Smit CF, Du Toit SHC, Strasheim C. Modern Statistics in Practice. 6th ed. 1998. p. 357.
88. Fuller CW, Taylor AE, Brooks JHM, Kemp SPT. Changes in the stature, body mass and age of English professional rugby players: a 10-year review. *Journal of Sports Sciences*. 2013;31(7):795–802.
89. Sedeaud A, Marc A, Schipman J, Tafflet M, Hager J-P, Toussaint J-F. How they won Rugby World Cup through height, mass and collective experience. *British Journal of Sports Medicine*. 2012;46(8):580–4.
90. Quarrie KL, Wilson BD. Force production in the rugby union scrum. *Journal of Sports Sciences*. 2000;18(4):237–46.
91. Quarrie KL, Handcock P, Toomey MJ, Waller AE. The New Zealand rugby injury and performance project. IV. Anthropometric and physical performance comparisons between positional categories of senior A rugby players. *British Journal of Sports Medicine*. 1996;30:53–6.
92. De Ruiter CJ, de Korte A, Schreven S, De Haan A. Leg dominance in relation to fast isometric torque production and squat jump height. *European Journal of Applied Physiology*. 2010;108(2):247–55.
93. Athanasios Z, Christos G, George D, Nikolaos Z. Bilateral Peak Torque of the Knee Extensor and Flexor Muscles in Elite and Amateur Male Soccer Players. *Physical Training*. 2005;1–10.
94. Swearingen J, Lawrence E, Stevens J, Jackson C, Waggy C, Davis DS. Correlation of single leg vertical jump, single leg hop for distance, and single leg hop for time. *Physical Therapy in Sport*. 2011;12(4):194–8.
95. Maly T, Zahalka F, Mala L. Differences between isokinetic strength characteristics of more and less successful professional soccer teams. *Journal of Physical Education and Sport*. 2011;11(3):306–12.

APPENDIX A

- DATA SHEET

Data Sheet

Code:	Age:	Playing position:	Dominant leg:
Measurements:			
Weight (kg)			
Height (m)			
Vertical Jump height: (cm)	R:	L:	
Biodex testing:			
60° Knee extension (NM)	R:	L:	
60° Knee Flexion (NM)	R:	L:	
180° Knee extension (NM)	R:	L:	
180° Knee Flexion (NM)	R:	L:	
300° Knee extension (NM)	R:	L:	
300° Knee Flexion (NM)	R:	L:	

APPENDIX B

- **PERMISSION LETTER FROM THE NORTH-WEST UNIVERSITY**

Wits Medical School
7 York Street
PARKTOWN
Johannesburg
2193

Private Bag X6001, Potchefstroom
South Africa 2520

Tel: (018) 299-1111/2222
Web: <http://www.nwu.ac.za>

Physical Activity, Sport and Recreation

Tel: (018) 2991821
Fax: (018) 285 6028
E-Mail: hanlie.moss@nwu.ac.za

RE: DATA FOR MASTERS DEGREE: MS E KRUGER

Ms Kruger, an employee of the North-West University, Potchefstroom campus, has access to data that has been collected during her duties related to the rehabilitation of Rugby players from the Rugby Institute of the North-West University. She has requested to use the data collected for the completion of her mini- dissertation at Wits.

As Director of the research focus area: Physical activity, Sport and Recreation (PhASRec), I give consent that the data may be used for a qualification obtained from Wits in the following circumstance:

- A co- or assistant supervisor from the research focus area PhASRec should be appointed in the study
- Any publications based on the data should include the student and co/assistant supervisor from NWU.

We are looking forward to this collaboration. Should you have any questions please contact me. Kind regards



Prof S.J. Moss
Director: PhASRec

APPENDIX C

- ETHICAL CLEARANCE CERTIFICATE



R14/49 Miss Esti Kruger

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M130232

NAME: Miss Esti Kruger
(Principal Investigator)

DEPARTMENT : Centre for Exercise and Sports Medicine
Medical School

PROJECT TITLE: The Predictive Value of Isokinetic Knee Joint
Muscle Strength for Vertical Jump Performance
in University Rugby Union Players of the North-
west University

DATE CONSIDERED: 22/02/2013

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR: Dr Kerith Aginsky

APPROVED BY:



Professor PE Cleaton-Jones, Chairperson, HREC (medical)

DATE OF APPROVAL : 05/04/2013

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 Secretary in Room 10004, 10th floor, Senate House, University.

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 resubmit the application to the Committee. I agree to submit a yearly progress report.

Principal Investigator Signature

Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRES

APPENDIX D

- **INFORMED CONSENT FORM FOR BIODEX EVALUATION**



NWU Biokinetics Institute
C/O Steve Biko str/ Borchard str
Cachet Park
Potchefstroom
2531

Tel: (018) 299 1824
Fax: (018) 299 1824
Practice number: 091 000 009 5397

INFORMED CONSENT FORM FOR BIODEx EVALUATION

1. Purpose and explanation of the test

You are going to take part in an isokinetic (Biodex) evaluation where muscle strength will be tested. The involved Biokineticist/Intern will explain the specific procedure. The evaluation may be stopped at any time. It is the right of the Biokineticist to refer you/ refer you back to the doctor if necessary.

2. Attendant Risks and Discomfort

During the observation part of the evaluation, you will be expected to remove some parts of your clothing enabling the Biokineticist to do a posture analysis. In order to do a better posture analysis, the Biokineticist may feel for certain landmarks on your body. Participants should take into account that there are both male and female personnel working at the Institute for Biokinetics and that any of previously mentioned may do your evaluation, unless preferred otherwise. Emergency equipment and trained personnel are available to deal with unusual situations that may arise.

3. Responsibilities of the Participant

Information you possess about your health status or previous experiences of heart-related symptoms (e.g. shortness of breath with low-level activity, pain, pressure, tightness, heaviness in the chest, neck, jaw, back, and/or arms) with physical effort may affect the safety of your exercise test. Your prompt reporting of these and any other unusual feelings with effort during the exercise test itself is very important. You are also expected to report all medications (including nonprescription), food and drinks taken recently and, in particular, those taken today, to the testing staff.

4. Benefits to be expected

The results obtained from the exercise test may assist in the diagnosis in evaluating what type of physical activities you might do for safe exercise prescription.

5. Inquiries

Any questions about the procedure used in the exercise test or the results of your test are encouraged. If you have any concerns or questions, please ask us for further explanations.

6. Use of Medical Records

The information that is obtained during exercise testing will be treated as privileged and confidential as described in the Health Insurance Portability and Accountability Act of 1996. It is not to be released or revealed to any person except your referring physician without your written consent. However, the information obtained may be used for statistical analysis or scientific purposes with your right to privacy retained.

7. Freedom of Consent

I hereby consent to voluntarily engage in an exercise test done by either a qualified Biokineticist/Intern to determine my exercise capacity and state of cardiovascular health. My permission to perform this exercise test is given voluntarily and I am aware that this is an educational training facility where students are in their first year of training and may assist in any of my needs. I understand that I am free to stop the test at any point if I so desire.

I have read this form, and I understand the test procedures that I will perform and the attendant risks and discomforts. Knowing these risks and discomforts, and having had an opportunity to ask questions that have been answered to my satisfaction, I consent to participate in this test.

Signature
(if under 18 yrs of age, parent/guardian)

Date

Signature of Witness

Date

APPENDIX E

- **LANGUAGE EDITING CERTIFICATE**

Declaration

This is to declare that I, Annette L Combrink , accredited
translator/language editor of the South African Translators' Institute, have
edited the study by

Esti Kruger

With the title

THE RELATIONSHIP BETWEEN ISOKINETIC KNEE EXTENSOR AND FLEXOR MUSCLE STRENGTH
AND VERTICAL JUMP PERFORMANCE IN UNIVERSITY RUGBY UNION PLAYERS OF THE NORTH-
WEST UNIVERSITY

P 
translator and language editor,
South African Translators' Institute
Membership no. 1000356
Date: 5 December 2013