Cardiff School of Sport

DISSERTATION ASSESSMENT PROFORMA:

Empirical [1]

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Programme:	SES
Dissertation title:	**The effects of varying squat technique and intensity levels on the power output within Rugby Union players.**
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Comments	**Section**
	Title and Abstract Title to include: A concise indication of the research question/problem. Abstract to include: A concise summary of the empirical study undertaken.
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	Discussion and Conclusions [2] To include: collation of information and ideas and evaluation of those ideas relative to the extant literature/concept/theory and research question/problem; adoption of a personal position on the study by linking and combining different elements of the data reported; discussion of the real-life impact of your research findings for coaches and/or practitioners (i.e. practical implications); discussion of the limitations and a critical reflection of the approach/process adopted; and indication of potential improvements and future developments building on the study; and a conclusion which summarises the relationship between the research question and the major findings.

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CARDIFF SCHOOL OF SPORT

DEGREE OF BACHELOR OF SCIENCE (HONOURS)

SPORT AND EXERCISE SCIENCE

TITLE

The effects of varying squat technique and intensity levels on the power output within Rugby Union players.

(Dissertation submitted under the discipline of
____Physiology and Health______)

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THE EFFECTS OF VARYING SQUAT TECHNIQUE AND INTENSITY LEVELS ON POWER OUTPUT WITHIN RUGBY UNION PLAYERS

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ACKNOWLEDGEMENTS

I would like to take this opportunity to thank all the participants within this study; it was recognised that each and every one of them gave up their own time to complete the testing and did so to a good standard.

I would also like to thank my dissertation tutor Dr Jon Oliver for his support throughout the whole dissertation process.

ABSTRACT

The purpose of this study was to investigate the influence of contraction type and movement type on optimal power production of the lower body musculature and identify the load that maximises power output within a squat. Fifteen males (20.7±0.7 years, 93.1±12.1 kg, 179.7±5.6 cm) currently playing for Cardiff Metropolitan RFC volunteered to participate in this research. An initial session was devised to establish each individual's 1RM (174.7±21.7 kg). In session two, four different squat conditions (Eccentric-Concentric Rebound, Concentric-Only, Eccentric-Concentric Rebound Jump, Concentric-Only Jump) were performed at six different load intensities (30%-80% of 1RM).

A load of 30% of 1RM was found to maximise average and peak power for all squat techniques. Optimal average and peak power was achieved through the Eccentric-Concentric Rebound Jump squat technique recording the highest mean peak power output; this technique was found to be significantly more powerful than the other techniques ($P<0.05$). The influence of the SSC muscle contraction was found to enhance performance for both non-jump (8.3%) and jump conditions (9.3%) compared to the concentric contractions. Movement types involving the ability to jump with the bar was found to be the most influential factor to maximal power production reporting enhancements in mean average power values (12.5% Ecc-Con Rebound and 10.0% Con-Only) and peak power values (20.4% Ecc-Con Rebound and 19.2% Con-Only) across all loads. Most instances were found to be significant ($P<0.05$). It can be concluded from the findings of this study that power output decreases as load increases for all squat conditions. The results of this study suggest that optimal power production can be achieved through performing an Eccentric-Concentric Rebound Jump squat at a load of 30% of 1 RM; thus, strength and conditioning coached should consider this when conducting power sessions.

CHAPTER ONE

INTRODUCTION

1.0 INTRODUCTION

1.1 Introduction To Power.

Muscular power is an important component in many modern day sports; the power an athlete can exert can often be a determinant of success within a training or competition environment. This is supported by Cormie *et al.* (2011) suggesting the ability to generate maximal power during complex motor skills is of paramount importance to successful athletic performance across many sports. Although it is evident that muscular function is improved through resistance strength training there is still continuous debate as to the most effective resistance strength training method to optimise power output (Cronin *et al.,* 2001).

Previous research has been conducted into the bench press technique and load producing optimal power; however there is limited research on lower body power production based on squatting technique justifying the need for further research (Cronin *et al.,* 2001). Identifying the effectiveness of different types of training is integral to improving performance throughout sport; therefore it is essential that methods of training be evaluated through testing. When considering assessing the effectiveness of power training, variables such as the velocity, force and power output are very important factors influencing training adaptations (Wilson *et al.,* 1993). When determining playing rank among professional rugby league player's strength and power are considered to be the best discriminators; as well as being considered as an indicator of effective training, testing can be used to distinguish between performance standards and ranking further justifying its importance (Baker *et al.,* 2008).

The definition of power is force x velocity; an increase in either force and /or velocity is required in order for an athlete to increase their power, therefore if an athlete is aiming to maximise power performance then both of these components must be trained (Hendrick, 2002; Newton, 1994). Maximum strength and velocity in weight training have been investigated greatly in the past however optimal power production has not been reviewed as extensively. Maximum strength differs from power as it refers to the ability of an individual to exert force; there is no consideration for the rate of force production or the athlete’s ability to sustain it (Young *et al.,* 2001). As previously stated power comprises of two components, strength and velocity; an optimum combination must be reached between maximum strength and velocity in order to attain optimal power production. The optimal force-velocity relationship of a squat technique is of great importance to lower body power production. Improving lower body power within well-trained rugby union players can be difficult during the competition phase of the season; consequently suitable power training methods need to be identified to overcome this difficulty (Argus *et al.*, 2012).

1.2 Issues Within Power Training.

A key issue associated with power training would be which load expressed as a percentage of the individuals one repetition maximum (%1RM) and which technique best facilitates optimum power production. The study conducted by Hendrick (2002) assessed the two components of power (Velocity and Force) and identified optimal peak power to be achieved at loads of 40-60%, it was also identified that peak force was increased lifting heavier loads of 70-90% of one repetition maximum as fast as possible. Conflicting studies conducted suggest different training loads ranging from 30-50% of 1RM, 40-50% of 1RM, 50-60% of 1RM and 80-100% of 1RM to facilitate peak power production (Gollinick *et al.,* 1973; Kaneko *et al.,* 1983; Cronin *et al.,* 2001; Zink *et al.,* 2006). It is evident that previous literature based on scientific findings contains contradiction of what is considered to be the optimum force-velocity relationship justifying further research production (Gollinick *et al.,* 1973; Kaneko *et al.,* 1983; Cronin *et al.,* 2001; Zink *et al.,* 2006).

A second issue in power development important to this study relates to the type of squat technique performed. When considering power-training techniques the types of muscle contractions and amount of force involved in the movements are important in determining the quality of the outcome. There has been on-going debate into the type of contraction that best facilitates optimal power production (Cronin *et al.,* 2001; Miyaguchi *et al.,* 2008). Varying squat technique can allow sport and exercise practitioners to control the type of muscle contractions being performed. A technique consisting of an eccentric muscle contraction prior to the concentric action may be important to producing optimal power of a squat technique. This action is known as the Stretch Shortening Cycle (SSC); Komi (1992) defines this as a natural type of muscle function where muscle is stretched immediately before being contracted; this eccentric/concentric coupling of muscular contractions (SSC) produces greater power output than a simple individual concentric contraction (Cronin *et al.,* 2001; Miyaguchi *et al.,* 2008).

A second variation of the squat technique is whether the load is projected at the end of the movement. Many athletes prefer to perform a squat without a jump especially on heavier loads; a study conducted by Hori *et al.* (2008) investigated into the use of eccentric breaking on the landing phase of the jump squat through incorporating breaking mechanisms to control the momentum on landing and impulse applied to decelerate. The fact that these breaking mechanisms exist suggests that a problem may be evident in jump squatting heavier loads, however not everyone has access to these breaking mechanisms. When performing the exercise with lighter loads large accelerations are achieved at the beginning of the concentric phase of the contraction, consequently this results in large amounts of time being spent in decelerating the load in the final stages of the concentric phase (Cronin *et al.,* 2001). The deceleration phase can be eliminated by allowing the bar to be projected through the means of a throw or a jump (Hori *et al.,* 2008). If the bar is not released movements will consist of shorter acceleration and longer deceleration phases as the athlete has to slow the bar; these longer decelerations result from shorter agonist activation and greater antagonist co-activation especially when performing at low intensities (Cronin *et al.,* 2001). This ensures a full range of motion and eliminates any undesired deceleration which may be important in producing optimal power production. For this reason one technique that has attracted a considerable amount of attention from scientists and practitioners is the weighted jump squat (Wilson *et al.,* 1993; Newton *et al.,* 1999; Hori *et al.,* 2008). From these technique variations four different squat types can be performed to facilitate the specific types of muscle contraction; an Eccentric-Concentric Rebound squat which will elicit the SSC whilst maintaining 100% ground contact, Concentric-Only squat isolating the concentric movement whilst maintaining 100% ground contact, Eccentric-Concentric Rebound Jump squat eliciting SSC in conjunction will terminating ground contact eliminating deceleration phase and finally a Concentric-Only Jump squat isolating the effects of projecting the bar without the SSC.

1.3 Aims And Objectives.

The purpose of this study is to identify which type of squat technique and resistance loading based on percentage of 1 repetition maximum is optimal for maximal power output production. Four different squat techniques will be used to investigate the effects of different muscle contractions (concentric only and SSC) on optimal power production; as well as different techniques consisting of the bar being projected through the means of a jump squat. Six resistance loads ranging from 30-80% of 1RM will be investigated with the aim of identifying the load that maximises power output within a squat.

CHAPTER TWO

LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 Importance Of Power.

In modern day sport muscular power is considered to be an important component of many athletic pursuits; success can be determined or at least muscular function and motor performance can be enhanced by the power of an athlete (Cronin *et al.,* 2001). The definition of power is force x velocity; an increase in either force and /or velocity is required in order for an athlete to increase their power, therefore if an athlete is aiming to maximise power performance then both of these components must be trained (Newton, 1994; Hendrick, 2002). The involvement and demands of power in sport has evolved dramatically over the last few decades. Various sports require one movement sequence with a goal of producing a high velocity of release or impact; the maximal power an athlete can exert can often determine success and therefore can be considered to be an important component of fitness (Cronin *et al.,* 2001; Ackland *et al.,* 2009). This is further supported by Cormie *et al.* (2011) suggesting the ability to generate maximal power during complex motor skills is of paramount importance to successful athletic performance across many sports. In order to account for these demands there has been increased importance for strength and conditioning practitioners to use a variety of exercises to enhance performer’s musculoskeletal and neuromuscular systems in order to achieve optimal performance (Siff, 1992). Strength and conditioning practitioners are faced with the challenge of identifying the most effective method of power training in order to optimise performance across a vast range of sports. Argus *et al.* (2012) highlights the difficulty of improving power within well-trained team sport athletes during competition phase when investigating lower body power in professional rugby union players; consequently power training methods that can be conducted by well-trained athletes during the competition phase need to be identified. The necessity for power development in sport needs no debate as coaches, athletes and strength and conditioning specialists dedicate a significant amount of time working on muscular power development (Mihalik *et al.,* 2008)

2.2 Load-Velocity Relationship And Power Output.

The load of the resistance and the velocity of the mass moved determines power output. Training studies have not yet determined the optimum combination of resistance and plyometric exercises needed to cause the best muscular power production (Mihalik *et al.,* 2008). It is well documented that resistance training is a vital consideration for athletes wishing to improve their power output (Fleck and Kraemer 1997). Key issues of power training discussed in Cronin *et al.*'s (2001) study seem to be which load (expressed as a percentage of one repetition maximum (1RM)) and which training technique best facilitates power development. When considering the technique the influence of contraction type and movement type on power output of the upper body were explored over a variety of training loads ranging from 30%-80% of 1RM (Cronin *et al.,* 2001). Cronin *et al.* (2001) identified several different power training techniques; one comprising of high velocity movements using lighter loads compared to contrasting heavy load training techniques involving lifting loads between 80-100% of 1RM. When considering power using resistance training the combination of load applied and the velocity of the movement are two vital factors; the optimal compromise of the two factors is an on-going issue in power training. Gollinick *et al.* (1973) identify that heavy load training is the superior type of training to facilitate power based on the physiological basis that there is a recruitment of the fastest high threshold motor units for the development of large forces to overcome the heavy loads accompanied with neural adaptations associated with motor neurons firing high frequency impulses for comparatively long durations. Comparatively; contrasting ideology favours lighter loads ranging from 30-50% of 1RM to achieve the optimal compromise between force and velocity for power development; this is attributed to the thought that fast twitch fibres are selectively activated during such high velocity movements (Kaneko *et al.,* 1983). This demonstrates the impact of load manipulation on power production isointertial exercise.

2.3 Power Training.

A crucial issue is faced by scientists and coaches to develop effective and efficient training programmes that improve maximal power production in dynamic, multi-joint movements (Cormie *et al.,* 2008). Cronin *et al.* (2001) raise issues over the optimum training intensity for power training. Whereas Cormie *et al.* (2008) identify ballistic, plyometric and weightlifting exercises to be suitable primary exercises within a power training programme that enhances maximal power; however considering the loads applied to these exercises will depend on the specific requirement of the particular sport in question and the specific types of movement being trained.

"Plyometrics is a specialised, high-intensity training technique that enables an athlete's muscles to deliver as much strength as possible in the shortest period of time so that power development results" (Azari *et al.,* 2012, p1). Buckenmeyer *et al.* (2000 p470) states "plyometric drills are used to improve vertical jumping ability and explosive performance in general." However when considering drop jump plyometric training techniques there is continuous debate into the optimal Drop Height considering performance and injury. Previous research has highlighted some key aspects when investigating drop height, Maarten *et al.* (1987) hypothesised that performing a drop from a higher position than 60 centimetres could be detrimental to lower extremity joints. Conflicting research findings conducted by Lees and Emad (1994) found that from 5 differing heights between 24 centimetres and 68 centimetres the optimal height was between 57cm and 68cm, this was calculated from recording Resultant Force, Negative Displacement and Peak Instantaneous force. Drop jumps incorporation within sport has been underlined as an important aspect with regards to plyometric training; however determination of the optimal height and its impact on plyometric training still requires further research. Although it is identified that plyometric training develops power output, it is not identified to produce the highest power output when compared to resistance exercises (Cronin *et al.,* 2001).

The importance of a strength and conditioning practitioner's role to identify the specific demands of a particular sport and impose the appropriate training programme to achieve the desired outcomes is pinnacle to improving performance. Lower body power training is considered essential to the game of rugby involving movement types such as running, changing of direction, and tackling; however data concerning lower body training has been less informative and attracted minimal research attention (Baker *et al.,* 2008). When considering the components of fitness contributing to power (force x velocity), a training programme that focuses on the least developed factor contributing to maximal force will prompt the greatest neuromuscular adaptations and therefore result in superior performance improvements for that individual (Cormie *et al.,* 2008).

2.4 Power Testing.

The imperative role that power plays within a variety of sports justifies the amount of on-going research by sport and exercise scientists trying to identify the optimum power training methods. Therefore it is essential that methods of training be evaluated through testing to ensure effectiveness and ensure the desired outcome is being accomplished. A standard training programme will generally consist of the monitoring of the weight lifted and the number of repetitions and sets successfully completed; when considering assessing the effectiveness of power training, variables such as the velocity and, force and power output are very important factors influencing training adaptations (Wilson *et al.,* 1993). Drop Height promotes investigation into the development of training drills in order to increase power and explosive abilities within athletes. Knowledge gained from such investigations can be integral to future power training methods. Similarly to Drop Height, Vertical Jump Height is considered to be useful exercise for testing the effects of power training (Mihalik *et al.,* 2008). This has furthered Mihalik *et al.*'s (2008) investigation into the effectiveness of a combination of power training techniques comprising of compound and complex training programmes; improvements in power output were determined through gains in Vertical Jump Height which is widely considered to be a strong outcome measure for Power testing (McNitt-Gray, 1993; Chu and Potach, 2000). Studies conducted by Newton *et al.* (1999) on NCAA Division 1 volleyball players considered Vertical Jump Height to be a valid indicator of power testing; findings identified subjects to have achieved a 5.9% increase in Vertical Jump Height correlating to their 8% increase in peak power recorded following an 8-week squat training programme. Testing the effectiveness of training is integral to improving performance throughout all levels of sport. As well as being considered as an indicator of effective training, testing can be used to distinguish among players of different ranks ranging from high school to elite professional standards of sport; strength and power were considered to be the best discriminators when determining playing rank among professional rugby league players (Baker *et al.,* 2008).

2.5 Power Training Techniques.

Demura *et al.* (2006 p.137) define muscle power “as the ability to produce a short burst of force power output evaluated from mechanical power (W) calculated by movement velocity (m/s) or work (J) in single or repeated muscle outputs for sub-maximal loads”. When considering power-training techniques the types of muscle contractions and amount of force involved in the movements are important in determining the quality of the outcome. When investigating into resistance training programmes a particular point of interest is assessing the effects of training on overall power production during the full concentric movement and associating the effects on power production of each individual phase of the overall movement (Drinkwater *et al.,* 2007). Power training programmes commonly consist of complex compound movements that can be broken down into several phases featuring different contraction types. The influence of contraction type and movement type on power output of the upper body was identified as an issue worth investigating by Cronin *et al.* (2001). Issues raised throughout the study were over the optimal compromise of force and velocity for the development of power and the type of contraction types most suited to facilitating power production based on different techniques. Cronin *et al.* (2001) identified that bench press techniques involving of counter-movements recruiting the stretch-shortening cycle (rebound) elicits higher power outputs across all loads (30-80% 1RM) when the load is both thrown and held compared to the concentric only techniques; techniques combining the rebound and throwing the load proved to produce significantly higher mean power output than the rebound only condition.

2.6 Contraction Type And Power Production.

There has been on-going debate into the type of contraction that best facilitates power production (Cronin *et al.,* 2001; Miyaguchi *et al.,* 2008). Muscle movements can be categorised into three types of actions; Concentric, Eccentric and Isometric (static). Movement types can consist of one or all of these muscle actions in co-ordination. A concentric muscle action is referred to by Wilmore and Wilmore *et al.* (2004) as a muscles principle action of shortening, consisting of actin and myosin filaments sliding across each other pulling the actin filaments closer together. Eccentric action is defined as the exertion of force whilst the working muscle is lengthening. As well as this muscles can be working without any change in muscle length occurring, this is termed as an Isometric muscle action (Wilmore and Costill 2004). During a muscle contraction muscles and their connective tissues have properties of elasticity; when these tissues are stretched the elasticity results in stored energy can then be released during muscle activity increasing the amount of force produced. Considering the speed of action the development of force differentiates between concentric and eccentric muscle contractions; during concentric muscle contractions maximal force development decreases at higher velocities whereas during eccentric actions, fast actions allow maximal application of force (Wilmore and Costill 2004).

Movement types consisting of explosive power such as “throwing” and “hitting” recruit a stretch-shortening cycle (SSC) of concentric muscle action immediately followed by eccentric muscle action is frequently used in a number of modern day competitive sports (Miyaguchi *et al.,* 2008). The SSC is defined by Komi (1992) as a natural type of muscle function where muscle is stretched immediately before being contracted; this eccentric/concentric coupling of muscular contractions is stated to generate greater power than an individual concentric contraction. When performing an exercise the elasticity of the muscle and tendons being recruited have been demonstrated to significantly affect performance in SSC movements; a highly compliant elastic system increases the use of strain energy SSC movements, through flexibility training the contribution of elastic strain energy to the movement will be increased facilitating the performance in a SSC movement (Wilson *et al.,* 1994).

Increasing support for power training involving SSC movements has been established over recent years; as a result the incorporation of SSC movements into modern day training programmes has increased dramatically (Cronin *et al.,* 2001; Miyaguchi *et al.,* 2008; Komi, 2011). According to Miyaguchi and Demura

(2008) studies investigating into SSC movements have been performed mainly using jumping and plyometric drills before their study; other lower body training movements that may provide a platform to investigate the SSC further may be squatting. O’Shea (1985) describes the squat as the “King” of all weight-lifting exercises as it stands supreme in its ability to maximise athletic potential. Rippletoe (2001) backs this up describing the squat as the most important exercise in the weight room. A back squat consists of the quadriceps and gluteal muscles working as the prime movers and the hamstring functioning as a synergist (Ebben and Jensen 2000). Squatting develops large muscle groups in the body and enhances neuromuscular efficiency; this allows the transfer of power to other biomechanically similar movements requiring a powerful trust form the hips and the thighs including all forms of running, lifting and pushing with the lower body (O’Shea, 1985).

2.7 Squat Technique.

Varying squat technique can allow sport and exercise practitioners to control the type of muscle contractions being performed. One technique that has attracted a considerable amount of attention from scientists and practitioners is the weighted jump squat (Wilson *et al.* 1993; Newton *et al.,* 1999; Hori *et al.,* 2008). Power output can be maximised during a given resistance- training exercise by allowing the barbell or the athletes body to be projected into the air, terminating ground contact; this allows the undesirable deceleration phase of the exercise to be minimised (Cronin *et al.,* 2001;Hori *et al.,* 2008). There have been arguments for and against the use of jump squatting based on threats posed by the landing phase. During the landing phase muscle groups of the lower extremities work eccentrically to decelerate the projected load which is considered to be more susceptible to muscle damage than concentric contractions (Hori *et al.,* 2008). In order to minimise the force of impact at the point of contact with the ground during the landing phase of a jump squat, breaking mechanisms have been considered to control and reduce the momentum of the barbell descending, therefore decreasing the impulse that must be applied by the subject to decelerate the load (Hori *et al.,* 2008). Conflicting ideas suggest that reducing the eccentric load on the landing phase of the jump squat may have negative effects on training;

however such ideas have not been fully investigated in previous research. Hori *et al.* (2008) did identify that the breaking mechanism aforementioned will modify the eccentric phase preventing a natural stretch-shortening cycle being experienced therefore leading to a decrease in training stimulus reducing the neuromuscular adaptations which can be considered beneficial to training performance. Once the subject is accustomed to the jump squat technique, the impact of the landing phase can improve strength without damaging working muscle groups supporting the idea that eccentric muscle action facilitates positive physiological adaptations eliminating the need for a breaking mechanism when performing squat jumps (Hori *et al.,* 2008). However the potential for injury with squat jumping is of the highest importance when being considered for a training programme. In the position statement from the National Strength and Conditioning Association (p16), it is said that “only athletes who have already achieved high levels of strength and conditioning should engage in plyometric drills”. Hori *et al.* (2008) considers weighted jump squat training without eccentric breaking to be similar in characteristics to plyometric drills in respect to the utilisation of the stretch shortening cycle and absorption of high landing impact; therefore the question of whether the subject can tolerate the landing impact of a weighted jump squat should be considered by practitioners before engaging in jump squats.

2.8 Methodical Issues Of Power Testing.

When considering the methodical protocol of investigating into power, past studies have generally used jumping (Miyaguchi *et al.,* 2008). There are numerous methods of investigating power. Hori *et al.* (2008) measured strength, power and athletic performance through several jump types comprising of countermovement jump, static jump, drop jump and weighted jump squats. Testing procedures devised by Wilson *et al.* (1994) consisted of using a Plyometric Power System (PPS) which enabled performers to safely throw a loaded bar whilst relevant kinetic data could be recorded by a rotary encoder attached to the machine producing pulses indicating the displacement of the bar. Linear bearings were attached to either end of the bar allowing the bar to slide about two hardened axle steel shafts with limited friction; however, the machine only allows vertical movements of the bar.

A similar study conducted by Miyaguchi *et al.* (2008) looked at the movement of a bicep curl and how a technique recruiting the SSC cycle affected the power output in comparison to a concentric only technique. Two different techniques performed were compared using two differing experimental conditions in the study: a static condition versus a countermovement SSC condition. Through comparison of the techniques it was identified that the countermovement SSC movement increased power compared to the static. A further example of using different techniques to distinguish between the effects of different muscle actions was a study conducted by Hori *et al.* (2008); static jump technique versus dynamic counter movement jump. Through comparison of these techniques it was identified that power output in the dynamic counter movement jump was greater than the static jump.

2.9 Measurement Of Power.

The need for a high degree of specificity between power output at which a subject trains and the power output a subject is tested has dramatically evolved over the last thirty years in order to keep up with the demands of modern day strength and conditioning (Drinkwater *et al.,* 2007). For a long time detailed analysis of power output was limited to video or cinematographic analysis. Video analysis is considered by Drinkwater *et al.* (2007) to be a very laboratory-intensive and resource-intensive method of analysis, limiting its research ability and practicality to apply it to the relevant sporting environment resulting in concerns of different recruitment patterns and mechanisms of fatigue inherent in different forms of contractions. Laboratory testing protocols devised should have initially been conducted within the laboratory environment and then transferred to a free-weight setting; however the degree of experimental control in the field does not always replicate that achieved in the laboratory posing a limitation of validity.

Considering the findings of Drinkwater *et al.* (2007) we can suggest that a more accurate method of monitoring training programmes will be to conduct the specific training research in an applied setting. The innovation of optical encoder technology has revolutionised the development of several commercial devices applied within various training and research settings. Drinkwater *et al.* (2007)

found an optical encoder to be a valid measurement of power for free weight movements with 95% confidence limits; the study also showed the optical encoder to provide a valid measure of power in a standard weight room setting eliminating the need to transfer a laboratory protocol to a practical environment further strengthening its value is that. The optical encoder is considered by Drinkwater *et al.* (2007) to be a portable device easily utilised by sport scientists to analyse valid measures of peak and mean power training variables in addition to the volume of work performed during weighty resistant training; applications derived from this are considered to help sport scientists design studies with greater control over training variables and further knowledge of free weight training. Considering future studies investigating into power it is hard to justify why a laboratory devised protocol transferred to a free-weight setting would be preferred to the use of an optical encoder.

2.10 Optimal Force- Velocity Relationship.

When considering developing power using resistance training the combination of load applied and the velocity of the movement are two vital factors; the optimal compromise of the two factors is an on-going issue in power training. Studies conducted by Hendrick (2002) assessed the two components of power (Velocity and Force) and findings showed that peak velocity was maximised when loads of 40-60% were lifted as fast as possible, it was also identified that peak force was increased lifting heavier loads of 70-90% of one repetition maximum as fast as possible. Conflicting studies conducted suggest different training loads ranging from 80-100% of 1RM and 30-50% of 1RM to facilitate power (Gollinick *et al.,* 1973; Kaneko *et al.,* 1983). It is evident that previous literature based on scientific findings contains contradiction of what is considered to be the optimum force-velocity relationship justifying further research (Kaneko *et al.,* 1983; Gollinick *et al.,* 1973).

2.11 Transferring Upper Body To Lower Body.

In training and testing the intensity at which a subject is working is an important variable to monitor. When considering weight training for the upper body muscle strength improvement, the bench press is a typical exercise; and its one repetition maximum (1RM) is the index of force production (Miyaguchi *et al.* 2008). When considering the lower body a squat is a typical exercise in which its intensity is measured as a percentage of the subject’s 1RM. Although the 1RM is transferable from the upper body to the lower body as an index of muscular power development, results based on upper body research cannot always be transferred to the lower body based on different muscle fibre distribution and movement mechanisms. Upper body studies conducted by Miyaguchi *et al.* (2008) compared to lower body studies conducted by Komi *et al.* (2011) suggest that the SSC potentiation that are observed in the upper body limbs may compared to that of the lower body limbs may not appear obviously. This is further backed up by Glasheen *et al.* (1995) pointing out that when comparing the upper limbs to the lower limbs it must be considered that the upper limbs do not have tendon tissues such as the Achilles tendon which possess strong elastic properties; furthering this the large muscle groups in the lower body may consist of recruiting alternate fibre types to upper body movements. Studies conducted by Cronin *et al.* (2001) were specific to the upper limbs and therefore based on differing findings between upper and lower limbs and attributed to differing elastic properties, further investigations should be conducted to identify if the findings of Cronin *et al.* (2001) are transferable to the lower body (Glasheen *et al.*, 1995; Miyaguchi *et al.*, 2008; Komi *et al.*, 2011).

CHAPTER THREE

METHOD

3.0 METHOD

3.1 Subjects.

Fifteen males currently playing for Cardiff Metropolitan RFC volunteered to participate in this research. All participants familiarised themselves with the participant information form (Appendix C) and completed both the informed consent form and health questionnaire prior to participating in any research (Appendix A and B). All players were in mid-season 2012-2013 and declared as fit. All subjects were experienced in resistance training; through rugby strength and conditioning subjects were consistently completing resistance training sessions 3 times a week and had two years of experience at this level, subjects were therefore very familiar with squatting and power training. The subjects mean (±SD) age, weight and stature were 20.7±0.7 kg, 93.1±12.1 kg, 179.7±5.6 cm. Mass and stature data was collected using a set of digital scales (Digital Scales, SECA- Model 770, Vogel & Halke, Hamburg, Germany) and an anthropometric stadiometer (Stadiometer, Holtain Fixed Stadiometer, Holtain LTD, Crosswell, Crymych) and measured to the nearest 0.1kg and 0.1cm. The Human Ethics Committee of the Cardiff Metropolitan University School of Sport approved all the procedures undertaken in this study.

3.2 Description Of Protocols

Subjects performed all squats using a barbell free weight inside a squat cage with safety bars attached and spotters in place. A Tendo Accelerometer (Accelerometer, Tendo weightlifting analyser, Tendo Sport Machines, Trencin, Slovak Republic) was attached to the barbell and measured bar displacement. From the measurement of displacement Peak power and Average power can be calculated. Results were input to my personal computer.

3.3 Experimental Summary.

This study was designed to investigate into which type of squat technique and resistance loading based on percentage of 1 repetition maximum is optimal for maximal power output production. Four different squat techniques were selected to facilitate the specific types of muscle contraction; two protocols where ground contact was maintained for the whole technique: Eccentric-Concentric Rebound squat which will elicit the SSC and a Concentric-Only squat isolating the concentric movement. A further two protocols where ground contact was terminated during the concentric phase: Eccentric-Concentric Rebound Jump squat eliciting SSC in conjunction will terminating ground contact eliminating deceleration phase and finally a Concentric-Only Jump squat isolating the effects of ground projecting the bar without the SSC. All four techniques were performed at six different resistance intensities (30-80% of 1RM). Peak power and Average power was recorded for each squat.

3.4 Testing Procedures.

The experimental design used in this investigation was similar to Cronin *et al.*'s (2001) study; similar patterns of muscle contractions and load intensities were tested based on the lower body instead of the upper body. Testing was performed over two sessions; session one determined each participant's 1RM. Similarly to Hori *et al.* (2008) this was conducted using a rebound eccentric-concentric squat technique; subjects would position themselves under the bar placed on the power rack approximately 10cm below shoulder height, stand up and step back a few spaces with the assistance of a spotter and squat down to 90˚ flexion of the knees, if the angle was exceeded or not achieved the squat was rejected, ground contact had to be maintained for 100% of the movement. 90˚ flexion of the knee was determined by visual inspection (Baker *et al.* 2008). Participants completed a generalised warm up comprising of a light jog, dynamic and static leg stretches and two sets of 8 squats using a light resistance of 60kg (Cronin *et al.,* 2001; Baker *et al.,* 2008). Subjects were allowed three attempts to successfully squat each load with one minute rest between each attempt, if successfully lifted within protocol they were allowed to increase the load by 10kg. When a participant failed three times on a load the previous successful lift was recorded as their 1RM (Baker *et al.,* 2008). Safety bars and spotters were in place for all squats performed until failure.

Once 1RM testing was completed subjects familiarised themselves with the four squat techniques they would be performing in session two. Familiarisation consisted of as many repetitions as required over a range of loads (30-80% 1RM) and was deemed completed when both the participant and I were satisfied with performance of each technique. Technique one was an Eccentric-Concentric Rebound squat (RS) and was the technique used for 1RM testing; participants started standing up and were instructed to lower the load as fast as possible to 90˚ flexion of the knees, and then immediately push the bar upward back to the starting position of standing as fast as possible ensuring ground contact was attained for 100% of the movement (Hori *et al.,* 2008). Technique two was a Concentric-Only (CS) squat; safety bars were used to fix the starting position of the barbell to a depth that facilitated a starting squat position of 90˚ flexion of the knees. Participants were then instructed to perform the upward concentric phase of the squat as fast as possible finishing in the standing position. Technique three was an Eccentric-Concentric Rebound Jump Squat (RJS); this consisted of participants eccentrically squatting to a depth of 90˚ flexion of the knees and immediately performing the concentric phase of the squat, the participant is instructed to terminate ground contact by jumping with the barbell as high as possible and then landing back in a standing position (Hori *et al.* 2008). By allowing the bar to be projected through the means of a jump the deceleration phase at the end of the concentric phase was eliminated and a full range of movement was ensured. Technique four was a Concentric-Only Jump Squat (CJS); like technique two (CS) the barbell will be fixed in position ensuring the starting squat position was at a depth facilitating 90˚ flexion of the knees, participants were instructed to perform the concentric phase as fast as possible and to try and terminate ground contact projecting the bar into the air where possible and then landing back in the neutral position. Spotters and safety bars were in place when familiarising themselves with and performing the techniques.

Session two began with a generalised warm up consisting of a light jog, dynamic and static leg stretches and two sets of 8 squats at 40% 1RM (Cronin *et al.,* 2001). Participants were instructed to perform all squats as fast as possible to the best of their ability for all techniques and intensities. Four squat techniques were performed at six different training loads (30, 40, 50, 60, 70 and 80% 1RM). The four squat techniques as previously explained were: An Eccentric-Concentric Rebound Squat (RS); A Concentric-Only Squat (CS); An Eccentric-Concentric Rebound Jump Squat (RJS); and a Concentric-Only Jump Squat (CJS). Starting at 30% 1RM loads were performed across all four techniques; one minute rest was allocated between each squat and to allow time for any safety bar and barbell positions to be altered; two minutes rest were allocated between changes of loads in order to change weights and enable subject to rest before the increased resistance (Cronin *et al.,* 2001). For rebound techniques no pause was allowed between the eccentric and concentric phases; if the eccentric phase failed to achieve or exceeded a 90˚ flexion of the knees the squat would be rejected. Sessions one and two were conducted within two weeks of each other.

3.5 Data Analysis.

A repeated measures ANOVA was used to test the difference in power output with changes in load within each squat condition. This same approach was used to examine the changes in power when a comparing a jump squat technique versus a non-jump squat technique. This approach was further used to examine the differences between any of the four exercise condition on power output. The SPSS software (Version 20) was used to conduct significance testing; criterion for significance was set at $P<0.05$ for all analysis. A repeated measure ANOVA was used to assess significant differences; where a significant difference was found post-hoc contrasts using a Bonferroni were used to find between which pairs of data were significantly differently.

CHAPTER FOUR

RESULTS

4.0 RESULTS

4.1 Comparison Of Power Output Across Six Load Intensities.

The power outputs as described in this study represent the power transmitted from the subject to the bar. The first session undertaken by subjects established individuals 1 Repetition Maximum's (mean 174.7 ±21.7kg). Figures 1 and 2 show a negative reduction; both peak and average power outputs decrease as load intensities increase. Peak power occurred at 30% of 1RM for all four squat techniques. Figures 1 and 2 comprise of eight graphs displaying the comparison of mean average and peak power outputs across each of the six loading intensities (30%-80%) for each of the four different squat techniques. Out of the eight sets of data five were found to contain data showing that all power outputs were significantly different (<0.05) across all loads; these were mean average power for all four of the conditions and mean peak power for the Eccentric-Concentric Jump condition. The remaining three mean peak power sets of data contained mostly significantly different data. Mean peak force for the other three squat conditions, Eccentric-Concentric Rebound, Concentric-Only and Concentric-Only Jump were all found to have mostly significantly different data. Pairwise comparisons recorded comparisons to not be significantly different (>0.05) between 50% and 60% of 1RM for mean peak powers for the Eccentric-Concentric squat; Concentric-Only squat technique between training loads 30% and 40%, 40% and 50% of 1RM and finally between training loads 40% and 50% for the Concentric-Only Jump technique.

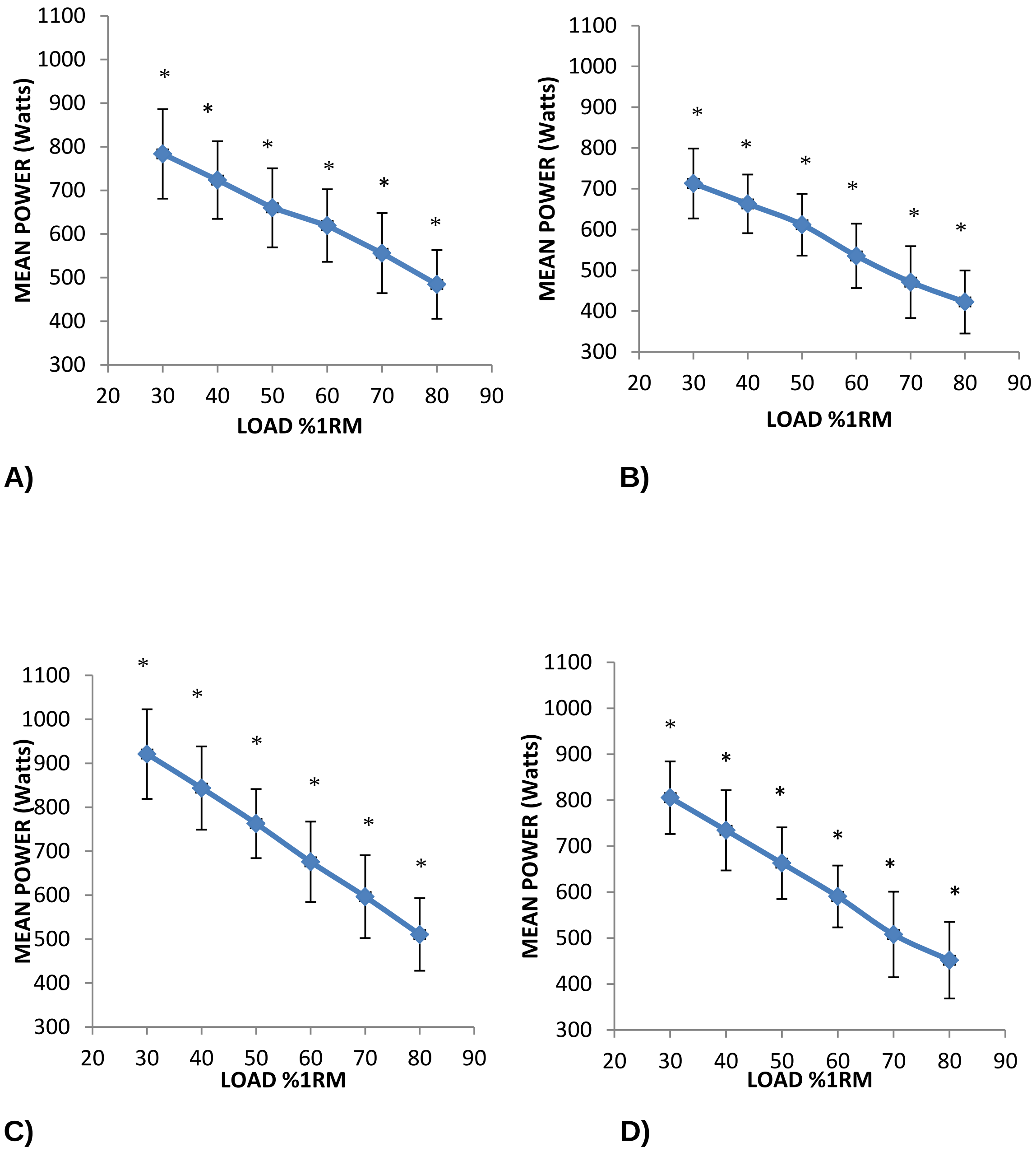


Figure 1: Comparison of Average Power output across each of the different load intensities (30-80%) (Mean ± *s*); A= Eccentric-Concentric Rebound without jump, B= Concentric-Only without jump, C= Eccentric-Concentric Rebound Jump and D= Concentric-Only Jump. *= Significant difference to all other loads (P<0.05).

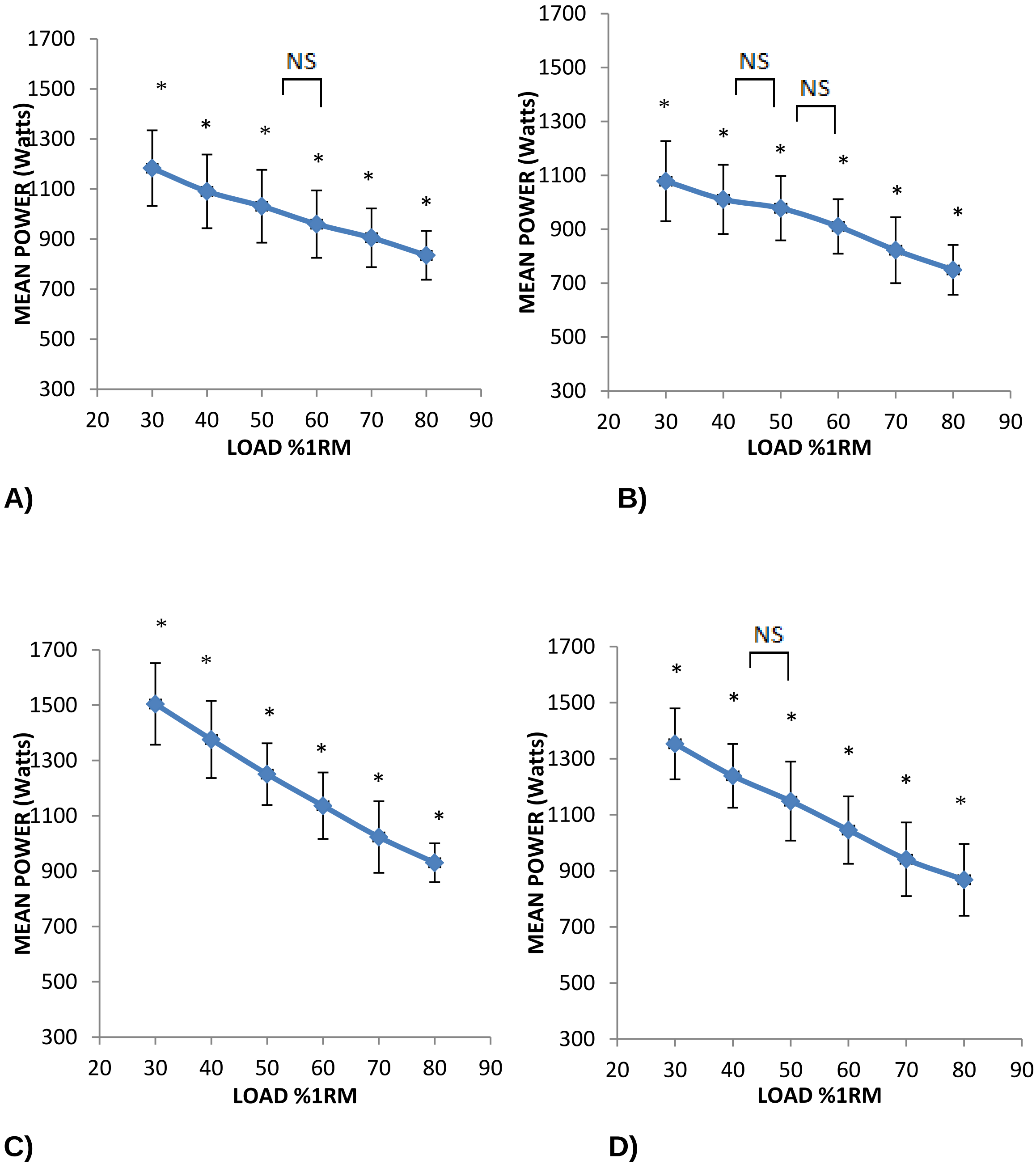
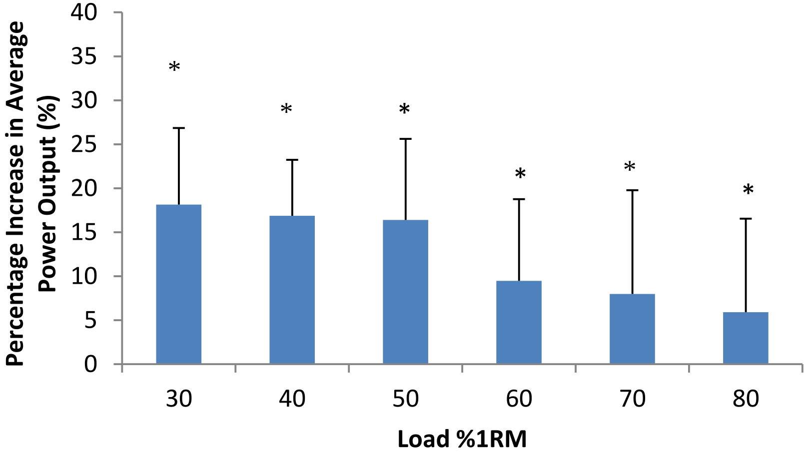


Figure 2: Comparison of Peak Power output across each of the different load intensities (30-80%) (Mean ± *s*); A= Eccentric-Concentric Rebound without jump, B= Concentric-Only without jump, C= Eccentric-Concentric Rebound Jump and D= Concentric-Only Jump. *= Significant difference to all other loads (P<0.05), except where shown as non-significant (NS, P>0.05).

4.2 Effects Of Jumping With The Bar On Power Output.

Figure 3 shows the effects of jumping with the bar on the average and peak power outputs across the six intensities. Each bar chart shows the percentage increase in average or peak power output for both jump techniques as a result of being able to terminate ground contact. It is evident that across all load intensities both average and peak power is increased as a result of being able to jump with the bar. Results shown in figure 3 show that lower load intensities 30%-40% of 1RM have greater percentage increases as a result of incorporating a jump into the squat technique recording a mean peak power enhancement of 28% for the rebound techniques. Average power significance testing identified all comparisons to have non-significant differences ($P>0.05$) between all load intensities; Peak power significance testing identified non-significant differences ($P>0.05$) and significant differences ($P<0.05$) to be evident between loads. Significant differences were evident between load intensities that had greater disparity; non-significant differences were found between consecutive load intensities, these are illustrated in figure 3. Other peak power measurements were found to be significantly different. All significance testing for peak and average power identified no significant difference.


Percentage Increase in Average Power Output (%)
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35
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25
20
15
10
5
0
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30
40
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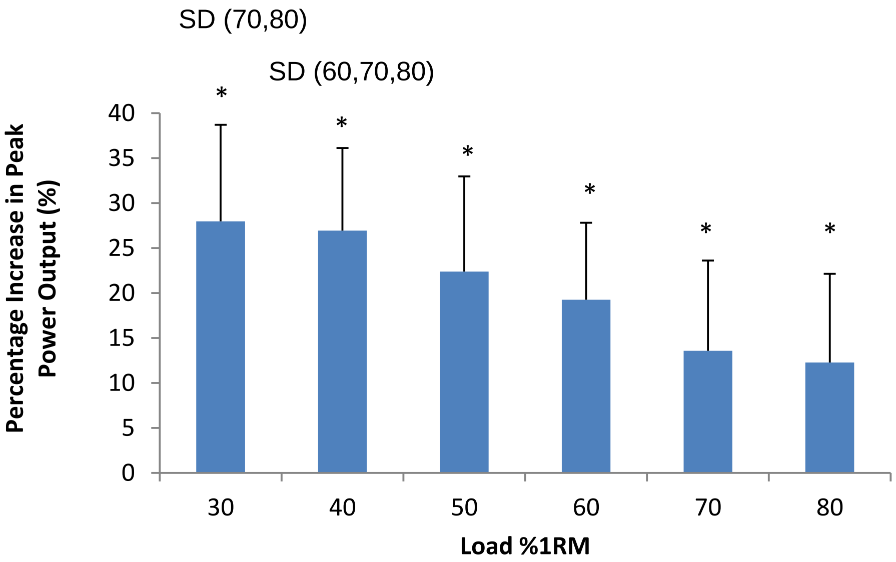
60
70
80
Load %1RM

A)


SD (70,80)
SD (60,70,80)
Percentage Increase in Peak Power Output (%)
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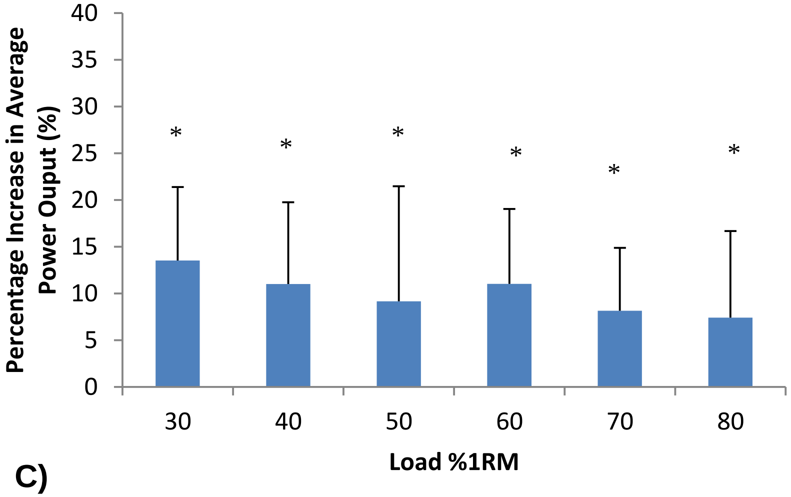
60
70
80
Load %1RM

B)


Percentage Increase in Average Power Ouput (%)
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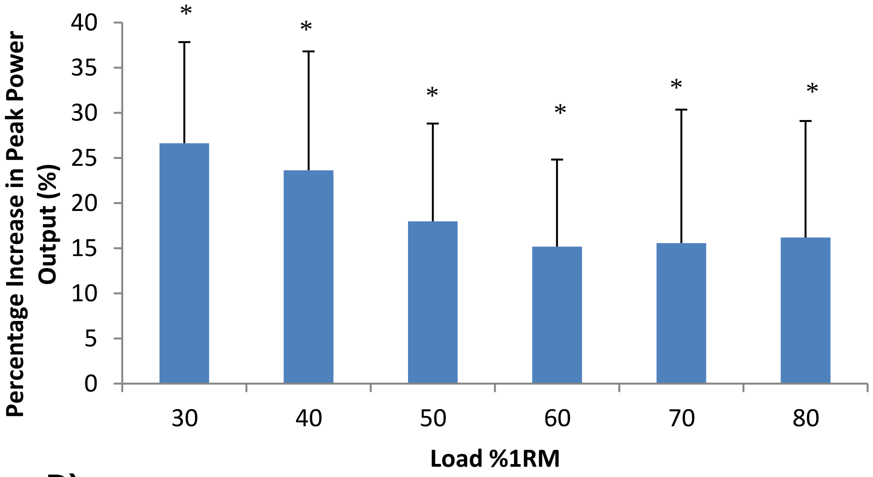
80
Load %1RM

C)


Percentage Increase in Peak Power Output (%)
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40
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70
80
Load %1RM

D)

Figure 3: The effect of jumping with the bar in terms of percentage enhancement of Average and Peak Power across loads of 30-80% 1RM (Mean ± *s*); A= Average power percentage increase for Eccentric-Concentric Rebound techniques, B= Peak power percentage increase for Eccentric-Concentric Rebound techniques, C= Average power percentage increase for Concentric-Only non-rebound techniques and D= Peak power percentage increase for Concentric-Only non-rebound techniques, *= Non-Significant Difference to all other loads (P>0.05), except where shown as significantly different (SD, P<0.05).

4.3 Comparison Of Maximal Power Production Between Different Squat Techniques

Optimal average and peak power production was achieved through the Eccentric-Concentric Rebound Jump squat technique. Figure 4 provides a comparison of maximal average power output and maximal peak power output for each of the four different squat techniques. For all conditions peak power occurred at the load of 30% of 1RM. Significance testing for maximal average power reported Eccentric-Concentric Rebound and Concentric-Only Jump squat techniques to not be significantly different ($P>0.05$). All other comparisons were recorded to be significantly different ($P<0.05$). Comparison between all squat conditions for maximal peak power outputs were all found to be significantly different also ($P<0.05$). Statistically the most powerful contraction was the SSC and the most powerful squat technique was the Eccentric-Concentric Rebound Jump squat facilitating the SSC contraction and jump technique.

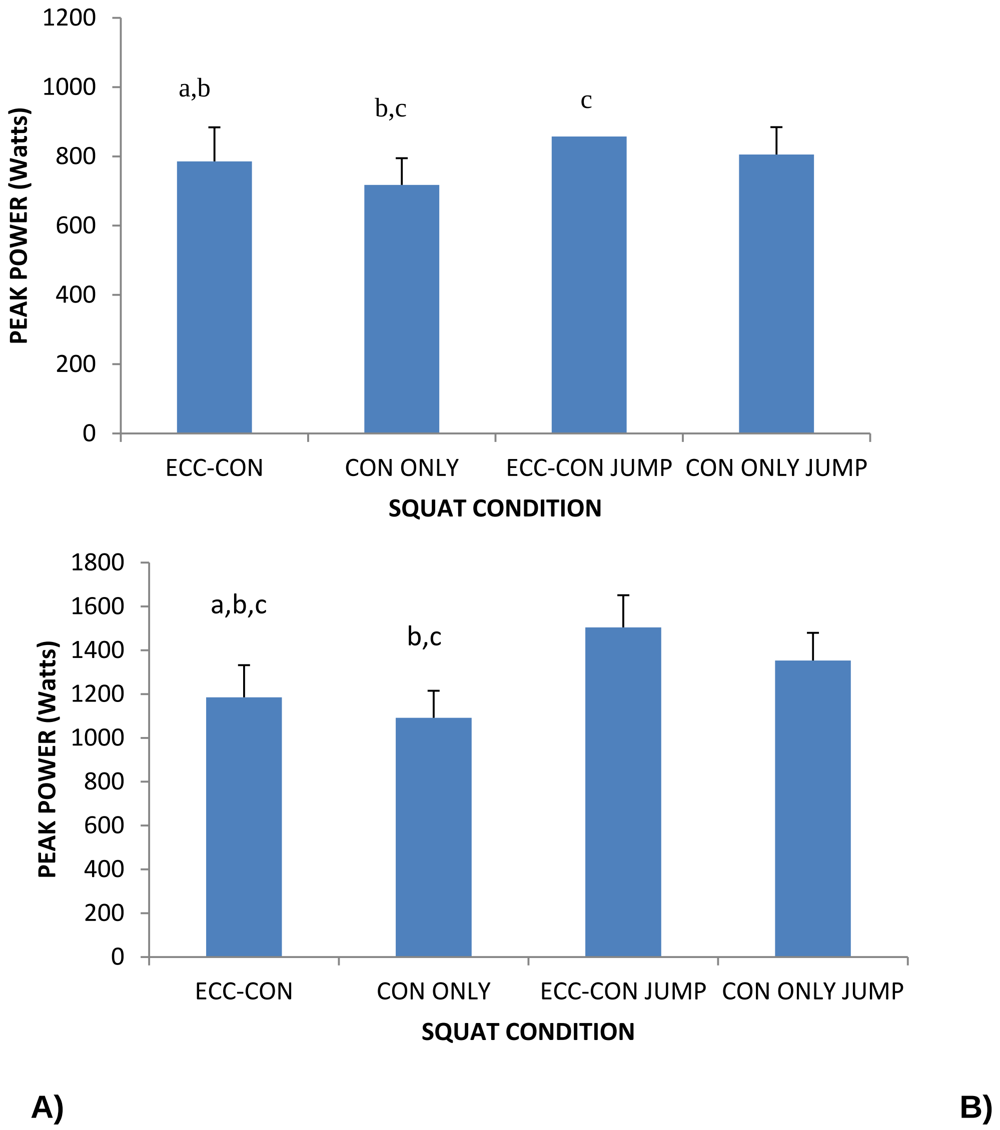

Figure 4: Comparison of Maximal Average and Peak power output for different squat techniques (± *s*); A= Average Power Comparison, B= Peak Power Comparison, a= Significant difference to Con-Only (P<0.05), b= Significant difference to Ecc-Con Jump (P<0.05), c= Significant difference to Con-Only Jump (P<0.05).

4.4 SSC Muscle Contraction Performance Enhancements

The performance enhancements acquired through the SSC muscle contractions were also evident across all loads; percentage increases were calculated through comparing mean average and peak power values for eccentric-concentric rebound conditions against concentric-only conditions for jumping and non-jump techniques. Results identified an increase in mean average power for non-jump conditions for the SSC rebound condition to be 12.6%±4.3; mean average power for jumping conditions 14.9%±1.4; mean peak power for non-jump conditions to be 8.3%±2.5 and mean peak power for jumping conditions to be 9.3%±1.6. Significance testing reported all comparisons to be significantly different ($P<0.05$) between the four squat conditions. It is evident that the pre-stretch involved in the rebound techniques increased mean average and peak power for all loads compared to the concentric-only muscle actions.

CHAPTER FIVE

DISCUSSION

5.0 DISCUSSION

5.1 Overall Findings.

The purpose of this study was to determine the optimal load, contraction type and squat technique to facilitate optimal power production. Six different loads were investigated in this study (30%-80% of 1RM); optimal power output was found to be generated at a load of 30% of 1RM across all squat techniques however loads below this were not tested. As the load progressively increased from 30%-80% of the subject's 1RM there was a significant decrease in average and peak power for all conditions. From these findings it can be hypothesised that the greater the load, the lower power output generated. Four techniques were used in order to investigate the effects of different muscle contractions and the effects of jumping with the bar. It was found that power production was maximised for all loads in the Eccentric-Concentric Rebound Jump technique. The muscle contraction type facilitated by this squat technique is the Stretch Shortening Cycle showing evidence that this type of muscle contraction is superior to concentric only muscle actions when considering optimal power production, which is not uncommon based on previous findings (Komi, 1992; Miyaguchi *et al.,* 2008). The squat technique also consists of ground contact being terminated through the subject being allowed to jump with the bar; this provides us with evidence that a jump squat is superior to non-jump squats when considering optimal power production. This evidence is presented in figure 3 showing jump squat techniques to have an average increase in peak power output of 12.1% for all loads. It was also evident that the performance enhancements experienced from the jump techniques were greater at lower loads; results showed a mean percentage increase in peak power output for the Eccentric-Concentric Rebound squat techniques to be 28% at a load of 30% of 1RM and 12.3% at a load of 80% of 1RM and 26.6% and 16.2% for the Concentric-Only squat techniques. This study therefore identifies that the Eccentric-Concentric Rebound Jump squat technique is the optimal condition through maximal power production being obtained at all loads, and this advantage is maximised at the lowest intensities.

5.2 Group Characteristics.

Similar to Baker *et al.*’s (2008) sample group all subject’s for this study were recruited from the same rugby club (Cardiff Metropolitan RFC). The sample group consisted of fifteen rugby union players; this was considered a sufficient sample size for my research based on the number of subjects used in previous studies investigating into similar physiological aspects (Wilson *et al.,* 1994; Miyaguchi *et al.,* 2008). Zink *et al.* (2006) identified a limitation in their study to be a lack of significant difference in peak power among the loads and this was primarily attributed to considerable variances in peak power output at each load; it was speculated that this was caused by varied training backgrounds of subject’s and a possibility that different training programmes were being completed by subject’s during weeks of data collection influencing their peak power output and different loads. This limitation was avoided in this study; all players had an athletic background and experience in resistance training of a similar level through completing the same training programmes for the previous two years. This ensured that all subjects were of a similar standard in order to strengthen the validity of the results; this consistency within the sample group is evident in previous studies justifying my reasons for imposing similar characteristics in my study (Cronin *et al.,* 2001; Wilson *et al.,* 2008). All fifteen participants completed a 1 Repetition Maximum testing session in their first session so relative loading could be established to facilitate testing loading intensities; subjects 1RM ranged from 150 kg to 220kg.

5.3 Effects Of Load.

In previous studies load, contraction type and squat technique have been identified as important aspects of power training and have been examined (Cronin *et al.,* 2001; Hori *et al.,* 2008; Mihalik *et al.,* 2008). Conflicting results have been found based on these three factors when investigating optimal power production. When considering the effects of load on peak and average power output Gollinick *et al.* (1983) suggests heavy loads of 80%-100% of 1RM is the superior type of training to facilitate power; contrasting findings of Kaneko *et al.* (1983) stated that the optimal compromise between force and velocity is achieved at lighter loads between 30% and 50% of 1RM; Wilson *et al.* (1993) also reported that the optimal load for improving power production was 30% of 1RM. Other more recent research conducted Zink *et al.* (2006) investigated into the difference in the magnitudes of power of the standard parallel squat under loading conditions ranging from 20%-90% of 1RM; findings reported that peak power was observed to increase from 20%-40% of 1RM and then to decrease from 40%-80%. Upper body investigations conducted by Cronin *et al.* (2001) identified intermediate loads of 50%-70% of 1RM to be the optimal training intensity dividing of the previous findings stated. The average and peak power output results of this study found 30% of 1RM loading to maximise power output for all squat techniques using isoinertial equipment. When considering differing findings it must be considered that some of these studies are based on upper body studies (Cronin *et al.,* 2001) and others lower body studies (Zink *et al*., 2006; Miyaguchi *et al.,* 2008; Komi *et al.,* 2011); contrasting findings may therefore be attributed to differences in muscle fibre distribution and movement mechanisms between the upper and lower body. Further reasoning for this is it must be considered that upper limbs do not have tendon tissues such as the Achilles tendon that possess strong elastic properties (Glasheen *et al.,* 1995). The difference between this previous studies and this research may be explained by differing force-velocity responses according to the training status of subjects (Komi *et al.,* 1988). This study consisted of well-trained subjects in mid-season; other subjects may have been athletes or volunteers of different training statuses or at a different period of their season which may well affect their force-velocity response.

There was a significant decrease in average and peak power as loading intensity increased from 40%-80% of 1RM; the greater the load the significantly less it was to the 30% of 1RM loading in optimising average and peak power for all four techniques. This study therefore supports the findings of Kaneko *et al.* (1983) and Wilson *et al.* (1993) favouring lighter loads in order to achieve optimal power production; performance enhancements were attributed to fast twitch fibres being selectively activated during high velocity movements; this theory is not uncommon and further supported by Nardone *et al.* (1989). This may potentially explain differences across previous studies; those who are explosively trained may be more efficient at recruiting and utilising high velocity movements to produce power. Those who are unfamiliar with such high velocity movements may not have experienced physiological and neuromuscular adaptations restricting their ability to produce power.

It is stated by Majumdar *et al.* (2011) that maximal power training cannot be achieved by traditional heavy resistance strength training that follows a high force and low velocity format; an increase in power will be achieved through resistance training conducted at high speed. This statement supports the findings of this study. When considering the optimal combination between force and velocity in this study, maximal power is being achieved at a light load of 30% of 1RM suggesting that power production is more reliant on the speed of the bar being moved than the amount of resistance being lifted. Speed is determined by a number of physiological factors such as muscle fibre characteristics, metabolic pathways and pulmonary physiology (Pitsiladis *et al.,* 2011). Human variations in skeletal muscle fibre compositions and their ability to recruit these fibres will affect maximal speed potentials. An increase in muscular strength is accompanied by muscle hypertrophy; however an increase in the muscles ability to generate force does not always occur with an increase in muscle cross-sectional area. This phenomenon is a result of an improvement in the capacity of the neuromuscular system to recruit and activate a greater number of muscle units (Majumdar *et al.,* 2011).

5.4 Effects Of Contraction Type.

As stated earlier, greater average and peak power values were recorded for the Eccentric-Concentric Rebound techniques when compared to Concentric-only contractions. This can be seen in figures 1 and 2 illustrating this point; figures show Eccentric-Concentric Rebound squat techniques to be superior to Concentric-Only squat techniques recording higher mean values for average and peak power across all loads for both jumping and non-jump conditions. Results identified that the SSC muscle contraction increased mean average power for non-jump conditions 12.6% and jumping conditions 14.9%; mean peak power increases recorded for non-jump conditions were 8.3% and 9.3% for jumping conditions. It is evident that the pre-stretch involved in the rebound techniques increased mean average and peak power for all loads compared to the concentric-only muscle actions. This is similar to the findings of Cronin *et al.* (2001) reporting an 11.7% increase in mean power output when comparing Eccentric-Concentric Rebound bench press techniques against Concentric-Only bench press techniques. Cronin *et al.* (2001, p.67) states that “it is recognised that rate of concentric contraction is augmented in SSC movements, especially in the initial period of the concentric phase”. This study’s findings support this statement along with a number of other previous studies (Wilson *et al.,* 1994; Miyaguchi *et al.,* 2008). The mechanisms underlying performance enhancements during the SSC are highly debateable; Byrne and Eston (2002) propose four possible mechanisms for these enhancements: the time available to develop force, storage and re-utilisation of elastic energy, potentiation of the contractile machinery and the contribution of reflexes. These performance enhancements are also typically attributed to a part of work done on the muscle during the eccentric phase being recovered by elastic energy which then adds to the pull in the concentric phase of the muscular contraction increasing the energy output (Komi, 2011).

5.5 Effects Of Jumping.

The definition of power is force x velocity; if an athlete is aiming to develop their power output an increase in either force and/or velocity is required (Newton, 1994; Hendrick, 2002). In this study subjects were instructed to move the bar as rapidly as possible during the lift. If the subject is restricted from jumping with the bar, these techniques will result in shorter acceleration phases and longer deceleration phases as the subject has to slow the bar earlier in the movement at the end of the concentric phase (Hori *et al.,* 2008; Cronin *et al.,* 2001). Efficient neuromuscular interactions between agonist, antagonist and synergist muscles in joint kinematics are key characteristics in achieving optimal speed and power; the agonist (active muscle) must have the ability to effectively generate force whilst the antagonist muscle simultaneously relaxes for the greatest force to be produced (Majumdar *et al.,* 2011). The effort made to decelerate the bar results in shorter agonist activation and greater antagonist co-activation preventing peak power being achieved in this state (Newton *et al.,* 1994). From this study and previous research we can depict that techniques not allowing the bar to be projected offers a sub-optimal training stimulus (Cronin *et al.,* 2001). However, there may be instances where it is preferable for individuals not to jump; an instance where an athlete may be inexperienced or returning from injury may be more suited to a squat technique that maintains ground contact as landing with a loaded bar may provide an injury risk. For the non-jump techniques the Eccentric-Concentric muscle contraction generated the highest power output compared to the Concentric-Only contraction. The Eccentric-Concentric Rebound technique reported very similar power output values to the Concentric-Only Jump technique; therefore when deciding between these two techniques it can be taken into consideration that a similar power output will be achieved through a non-jump technique that facilitates the SSC, this will avoid any potential issues raised with the landing phase of a jump squat.

Figure 3 illustrates the mean percentage increases in average and peak power output for techniques that subjects are allowed to jump with the bar; with the ability to terminate ground contact and jump with the bar peak power output was increased on average by 12.1% for all loads. As previously mentioned the greatest mean power outputs values were found in jump squats using a rebound motion (Eccentric-Concentric Rebound Jump). The percentage increase is greatest at the lowest loads of 30%-40% of 1RM; interestingly these results were opposite to Cronin *et al's.* (2001) finding's based on the upper body bench press movement. Testing procedures such as a 1RM test can easily be transferable from the upper body to the lower body as an index of muscular power development; however results based on upper body research cannot always be transferred to the lower body based on different muscle fibre distribution and movement mechanisms (Glasheen *et al.,* 1995).) Based on previous research the SSC potentiation that are observed in the upper body limbs may compared to that of the lower body limbs not appear obviously which should be considered when comparing Cronin *et al's.* (2001) study against this study (Miyaguchi *et al*., 2008; Komi *et al*., 2011). In this study it was evident that the power enhancements of jumping with the load were greater at the lower loads and less at the heavier loads; this may be attributed to the storage and re-utilisation of elastic energy (one of Byrne and Eston's proposed mechanisms), a loss of elastic energy may be caused due to slower velocities when lifting heavier loads resulting in a decrease in power output (Byrne *et al*., 2002).

Hori *et al.* (2008) investigated the risk of injury to muscle groups being exposed to potential damage when eccentrically decelerating the projected bar when performing the landing phase of a jump squat. The use of breaking mechanisms have been considered to prevent this injury risk; however arguments for and against this mechanism have been extended considering the effects on landing stress and the desired training stimulus (Hori *et al.,* 2008*)*. When considering this study the Eccentric-Concentric Rebound squat condition achieved very similar power output values to the Concentric-Only Jump squat condition; therefore if subjects are not accustomed or comfortable to perform the jump squat the Eccentric-Concentric Rebound squat can be performed instead whilst achieving the same training outcome. In accordance to the position statement from the National Strength and Conditioning Association (p16), it is said that “only athletes who have already achieved high levels of strength and conditioning should engage in plyometric drills”. Hori et al (2008) consider weighted jump squat training without eccentric breaking to be similar in characteristics to plyometric drills; therefore whether the subject can tolerate the landing impact of a weighted jump squat is an important factor that should always be considered by practitioners before engaging in jump squats.

5.6 Limitations

In this study the optimal load for all conditions was reported to be 30% of 1RM; what the study failed to do was investigate whether lighter loads of 20% of 1RM was superior to 30% in generating optimal power production. Previous studies conducted by Zink *et al.* (2006) investigated the difference in the magnitudes of power of the standard parallel squat under loading conditions ranging from 20%-90% of 1RM; they found that greatest peak power was achieved within loads of 40%-50% of 1RM. This study may pose argument against performing the jump squat techniques with 90% of 1RM for health and safety reasons; however 20% loading may have been beneficial to this study considering the results. The range of loading intensities (30%-80% of 1RM) was chosen based on previous studies

(Cronin *et al.,* 2001; Hori *et al.,* 2008). Although Zink *et al.* (2006) investigated into loads as low as 20% of 1RM; they identified that peak power output was achieved within loads of 40%-50% of 1RM. Based on these findings along with other previous studies it can be assumed unlikely that power would increase below 30% because of the force-velocity power relationship, however, data is needed to confirm this (Gollinick *et al.,* 1983; Cronin *et al.,* 2001).

A second limitation within the study may be that power output was measured at the bar using a Tendo Accelerometer (Accelerometer, Tendo weightlifting analyser, Tendo Sport Machines, Trencin, Slovak Republic); a preferred method of measuring power may have been to use a force plate where force/power is measure at the ground. Using a Tendo accelerometer shows force as a fixed value; however, even with a fixed mass the force will change at the ground during a movement. Therefore if a counter-movement jump such as the Eccentric-Concentric Rebound Jump squat is performed on a force plate, the mass remains fixed whilst the force will vary considerably.

CHAPTER SIX

CONCLUSION

6.0 CONCLUSION

6.1 Aims And Objectives.

The aim of this study was to identify which type of squat technique and resistance loading based on percentage of 1 repetition maximum is optimal for maximal power output production. The first aim of the study was to identify the load that maximises power output within a squat. A second aim was to investigate the effects of different muscle contractions (Concentric only and Eccentric-Concentric) on optimal power production using four different squat techniques. A final aim consisted of altering techniques to investigate into the effects of the bar being projected through the means of a jump squat. While similar work has been conducted into upper body exercise (Cronin *et al.,* 2001) to the best of my knowledge no similar research has examined lower body exercise.

6.2 Study Findings.

Results concluded that a load of 30% of 1RM was found to maximise average and peak power for all squat techniques. When considering heavier loads it was evident in this study that the potentiating effects of the rebound and jump techniques were decreased compared to the lighter loads. This is illustrated in Figures 1 and 2 displaying negative co-relations. As the load increased the subject’s ability to jump with the bar and terminate contact with the ground became increasingly difficult; this is attributed to slower shortening velocities which are unfavourable when considering the force-velocity relationship (Cronin *et al.,* 2001). The potentiation acquired through employing a rebound technique is decreased in heavier SSC contractions; this can attributed to a slower rate of eccentric muscle action as the duration of the eccentric muscle action is increased and slowing muscle action coupling times.

Optimal average and peak power production was achieved through the Eccentric-Concentric Rebound Jump squat technique. The effect of the SSC contraction was identified through the rebound squat techniques; such techniques produced greater peak power values for both non-jump and jumping conditions (8.3% for non-jump conditions and 9.3% for jump conditions) compared to the Concentric-Only techniques identifying the SSC muscle contraction to be superior to a singular concentric contraction when considering optimal power production. Maximal power production was most influenced by the ability to jump with the bar, the greater mean average power values (12.5% Eccentric-Concentric Rebound and 10.0% Concentric-Only) and peak power values (20.4% Eccentric-Concentric Rebound and 19.2% Concentric-Only) across all loads achieved through such a technique appeared the most dominant factor.

6.3 Practical Implications.

Coaches that are faced with the challenge of imposing an effective strength and conditioning session for Rugby Union players whilst in season should choose an Eccentric-Concentric Rebound Jump squat technique using a light load in aim of eliciting maximal power. However in accordance to the position statement from the National Strength and Conditioning Association (1993), it is documented that “only athletes who have already achieved high levels of strength through standard resistance training should engage in plyometric drills”. As stated by Hori *et al*. (2008) weighted jump squats such as the Eccentric-Concentric Rebound Jump squat aforementioned have similar characteristics to plyometric drills; therefore strength and conditioning practitioners should consider each players training background before using this technique. If an individual’s training status is considered to be insufficient for a session containing jump squats, training without a jump could be used; a light load should still be used and an eccentric-concentric muscle contraction should be imposed. Removing the jump from the squat technique will reduce power but will improve safety and still provide a training stimulus.

6.4 Further Research Direction.

This study investigated six different load intensities (30%-80%); a load of 30% of 1RM was found to maximise average and peak power for all squat techniques. Based on this study 30% of 1RM was the lowest load investigated, future research should consider investigating into lower load intensities such as 20% of 1RM in aim of finding the point at which power output begins to peak before decreases occur at higher loads.

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APPENDICES

APPENDIX A

EXAMPLE INFORMED CONSENT FORM

APPENDIX A

EXAMPLE INFORMED CONSENT FORM

CARDIFF METROPLOLITAN
INFORMED CONSENT FORM

CSS Reference No:

Title of Project: A study into the effects of varying squat technique and intensity levels on the power output within Rugby Union players.

Name of Researcher: James Pool

Participant to complete this section: Please initial each box.

1. I confirm that I have read and understand the information sheet dated 01/11/2012 for this evaluation study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that it is possible to stop taking part at any time, without giving a reason. ☐
3. I also understand that if this happens, our relationships with the Cardiff Metropolitan University, or our legal rights will not be affected ☐
4. I understand that information from the study may be used for reporting purposes, but I will not be identified. ☐
5. I agree to take part in this study on …………. ☐

____
Name of Participant

____
Signature of Participant

Date

____James Pool____________________________
Name of person taking consent

Date

____
Signature of person taking consent

APPENDIX B

EXAMPLE HEALTH QUESTIONNAIRE

APPENDIX B

EXAMPLE HEALTH QUESTIONNAIRE

Health Questionnaire

The purpose of this questionnaire is to ensure that the participant is fully able to conduct the testing's proposed. All information received on this form will be treated as strictly confidential. Please fill out the forms completely and accurately:

NAME: ……………………………………… **DATE:** …………………………………..

SEX: ………………………… **DOB:** ……………………………………………..

STUDENT NUMBER: ………………………………………..

Do you suffer from any of the following health conditions? Yes/No

1) Diabetes ………
2) Heart or circulatory disorders ………
3) Stomach or intestinal disorders ………
4) Sleeping difficulties ……...
5) Chronic chest disorders ……..
6) Any other health factors/ previous injuries that may affect participation ……..

If you have answered 'yes' to any of the above questions please give details below; you may be required to see a seek further assessment from your Doctor.

……………………………………………………………………………………….............

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I, ……………………., confirm that the above is correct to the best of my knowledge.

Signed……………………………………………… Date……………………

APPENDIX C

PARTICIPATION INFORMATION SHEET

APPENDIX C

Cardiff School of Sport Ethics Committee
Research Participant Information Sheet

Project Title: A study into the effects of varying squat techniques and intensity on the power output within Rugby Union players.

Date: 01/11/2012

This document provides a run through of:

1) the background and aim of the research,
2) my role as the researcher,
3) your role as a participant,
4) benefits of taking part,
5) how data will be collected, and
6) how the data / research will be used.

The purpose of this document is to assist you in making an *informed* decision about whether you wish to be included in the project, and to promote transparency in the research process.

1) Background and aims of the research

In modern day sport the effectiveness of strength and conditioning is integral to the success of a team or individual. Power is a component of fitness utilised in numerous sports, the effectiveness of training and what is considered to be the optimal power training session is however a popular topic of debate among academic researchers. I aim to identify each participant's optimal force-velocity relationship required to optimise power output and development through the analysis of four different squat techniques at six different training loads. This will be applied to the real world through investigating into the effects of fatigue has on power training.

2) My role as the researcher:

The project involves me (James Pool), the researcher, conducting two testing sessions where I will use scientific technology to record and analyse different power variables of each squat performed by you the participant.

3) Your role as a participant:

Your role is to attend the all training sessions fit and prepared to participate. Session one will involve repeated eccentric-concentric squatting to determine your squat 1RM. You will also be familiarised with the four squat techniques being performed in the testing's. Session two, participants will be required to arrive fresh and non-fatigued. The session will involve you performing each type of squat technique once at each of the six training loads (totalling 24 squats). For all squats your aim is to move the bar as fast as possible in order to generate maximal power.

4) Benefits of taking part:

The information I obtain from this study will allow better insight into the types of power training that will produce optimal results specifically for you. From this I will be able to identify the optimal squat technique for power training and at what training load participants exerted and developed maximal power. A better understanding into the force and velocity components of power training will be obtained which can be applied to real-world experiences when conducting a training block of training for your chosen sport. If participants wish to have access to their power training results to aid their personal sporting performance please make a request.

5) How data will be collected:

Data will be collected using a Tendo Accelerometer attached to the bar bell inside the squat cage.

6) How the data / research will be used:

In agreeing to become a *voluntary* participant, you will be allowing me to use the testing results obtained to further knowledge within this discipline. Individual results will be included within a larger data set that includes the data of other participants. Your personal data will be anonymous and will not be reported alone, but within the total sample of participants.

Your rights

Your right as a *voluntary* participant is that you are free to enter or withdraw from the study at any time. This simply means that you are in full control of the part you play in informing the research, and what *anonymous* information is used in its final reporting.

Protection to privacy

Concerted efforts will be made to hide your identity in any written transcripts, notes, and associated documentation that inform the research and its findings. Furthermore, any personal information about you will remain *confidential* according to the guidelines of the Data Protection Act (1998).

Contact

If you require any further details, or have any outstanding queries, feel free to contact me on the details printed below.

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