Optimal Loading Scheme for the Development of Muscular Power by Assessing Bar Speed

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Contents

Abstract

Overview: The objective of this research was to determine the optimal load for developing muscular power in the squat and power clean exercise, by assessing bar speed at different percentages of a participants one rep maximum (1RM). Fast bar speed was categorised as a speed which is faster than the midpoint speed between the fastest and slowest repetition speed recorded, at different percentages of a participants 1RM. **Method:** (N=14) male college athletes ((N=10) rugby players & (N=4) powerlifters) participated in this study (mean: 21.9years, 85.2kg & 185.4cms). Participants performed a 1RM in the squat and power clean. Participants then performed repetitions of the squat and power clean at percentages of their 1RM. Loading rage for the squat and power clean ranged from 20% - 100% 1RM, increments in the squat were 5% 1RM and 10% 1RM in the power clean. Repetitions were recorded at 120 frames per second (fps) using a Nikon Coolpix S6500 camera, recordings were analysed using Dartfish video analysis software. Dartfish measured the distance the bar travelled during the concentric phase of the squat and during the second pull in the power clean, and time taken to complete the phase of the lift. Bar speed was then calculated using this information. **Result:** Results indicate that the optimal load for developing muscular power in the squat is <60% 1RM (45% 1RM in (N=4) powerlifters & 55% 1RM in (N=10) rugby players, and <56%1RM in the power clean (64% 1RM in (N=4) powerlifters & 61% in (N=10) rugby players), beyond these loads there was a reduction in bar speed below the midpoint. A negative relationship between bar speed and weight lifted was found; as the load (%1RM) increased, bar speed (m/s) was reduced. **Conclusion:** Results of this investigation suggest that the optimal load for the power clean occurs at a much lower percentage 1RM than previously reported. Differences in methodologies and population samples could be responsible for the variance in results. The optimal load for developing muscular power in the squat in this investigation, is in line with previous recommendations 60% 1RM; 45% 1RM in (N=4) powerlifters and 55% 1RM in (N=10) rugby players.

Abbreviations

WIT	–	Waterford Institute of Technology
KG	–	Kilograms
M/S	–	Metres per second
1RM	–	One Repetition Maximum
HPL	–	High Performance Lab
SPSS	–	Statistical Packages for Social Science

1.0 Introduction

Power is having the ability to execute the greatest amount of force possible in the shortest duration of time and is the result of two variables; speed and strength (Bompa, 1994). Having this ability to generate high forces against large resistances (strength), and to produce high work rate (power) is a quality that is typical of a professional athlete (Young, 2006). It is an attribute which is highly sought after in some athletes. Training methods such as resistance training, plyometric training and post activation potentiation (PAP) have been shown to improve power development (Batista, 2007; Adam, 1992; Harris, 2000; Markovic, 2007). A goal for all strength and conditioning coaches is exercise efficiency; this is achieving the maximum gains in performance for a given amount of effort. Therefore the concept of maximising the transfer of training to pitch performance is paramount (Young, 2006).

Training at an intensity that optimises power output is essential for athletes in order for them for them to optimise their results. However debates exist over what is the optimal load for developing muscular power in a range of exercises (Young, 2001). Research suggests that a load of 80 – 100% 1RM is the optimal load for developing the force component, while loads of 60% 1RM are optimal for the enhancement of the rate of force development. However these training loads cannot be generalized for everyone, they are merely guideline loads. The optimal load for one athlete will not necessarily be the optimal load for another athlete with similar attributes (Cronin, 2005 & Wilson, 1993). This is why strength and conditioning programmes for team sports should not be generalised, as no two athletes are the same.

Previous studies have identified the optimal load for developing muscular power in the squat to be 60%1RM (Izquirdo, 1999 & 2002; Siegel, 2002), and 70-80%1RM in the power clean (Haff, 1997 & Wood, 1982). The load-power relationship differentiates between these exercises because of the nature of the movements involved. A power clean is a high-velocity and high-force exercise, maximal power output is achieved at a much higher %1RM than the squat and jump squat (Haff, 1997). According to research peak power in the squat is 60% 1RM (Baker, 2001; Cormie, 2007; McBride, 1999 & Siegel, 2002). The optimal load in power cleans is between 60-80% 1RM (Cormie, 2007; Haff, 1997; Kawamori, 2005 & Kilduff, 2007).

Methods of increasing elements of sports performance in athletes such as speed and power output have always been important to sports scientists and strength and conditioning coaches (Palmieri, 1987). Studies have suggested that training with a faster repetition speed was shown to produce significantly more force and velocity than those training with a slow repetition speed (Caiozzo, 1981; Coyle, 1980 & Moffraid, 1970). Field sports are performed at high velocities, Promoli et al. (1979) believes that a strong muscle is useless unless it can develop the required force or velocity required to complete an activity. Research by Rhea et al. (2009) found that the athletes who performed repetitions faster had significant increases in power output when compared with athletes who performed slow repetitions after a 12 week training intervention. Interestingly both groups had similar increases in strength. This suggests that strength and power are related and should be trained alongside each other. These findings by Rhea et al. (2009) also suggest that in order to optimise power results in training, fast bar speed is essential.

Considerable research has been carried out on the optimal load for developing muscular power in various exercises, and the effect training at this load has on power output and sprint speed. However to the best of the author's knowledge, there is no study which has looked at bar speed as a data collection method for determining the optimal load for developing muscular power. The aim of this investigation is to calculate the optimal load for developing muscular power in the squat and power clean exercises, by assessing bar speed in (N=14) male college athletes.

2.0 Literature Review

2.1 Power & Loading

Power is having the ability to execute the greatest amount of force possible in the shortest duration of time and is the result of two variables; speed and strength (Bompa, 1994). Muscular power is fundamental for the successful completion of many athletic and sporting activities (Cronin & Sleivert, 2005). Having the ability to generate high forces against large resistances (strength), and to produce them at a high work rate (power) is a common attribute of professional athletes (Young, 2006). Therefore training power may have implications for improving peak power output in athletes which may result in increases in performance. Training methods such as resistance training and plyometric training or a combination of both have been shown to improve power development (Adam, 1992; Harris, 2008; Markovic, 2007). A key factor for strength and conditioning coaches at all levels of sport is efficiency of training, achieving the maximum gains in performance for a given amount of effort. Therefore the concept of maximizing the transfer of training to performance is paramount (Young, 2006).

Training at the intensity and load that optimises power output is essential for athletes in order for them to optimise their results. Debate exists on what range of resistance or load makes for the most effective adaptations in power development during explosive resistance training (Young, 2001). Some studies suggest that a load of 80 – 100% 1RM is the optimal load for developing the force component of a power equation, while loads of 0-60% 1RM for the enhancement of rate of force development. Although these percentage loads cannot simply be generalised for every resistance training exercise, with each exercise and athlete the optimal load tends to vary. Generalising strength and conditioning programs for teams should not be recommended in order to achieve optimal results for each athlete. The load that maximizes mechanical power output for one player will not necessarily be the optimal load for power development in a teammate who has similar attributes (Cronin, 2005; Wilson, 1993).

Extensive research has been carried out on the optimal load for the jump squat, however the guideline load range varies from 0%1RM (Baker, 2001 & Bourque, 2003) and 60%1RM (McBride, 2002) between studies. Argus et al. (2011) however identified a weakness when trying to determine the optimal load for jump squats in (N=18) professional rugby players, the research identified that with increased load athletes performed less of a countermovement. These large variations in results can be put down to weak protocols, variation in procedures and different subjects used in studies.

Previous studies have identified the optimal load for the squat to be 60%1RM (Izquirdo, 1999 & 2002; Siegel, 2002), and 70-80%1RM for the power clean (Haff, 1997 & Wood, 1982). The load-power relationship differentiates between these exercises because of the nature of the movements involved. As the power clean is such a high-velocity and high-force exercise, maximal power output is achieved at a much higher %1RM than the squat and jump squat (Haff, 1997). Peak power in the squat is in around 60% 1RM (Baker, 2001; Cormie, 2007; McBride, 1999 & Siegel, 2002). The optimal load in hang or power cleans occur between 60-80% 1RM (Cormie, 2007; Haff, 1997; Kawamori, 2005 & Kilduff, 2007). Kawamori et al. (2005) found that peak power was achieved in the power clean when a load of 60%1RM was applied during mid-thigh pull when compared with 30/90/120% 1RM power cleans.

Previously Kawamori et al. (2005) found that peak power during the hang clean was achieved with 70% 1RM of a power clean. More recently Kilduff et al. (2007) carried out research on peak power output during the hang power clean, it was found that power output did not differentiate greatly between loads of 50-90% 1RM. All of these differing results have been reported on what is the optimal load for the power clean, and it’s clear that there is no general agreement among researchers, this can be put down to technical proficiency of the subjects or failures in methodologies in assessing power.

Weightlifting movements such as the power clean and hang power clean are considered specific to sports performance as they incorporate large muscle groups, are multi-joint movements and can occur at speed (Comfort, 2012). Increasing muscular power in an athlete is a key component when trying to increase performance. Training with a load that maximises power output (the optimal load), has been shown to result in the greatest increases in muscular power (Kaneko, 1983). Therefore identifying the optimal load for power training is critical in order to maximise performance.

Baker et al. (2001) research aimed to identify if muscular power levels distinguish between athletes of different ability. Semi and professional rugby league player's power output results were compared, using upper body tests such as ballistic ball throws and bench press throws. Professional players were found to be significantly more powerful and stronger than semi-professional players. This research was supported by a follow up study by Baker et al. (2002) which compared the physical attributes of college aged and professional rugby league players, it was found that professional players were stronger and more powerful than college aged players. This ability to generate maximal power, and power against large resistances seems to be the significant difference between playing level in the sport. These studies would indicate that maximal upper body power output generated against resistance, along with maximal strength would be a critical factor in determining the success of a physical team sport such as rugby league or union.

In sports specific training strength exercises are completed to improve power, velocity of a given movement against a given resistance (Zatsiorsky, 1995). Maximal strength is a prerequisite for high movement speed. However this translation from gains in strength to velocity gains are not straight forward, correct selection of training exercises and training speed is vitally important (Zatsiorsky, 1995). Cormie et al. (2011) examined the relationship between maximal strength and maximal power. It has previously been shown in numerous studies that athletes that have a higher 1RM will also have a higher maximal power output load when compared with weaker athletes (Appleby, 2012; Baker and Newton, 2006; McBride et al, 1999; Bourque, 2003). This research is contradicted by research by Baker (2001) findings which showed that stronger individuals had a lower percentage 1RM load that maximised power output in comparison to weaker individuals in the investigation, it was comprised of (N=6) individuals with a high 1RM's and (N=6) with generally low 1RM's.

Cormie et al. (2011) carried out research on (N=12) elite athletes (football players, sprinters and long jumpers), the research found that the optimal load for developing muscular power in these elite athletes was 56%1RM in the squat, 80% 1RM in the power clean and 0% 1RM in the jump squat. Researchers did however conclude that these loads would not represent the optimal load for the general population, but are typical of powerful professional athletes that were used in the investigation.

Fleck et al. (1986) reported a method of Russian training that they called complex training in the early 1980's, it was a relatively new training method that looked at varying loads and / or exercises to enhance short term power development. This method of training used loads of >85%1RM for strength and 30-45%1RM for power exercises, the reason for this alteration from set to set is to cause the neutral system to be 'super simulated', which makes the power load feel lighter. Examples of this kind of training would be performing heavy squats followed by jump squats with a lighter load (Baker, 2001). This method of training aimed to generate more power with this lighter load than would be normally generated by doing ordinary sets. Baker (2001) compared and contrasted loading and straight sets on power output in (N=6) professional rugby league players, the intervention group that alternated heavy and lighter resistances during the power training had the largest increase in power development. Athletes who performed straight sets had no significant increase in power. These finding were similar to a study by Gulich et al. (1996), although Baker et al. (2001) study was conducted with lighter loads. The use of heavier and lighter weights with contrasting resistances had an acute impact on increasing power output, and has been shown to be effective in lower body exercise such as the squat, jump squats and half squats (Young, 2001). Young (2001) showed that training with contrasting resistances with the same power exercise could prove more beneficial, further research in this area is needed.

2.2 Speed

In sports such as squash, tennis and basketball an athlete is never at their maximum speed, these athletes are constantly generating large amounts of force to accelerate across the court, having this ability to rapidly increase acceleration is of great importance for a successful performance (Cronin, 2005). It is also said that the acceleration phase in these types of athletes is much shorter than in top track sprinters (Baker, 1999). This shows the value of the speed of the first few steps in sports athletes, fast acceleration could be the difference between them winning or losing possession.

For strength and conditioning coaches working with sportsmen and women, understanding the methods of how to and develop sports speed is essential given the importance of the initial first few steps. However the majority of research has been carried out on track athletes and not on team sports athletes. Young et al. (2001) showed that there are clear biomechanical differences between track athletes and team-sports athletes running styles, track athletes have a higher centre of gravity and have more knee flexion during recovery, track athletes also have a higher knee lift. This suggests that sports speed could be different from 100-m track speed. Cronin et al. (2005) carried out research on (N=26) professional rugby league players, its goal was to identify the relationship between strength and power and measures of first-step quickness. The research found that there was no significant link between maximal strength and power output in jump squat heights. This supports Abernethy et al. (1995) that strength and power are not the same and should be trained separately. Cronin et al. (2005) also found that the link between 3RM and 10-m sprint speed to be also non-significant, squat strength was shown to have the lowest correlation to speed, however the research did find a significant link between power output in the jump squat and sprint speed.

Research has indicated that there is a significant correlation between sprint speed over various distances with measures of strength (Alaxander, 1989 & Bret, 2002) and power (Meckel, 1995 & Bret, 2002). Strength is not a critical factor when it comes to sprint speed, the amount of force an athlete can produce determines how fast they can run, how high they can jump and how quick they can change direction. Athletes have a considerable amount of time to develop what strength levels they possess, it has been shown that 0.3 / 0.4 seconds are required to maximise force levels (Rhea, 2002). During maximal lifts (1RM) in the squat or deadlift concentric phase of the lift can last 0.6 seconds. Athletes who are looking to produce maximal force in explosive movements such as running and jumping have much less time available to them, maximal force is achieved close to 0.1 / 0.2 seconds (Heinecke, 2004; Newton, 1996; Wallace, 2006). The rate of force development is a lot more important to performance alone than strength.

Methods of increasing elements of sports performance in athletes such as speed and power output have always been important to sports scientists and strength and conditioning coaches, Palmieri et al. (1987) research aimed to identify the effects of repetition speed on weight training. It is widely accepted that taking part in weighted resistance training will improve your muscular strength (Anderson, 1982; Berger, 1962; DeLorme, 1948; O'Shea, 1966; Stone, 1981 & Withers, 1970).

Periodization is believed to be the most effective method of increasing muscular strength and power (Stone, 1981), it brings the body through a high intensity and low intensity training volume over a period of several weeks. During this period, sets, repetitions, repetition speed and load intensity's vary. While there is a general agreement among researchers that resistance training will increase muscular strength and power, disagreement does exist as to the speed at which exercises should be performed at. Pipes et al. (1979) recognised that a slow contracting muscle can exert greater amount of force, compared with the same muscle at a faster contraction, therefore training with slower repetitions will develop stronger contractions than faster repetitions. Pipes et al. (1979) eluded to how developing a stronger contractile will result in a muscle that contains more contractile properties, which will in turn result in the muscle contracting faster whether the training speed is fast or slow.

However other studies (Caiozzo, 1981; Coyle, 1980 & Moffraid, 1970) have suggested that training with a faster repetition speed has been shown to produce significantly more force and velocity than those training with a slower repetition speed. Since field sport activities like Gaelic games, basketball and rugby are performed at high velocities, Promoli et al. (1979) believes that a strong muscle is useless unless it can develop the required force or velocity required to complete an activity. Palmieri et al. (1987) study tested (N=55) college students over a 10-week strength and conditioning cycle, they were separated into fast concentric, slow concentric and a combination of both. At the end of the ten week programme all three groups had significant increases in leg power and strength when compared with pre-tests. Although there was no significant increase in one group compared to another. Rhea et al. (2009) looked at alterations in the speed of a movement in (N=48) college athletes from a range of different sports. Their aim was to assess the effect of heavy / slow repetitions had on peak power and strength after a 12 week training intervention. Research found the post-test group performing repetitions faster had a significant increase in power output when compared with the slow repetitions group. Both groups had a similar increase in strength over the 12 week training intervention, which reinforces the belief that strength and power are related and should be trained alongside each other for optimal results.

To increase performance, specific training with constant elements must be adhered too (Zatsiorsky, 1995). Four variations in training are used to increase velocity.

1. Varying the use of heavy and light implements in training.
2. Training with a high resistance and low velocity range in training.
3. Training with a low resistance and high velocity range in training.
4. Intermediate resistance and intermediate velocity range in training.

To significantly improve performance at a given resistance, an athlete must achieve positive results in both high / low resistances. Although this specific training elicits a force velocity change, these changes are only short term. On the other hand, a substantial performance improvement can be achieved by doing less specific exercises in a high velocity, low resistance domain as in the high resistance, low velocity range (Zatsiorsky, 1995).

Various studies have examined the effect load has on peak force, velocity and power during the jump squat, power clean and squat (Baker, 2001 & Cormie 2007). However there is limited data on how the exercise type and load affects the bar, body and the system (bar and body). McBride et al. (2011) carried out research to identify if different movement patterns required different loads in exercises. It was identified that throwers or competitive weightlifters are more concerned with bar velocity and bar power during the lift, when compared to competitive sprinters and jumpers who are concerned with developing body or system velocity and power. Hori et al. (2007) had carried out similar research prior to this, however the research only examined hang clean and the jump squat. McBride et al. (2011) found that the load that optimized power output in the power clean was 80% 1RM; this was calculated based on the system (bar & body). The optimal load for the system in the squat was 56% 1RM and 0% 1RM in the jump squat. Maximum peak power was observed during a power clean at 90% 1RM, this peak power was significantly higher than at loads of 30-50% 1RM. Peak bar power in the squat was achieved at 90% 1RM, and this power output was significantly higher than when loads of 10-80% 1RM were applied.

Variable	Load
Bar	90%
Body	10%
System	50%

McBride et al. (2002) suggests that there is little difference when calculating power for the bar, body or system, the results is in line with previous findings Cormie et al. (2007). In the squat bar power was maximized at a load of 90% 1RM and body power was maximized at 10% 1RM. Bar power is lowest when lighter loads are applied in the trials in the squat and jump squat. As the load increased the force required to move the bar increased significantly, as a result the power output increased alongside the increase in load. A weightlifter is interested in moving the bar as fast as possible. However the range of loading for maximizing power in the bar, body and system is 80-90% 1RM, which is more homogeneous. So regardless of what one wanted to train bar, body or system, the loading would effectively be the same (McBride, 2002). Peak velocities of the bar, body and system varied depend on the exercise.

During a power clean the bar is moved from the ground to the catch position, the bar is at its highest velocity during the second pull, prior to the catch (McBride, 2002). During the squat a different motion is required, the bar moves with the body throughout the lift, although different velocities of the bar, body and system are produced. The bars velocity is usually the highest, this is due to the fact that the bar has the greatest distance to travel, and compared to the system which tends to have the lowest peak velocity. The system velocity is determined by the force plate and does not have an exact location throughout the lift; therefore the system peak power is lower than body and bar.

2.3 Summary & Rationale

In summary, power is having the ability to execute the greatest amount of force possible in the shortest duration of time and is the result of two variables; speed and strength. Methods of enhancing these attributes such as resistance training and plyometric training have been shown to be successful (Adam, 1992; Harris 2008 & Markovic, 2007). Therefore training at a load and intensity that optimises power output is essential for athletes in order for them to optimise their results. However it's clear from research that debate exists on what range of resistance or load makes for the most effective adaptations in power development during explosive resistance training (Young, 2001).

Studies have shown the optimal load for developing muscular power in the squat is 60%1RM (Izquirdo, 1999 & 2002; Siegel, 2002; Baker, 2001 & McBride, 2007). Cormie et al. (2007) found the optimal load in the squat to be 56% 1RM in (N=12) division one athletes. The optimal load in the power clean occurs at a higher percentage 1RM as the power clean is such a high-velocity and high-force exercise (Haff, 1997). The optimal load in hang power clean and power clean occur between 60-80% 1RM loads (Cormie, 2007; Haff, 1997; Kawamori, 2005 & Kilduff, 2007). However Kawamori et al. (2005) found that peak power was achieved in the power clean when a load of 60%1RM was applied during mid-thigh pull when compared with 30/90/120% 1RM power cleans.

It was noted that bar, body and system maximal power output vary according to the exercise and load applied (McBride, 2007). This should have training implications in for athletes looking to optimise their results from resistance training (McBride, 2002). Training should be specific to the desired power output method of an athlete; bar, body or system. Weightlifters or throwers are concerned with external forces, so they focus on bar power, whereas sprinters and jumpers concentrate on body or system power and velocity during the concentric phase of a lift.

Considerable research has been carried out on the optimal load for developing muscular power in various exercises, and the effect training at this load has on power output and sprint speed. However to the best of the author's knowledge, there is no study which has looked at bar speed as a method of data collection for determining the optimal load for developing muscular power. The aim of this investigation is to calculate the optimal load for developing muscular power in the squat and power clean exercises, by assessing bar speed in (N=14) male college athletes.

2.4 Research Questions

1. What is the optimal load for developing muscular power in the squat?
2. What is the optimal load for developing muscular power in the power clean?
3. Is bar speed an accurate method for collecting data?
4. Is there a significant difference between bar speed and weight lifted?
5. Is there a relationship between bar speed and weight lifted?

3.0 Methodology

3.1 Introduction

The purpose of this study is to accurately calculate the optimal load for developing muscular power in the squat and power clean exercises, by assessing bar speed. There has been considerable research completed on optimal loading for developing muscular power; however results have a large percentage error, with guidelines between studies showing contradicting results (Izquirdo, 1999 & 2002; Siegel, 2002 & Cormie, 2007). This study aims to accurately measure what is the optimal load for developing muscular power, by measuring bar speed in (N=10) semi-professional rugby players and (N=4) semi-professional powerlifters in the squat and power clean exercises; exercises will be performed at percentages of their one rep maximum (1RM).

3.2 Research Questions

1. What is the optimal load for developing muscular power in the squat?
2. What is the optimal load for developing muscular power in the power clean?
3. Is bar speed an accurate method for collecting data?
4. Is there a significant difference between bar speed and weight lifted?
5. Is there a significant relationship between bar speed and weight lifted

3.3 Research Design

The research design chosen for this study is a cross sectional study. The participants had a minimum of six months weight lifting experience, with a programme that previously incorporated the squat and power clean exercise. Prior to testing participants completed a 1RM test for the squat and power clean exercise. During testing participants were recorded on a Nikon Coolpix S6500 camera (HS480) doing repetitions of the squat and power clean at percentages of their 1RM, load range begun at 20% 1RM and increased each set by 5% 1RM in the squat, and 10% 1RM in the power clean, until they reached their 1RM. This high speed video footage was analysed using Dartfish video analysis software . It was a once off assessment of all participants, there were no repeat measures.

3.4 Study Population & Sampling

The study consisted of (N=14) male college athletes (mean age 21.9 years). A non-random sample of participants was selected, of the (N=14) participants (N=10) were semi-professional rugby players. Of the (N=10) rugby players, (N=4) were from Cork Constitution Rugby Club, and (N=6) were based in Waterford Institute of Technology. The remaining (N=4) participants were semi-professional powerlifters, who trained in Goldstone Gym in Waterford. Prior to selection all senior players from Cork Constitution Rugby Club, senior members of Waterford Institute of rugby team and members of Goldstone gym who competitively compete in powerlifting were given information on the study and invited to take part. Interested personnel were asked to email a Hotmail account declaring their interest in taking part in the study and to state which testing dates and times they were available for. Each of the participants had been involved in a structured weight lifting programme, and had previous experience of the squat and power clean exercise.

3.5 Inclusion criteria

- Minimum of six months weight lifting experience prior to this study. And to have had previous experience with the squat and power clean exercise.

- To have signed an informed consent form prior to data collection (Appendix).

3.6 Exclusion criteria

- Any prior injury to the body that involved the same musculature involved in the squat and clean exercise (i.e. quadriceps, hamstrings, and lower back muscles) which could be further damaged by partaking in the study.

3.7 Variables & Concepts

Three concepts were measured in this study; Speed, Distance and Time. During the study, participants were recorded on a Nikon Coolpix S6500 camera at 120fps performing repetitions in the squat and power clean exercise. Loading started at 20% 1RM and were increased by 5% 1RM in the squat and 10% 1RM in the power clean until the participant reached their 1RM. The camera was set-up 5m away from the participants, in view of the camera lens was a Leicester Height Measure scale. This scale was placed in the same plane of motion in which the exercise was performed.

This video footage was later assessed using Dartfish. The distance the bar travelled was identifiable using the measurement apparatus on Dartfish, it used the 2m Leicester Height Measure as a scale to identify the distance the bar had travelled. Time was measured using the clock apparatus on Dartfish.

3.8 Data Collection Methods

The data collection took place in three locations; Cork Constitution Rugby Football Club, the High Performance Lab (HPL) in Waterford Institute of Technology (WIT) and in Goldstone Gym in Waterford. Data collection for (N=4) rugby players took place in Cork Constitution Rugby club gym on the 17th of February 2014. The gym is designed to cater for Olympic weightlifting so it was an ideal location to carry out the testing. Data collection for (N=6) rugby players took place in the HPL in WIT on the 2nd, 3rd & 4th of March 2014, the gym is equipped for Olympic weightlifting. The final piece of data collection took place in Goldstone Gym in Waterford for (N=4) powerlifters on the 10th of March 2014.

On arrival to testing facilities participants took part in a dynamic warm up which included; high knee walk, high knee skip, high knee run heel-ups, straight-leg skip, backward walk and a back ward lunge. Each warm up exercise was performed for 10m. Following the dynamic warm up participants performed a 1RM test in the squat and power clean exercise. Participants were then given 20minute rest period before testing began. Testing began with the squat exercise, testing started with a 20% 1RM load applied. This load increased by 5%1RM each set until participants reached their 1RM. In order for a repetition in the squat to be counted the participant's squat depth had to be at least parallel, regardless of the load applied. This consistency in the squat depth was needed so that the bar speed at different loads could be compared accurately. If the squat is not performed to specific guidelines, a participant was asked to repeat the repetition at that load. Power clean testing began after the participant had received a 20minute rest period. Testing for the power clean started with a 20% 1RM load applied, this load increased by 10% 1RM until the participants reached there 1RM. The power clean began from the floor with a shoulder width grip, the lift was performed with a first pull, a double knee bend and then a second pull finishing in the catch position. The lift was considered a success if the catch position was achieved. Failure to compete the lift at a specific load required the participant to repeat the repetition at that load. Prior to data collection; subjects were made aware of criteria that had to be met performing the exercises; squat depth & power clean technique. Subjects performed two repetitions at each % 1RM and took exactly three minutes rest between each set. Subjects were allowed to consume a maximum of one litre of water over the duration of the test.

3.9 Data Analysis

3.10 Squat

Data analysis for the squat took place using Dartfish. Each percentage 1RM load was assessed individually. Before each video was played a scale had to be set using the measurement apparatus in Dartfish, the Leicester Height Measure acted as a 2m scale, having this large scale in each video allowed for accuracy and repeatability in collection of data. Once the scale was set, the video could be assessed for bar speed. As a participant reached parallel and started to have upward momentum in the concentric phase of the squat the video was paused and the time on the Dartfish clock was recorded. While the video was still paused, the bottom of a marker measuring 0.60m was accurately placed on the bar using the measurement apparatus and zoom function in Dartfish, following this video could be resumed. Once the bar had travelled 0.60m the video was once again paused and the time on the Dartfish clock was recorded again. The previous time was then subtracted from this time, this gave the researchers the time it took the bar to travel 0.60m at 120fps (High speed / slow motion). In order to convert this figure in to real time, it had to be divided by 4.071seconds. This was the amount of time that passed in real time while 1second passed on the Dartfish clock. This gave the researchers the time it took the bar to travel 0.60m in real time. To get bar speed, the distance the bar travelled (0.60m) had to be divided by the time taken in seconds to travel that distance, which gave bar speed in metres per second (m/s).

3.11 Power Clean

Data analysis for the power clean took place using Dartfish. Each percentage 1RM load was assessed individually. Before each video was played a scale had to be set using the measurement apparatus in Dartfish, the Leicester Height Measure acted as a 2m scale, having this large scale in each video allowed for accuracy and repeatability in collection of data. Once the scale was set, the video could be assessed for bar speed. Power clean had to be completed from the floor, as a participant transcended from the first into the second pull in power clean the video was paused. While the video was still paused the bottom of a marker measuring 0.50m was accurately placed on the bar using the measurement apparatus and zoom function in Dartfish, following this video could be resumed. Once the bar had travelled 0.50m during the second pull the video was once again paused and the time on the Dartfish clock was recorded again. The previous time was then subtracted from this time, this gave the researchers the time it took the bar to travel 0.50m at 120fps (High speed / slow motion). In order to convert this figure in to real time, it had to be divided by 4.071seconds. This was the amount of time that passed in real time while 1second passed on the Dartfish clock. This gave the researchers the time it took the bar to travel 0.50m in real time. To get bar speed the distance the bar travelled (0.50m) had to be divided by the time taken in seconds to travel that distance, which gave bar speed in metres per second (m/s).

3.12 Ethical Considerations

All participants who took part in this study were asked to sign a consent form prior to commencing the study. Failure to sign the consent form would result in the participant not being eligible for the study. The consent form highlighted the exact layout of the study and the testing process, it also notifies participants of the potential risks which are associated with weight training. Participants were all over 18 years of age. Participant's personal information and recordings from testing are being kept confidential. All participants are free to leave or cease participation in the study at any time if they wished, without any questions or objections.

4.0 Results Chapter

4.1 Introduction

The following section will depict the results from the research which set out to determine the optimal load for developing muscular power in the squat and power clean by assessing bar speed. Complete statistics from the section were gathered through quantitative method, statistical analysis was carried out using S.P.S.S. The results are presented using a range of graphs and tables while being complimented by inferential and descriptive statistics.

4.2 Description of Participants

Table4.2.1 displays the characteristics of the participants. There were (N=14) males involved in the study. All participants originated from a rugby and powerlifting sporting back grounds and had the necessary training experience to take part in the study.

Table 4.2.1

Table4.2.1 displays mean and standard deviation age, weight, height and training age of (N=14) participants.

Characteristics	Mean	Standard Deviation
Age	21.9	1.97
Weight	85.2kg	13.8kg
Height	185.4cm	51.2cm
Training Age	3.3years	1.1years

4.3 Testing Results

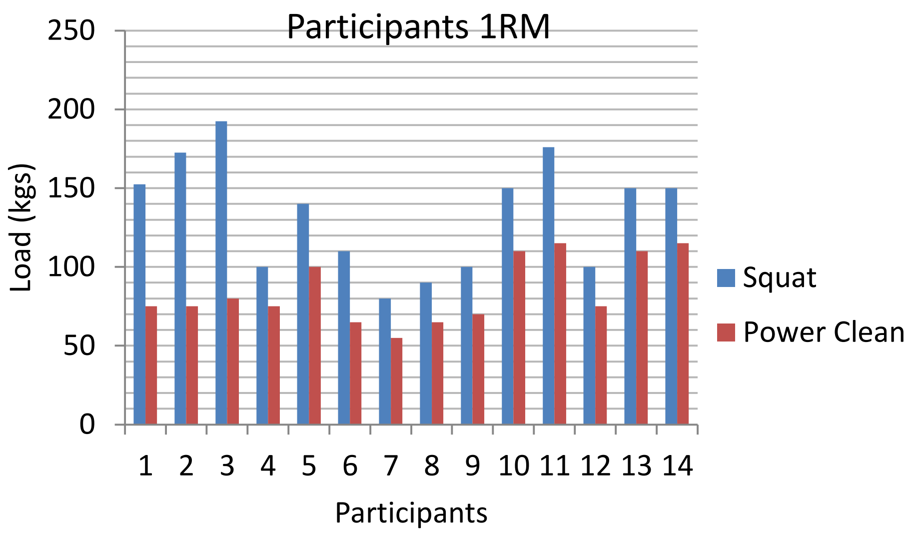


Figure 4.3.1

Figure4.3.1 displays participant's one repetition maximum (1RM) in the back squat and power clean. Outcomes are presented in Kg. The heaviest back squat was 192.5kgs and the lightest was 80kgs. The heaviest 1RM was 115kgs and the lightest was 55kgs.

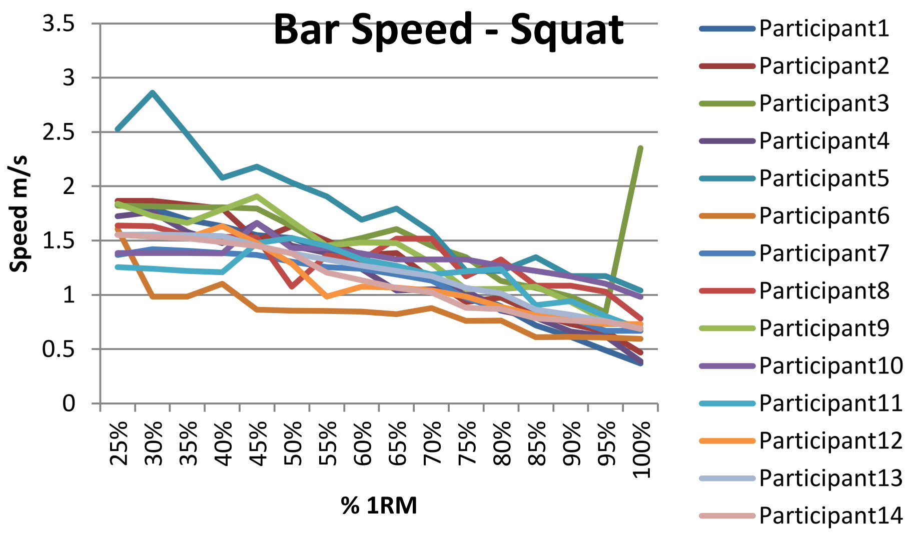


Figure4.3.2

Figure4.3.2 displays the (N=14) participants bar speeds in the squat. Speed is displayed in metres per second (m/s) with a load ranging from 20-100% 1RM.

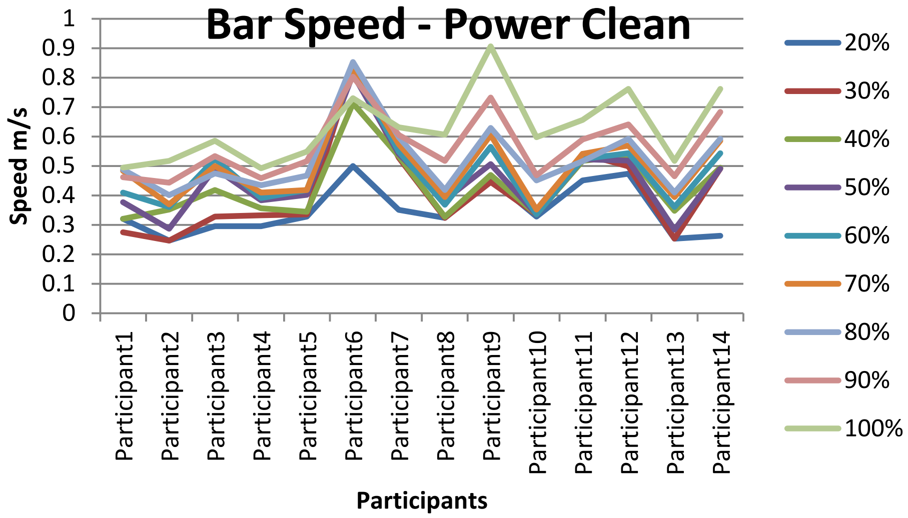


Figure4.3.3

Figure4.3.3 displays the (N=14) participants bar speeds in the power clean. Speed is displayed in metres per second (m/s) with a load ranging from 20-100% 1RM.

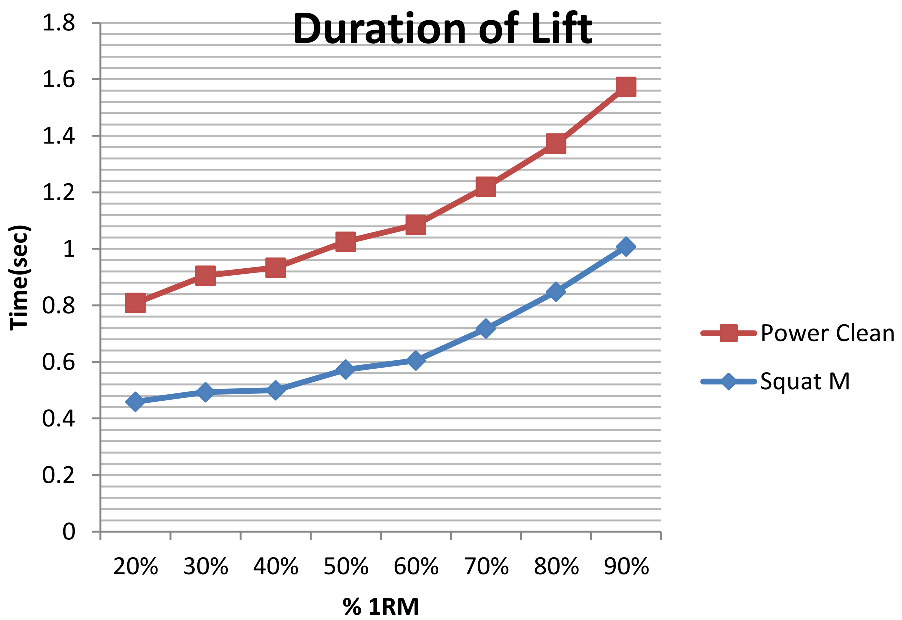


Figure4.4.4

Figure4.4.4 displays time taken to complete a phase of the back squat and power clean across different percentages of participants 1RM. Figure illustrates that as the load (%1RM) is increased, time taken to complete the phase of the lift is increased.

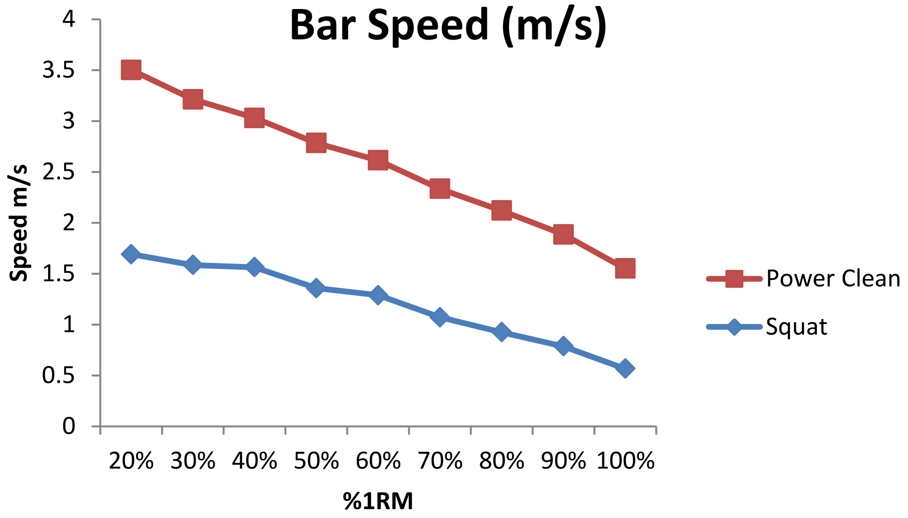


Figure4.4.5

Figure4.4.5 displays bar speed (m/s) in the back squat and power clean across different percentages of participants 1RM. Figure illustrates that as the load (%1RM) is increased bar speed slows down.

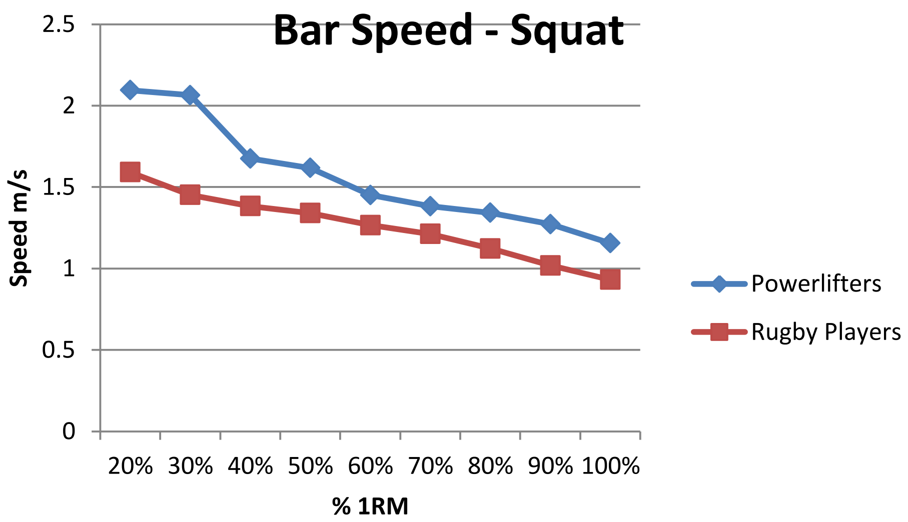


Figure4.4.6

Figure displays the bar speed (m/s) of two sub groups; powerlifters (N=4) and rugby players (N=10). The chart illustrates that powerlifters develop faster bar speed at each % 1RM than rugby players.

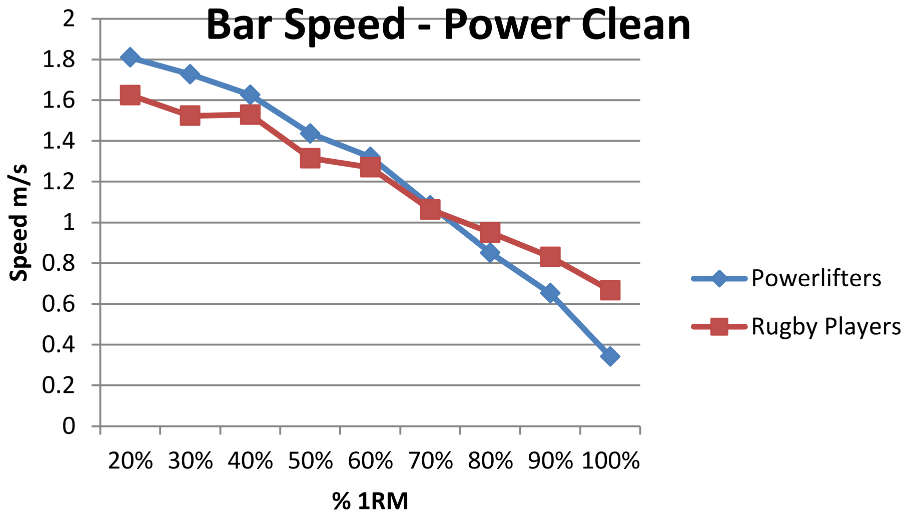


Figure4.4.7

Figure4.4.7 displays the bar speed (m/s) of two sub groups; (N=4) powerlifters and (N=10) rugby players. The chart illustrates that powerlifters develop faster bar speed at each % 1RM than rugby players.

4.4.8 Research Question1

What is the optimal load for developing muscular power in the squat?

Figure4.4.8 illustrates that the fastest bar speed is recorded at 20% 1RM travelling at 1.689m/s and the slowest at 100% 1RM travelling at 0.564m/s. Previous research by Rhea et al. (2009) categorised fast bar speed as 0.6 - 0.8m/s, and slow bar speed as 0.2 – 0.4m/s, however this bar speed was recorded against a large resistance with the use of elastic bands so bar speeds between studies cannot be generalised. However Rhea et al. (2009) fast bar speed as the midpoint speed between the fastest and slowest repetition speed recorded at different percentages of a participants 1RM. In order for a bar speed to be considered fast it had to be at or above this threshold speed. Bar speed in the squat remained faster than the midpoint of 1.1265m/s at 1.129m/s between loads of 65-65% 1RM, beyond this load bar speed decreased below this midpoint.

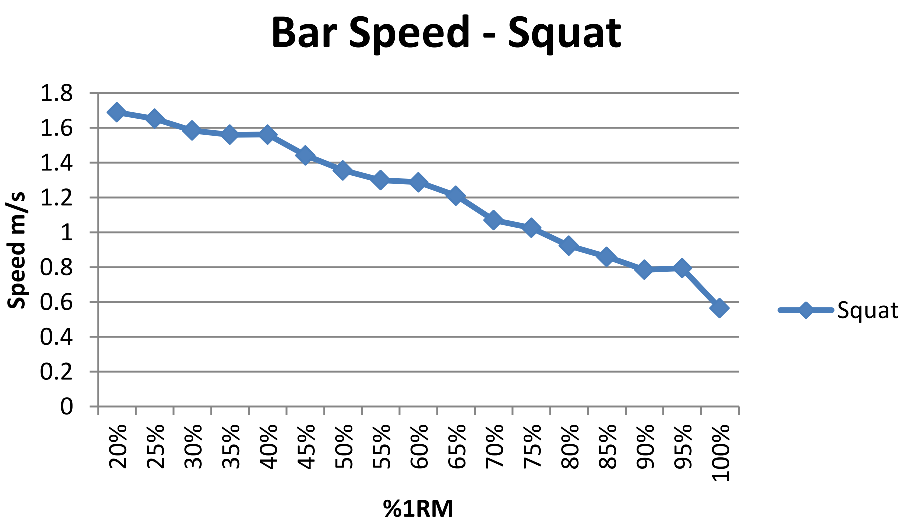


Figure4.4.8

Figure 4.4.8 displays bar speed in meters per second (m/s) for the back squat with loads ranging from 20% 1RM – 100% 1RM.

Figure4.4.9 illustrates that as the load (%1RM) increased, time taken to complete the phase of the lift increased. Time taken to complete the phase of the lift doubles, between loads of 20% 1RM (0.459sec) and 100% 1RM. Following the same principles as bar speed (Rhea, 2009), in order for a lift to be considered fast; duration of the lift must be less than the midpoint between the longest and shortest duration. This midpoint of 0.733sec occurs at 60% 1RM beyond this load the duration of the lift is >0.733sec.

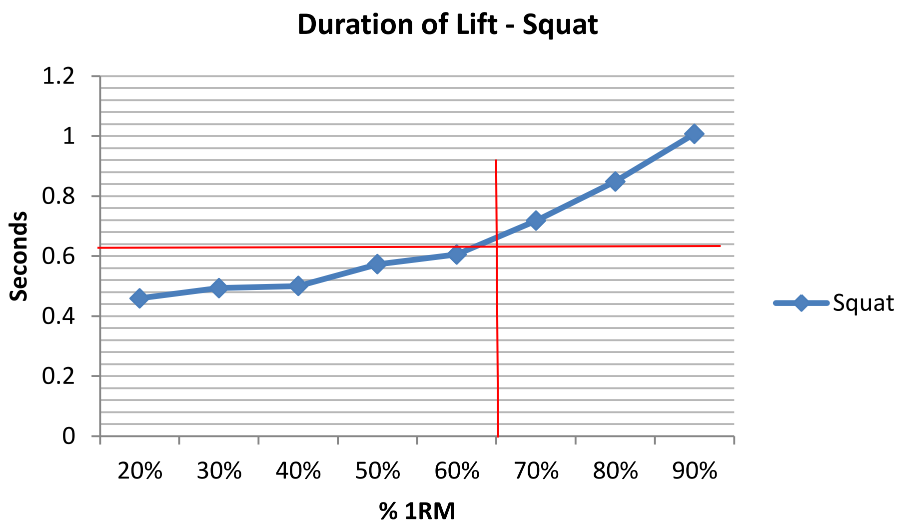


Figure4.4.9

Figure4.4.9 illustrates time taken (seconds) to complete the back squat, with loads ranging from 20% 1RM – 100% 1RM.

Note: Red line represents midpoint between the longest and shortest duration lift.

Figure4.4.10 displays (N=4) powerlifters bar speed across different percentages of their 1RM during the squat. The fastest bar speed was recorded at 20% 1RM travelling at 2.095m/s and the slowest at 100% 1RM travelling at 1.155m/s. Powerlifters bar speed in the squat remained faster than the midpoint of 1.625m/s at 1.617m/s with a 45% 1RM load applied, beyond this load bar speed was slower than the midpoint.

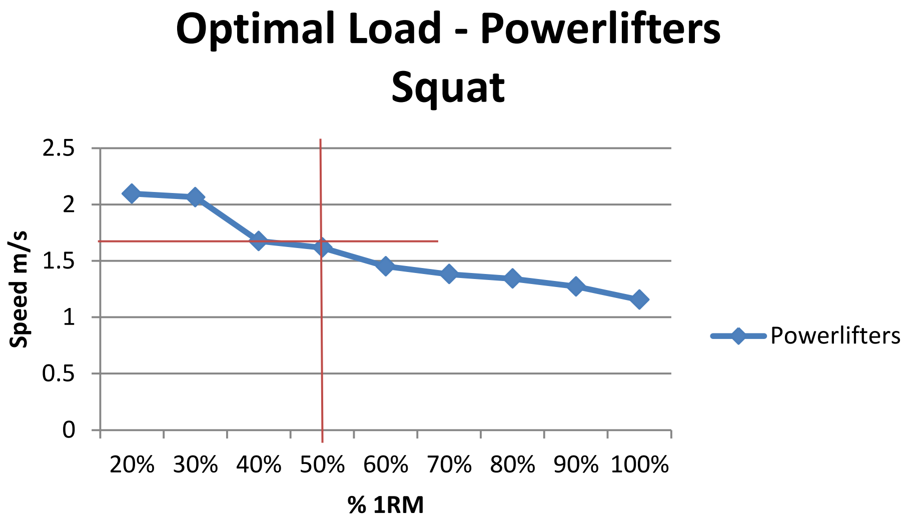


Figure4.4.10

Figure 4.4.10 shows bar speed in metres per second (m/s) in (N=4) powerlifters, with loads ranging from 20% 1RM and 100% 1RM.

Note: Red line represents the midpoint speed between the fastest and slowest repetition speed.

Figure4.4.11 displays (N=10) rugby players bar speed across different percentages of their 1RM during the squat. The fastest bar speed was recorded at 20% 1RM travelling at 1.592m/s and the slowest at 100% 1RM travelling at 0.931m/s. (N=10) rugby players bar speeds in the squat remained faster than the midpoint of 1.2615msm/s at 1.260m/s with a 55% 1RM load applied, beyond this load bar speed was slower than the midpoint.

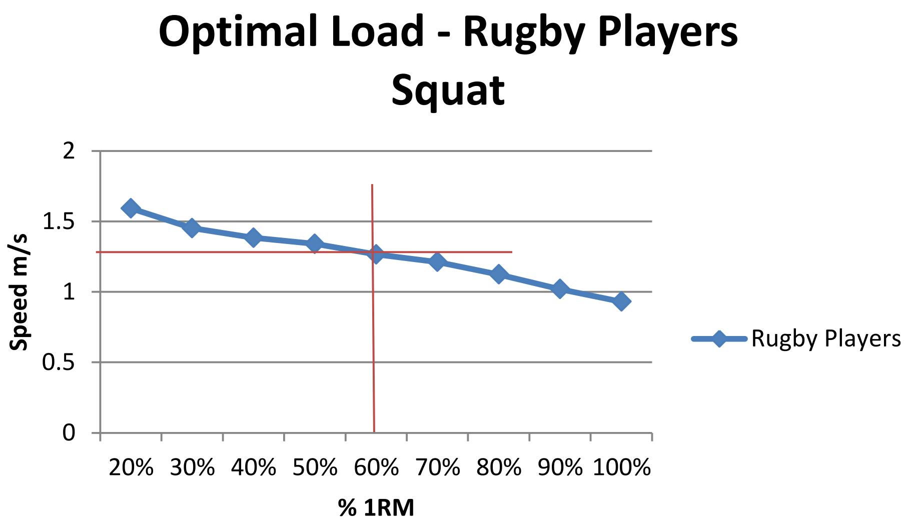


Figure4.4.11
Figure4.4.11 shows bar speed in meters per second (m/s) in (N=10) powerlifters, with loads ranging from 20% 1RM – 100% 1RM.

Note: Red line represents midpoint speed between the fastest and slowest repetition speed recorded.

4.5 Research Question2

What is the optimal load for developing muscular power in the power clean?

Figure4.5.1 illustrates that the fastest bar speed was recorded at 20% 1RM travelling at 1.811m/s and the slowest at 100% 1RM travelling at 0.985m/s. Previous research by Rhea et al. (2009) categorised fast bar speed as the midpoint speed between the fastest and slowest repetition speed recorded at different percentages of a participants 1RM. In order for a bar speed to be considered fast it had to be at or above this threshold speed. Bar speed in the power clean remained faster than the midpoint of 1.398m/s at 1.4m/s with a 56% 1RM load applied, beyond this load bar speed decreased below this midpoint.

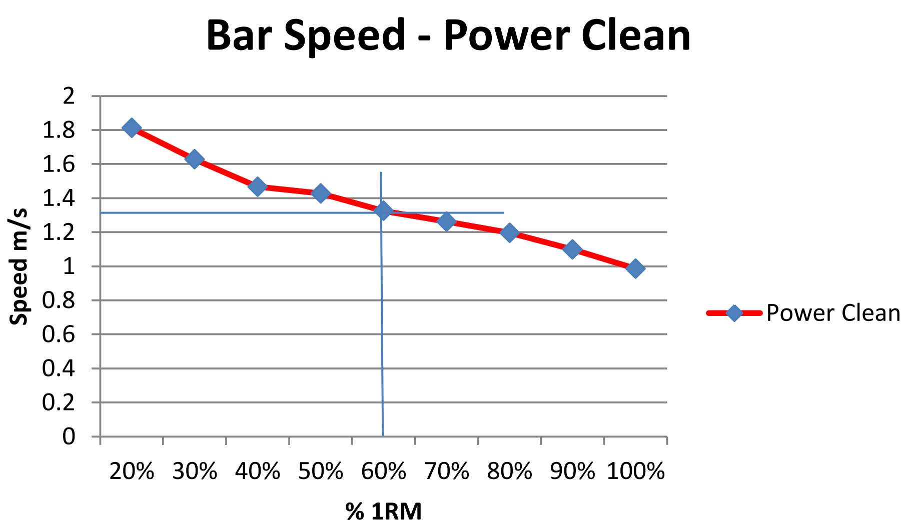


Figure4.5.1

Figure4.5.1 displays the speed of bar during the power clean at different percentages of participants 1RM.

Note: The blue line represents the midpoint between the fastest and slowest repetition speed recorded.

Figure4.5.2 illustrates that as the load (%1RM) increased, time taken to complete the phase of the lift increased. Time taken to complete the phase of the lift increases from 0.459sec when a 20% 1RM load is applied to 1.007sec when a 100%1RM load is applied. Following the same principles as bar speed (Rhea, 2009), in order for a lift to be considered fast; duration of the lift must be less than the midpoint between the longest and shortest duration. This midpoint of 0.457sec occurs at 60% 1RM beyond this load the duration of the lift is >0.457sec.

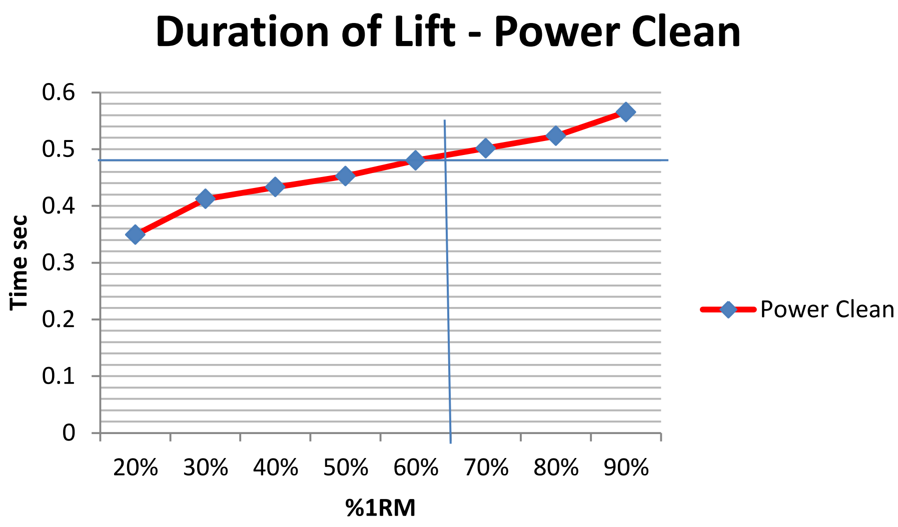


Figure4.5.2

Figure4.5.2 displays time taken to complete a phase of the power clean across different percentages of participants 1RM.

Note: The blue line represents the midpoint duration, between the longest and shortest duration recorded.

Figure4.5.3 shows that the fastest bar speed was recorded at 20% 1RM travelling at 1.809m/s and the slowest at 100% 1RM travelling at 0.341m/s. The midpoint between these two speeds is 1.075m/s. Powerlifters bar speed remained faster than this midpoint with a <64% 1RM load applied, beyond this point bar speed was slower than the midpoint.

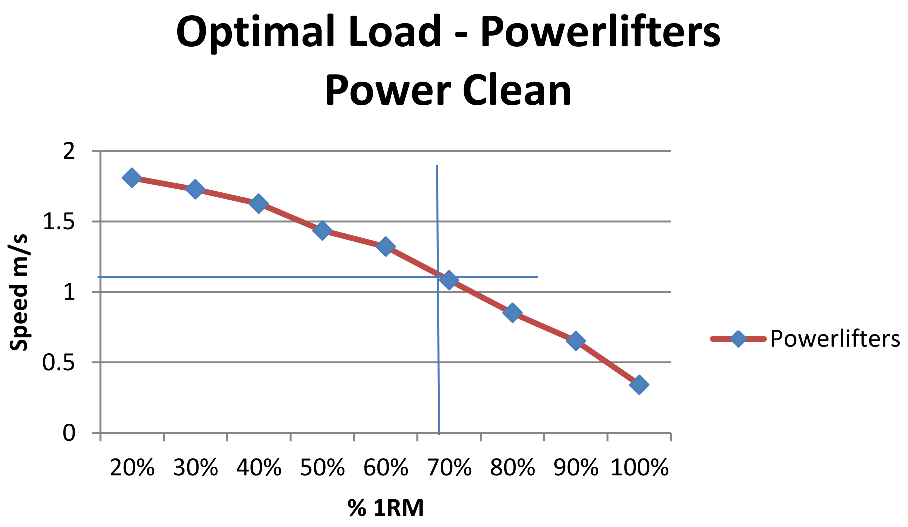


Figure4.5.3

Figure 4.5.3 displays the bar speed of (N=4) powerlifters at different percentages of their 1RM, loads ranging from 20% 1RM – 100% 1RM.

Note: The blue line represents the midpoint speed between the fastest and slowest repetition speed recorded.

Figure4.5.4 illustrates that the fastest bar speed was recorded at 20% 1RM travelling at 1.625m/s and the slowest at 100% 1RM travelling at 0.666m/s. The midpoint between these two speeds is 1.145m/s. Rugby players bar speed in the power clean remained faster than this midpoint when a <61% 1RM load was applied, beyond this load and the bar speed was slower than the midpoint.

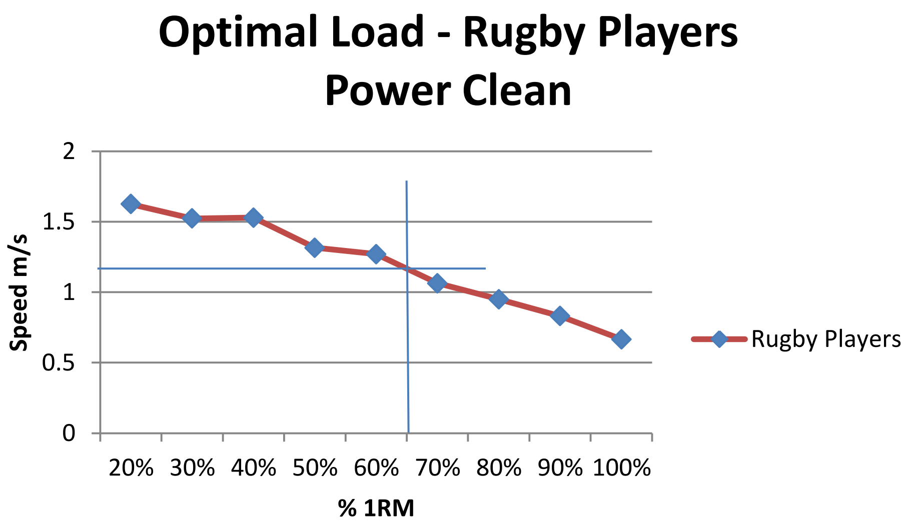


Figure4.5.5

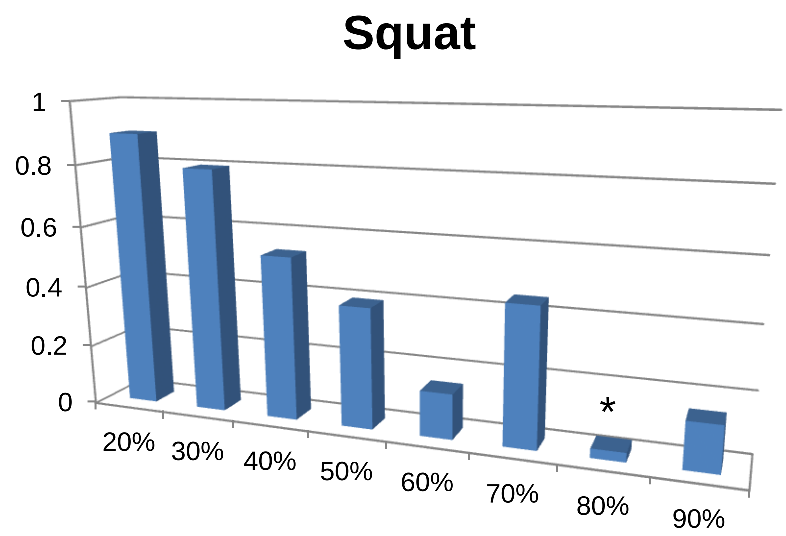
Figure 4.5.5 displays bar speed of (N=10) rugby players at different percentages of their 1RM during the power clean, loads ranging from 20% 1RM – 100% 1RM.

Note: Blue line represents the midpoint speed between the fastest and slowest repetition speed recorded.

4.6 Research Question3

Is there a significant difference between bar speed and weight lifted?

Figure4.6.1: A Pearson Correlation Sig. (2-tailed) test showed a non-significant difference ($p>0.05$) between bar speed and weight lifted in the squat at 20%1RM (0.897, $p>0.05$), 30%1RM (0.795, $p>0.05$), 40%1RM (0.534, $p>0.05$), 50%1RM (0.395, $p>0.05$), 60%1RM (0.148 $p>0.05$) and 90%1RM (0.15, $p>0.05$). The test showed a significant difference ($p<0.05$) between bar speed and weight lifted in the squat at 70%1RM (0.012, $p<0.05$) and 80%1RM (0.043, $p<0.05$) during the squat. Overall there is a poor correlation between bar speed and weight lifted in the squat.

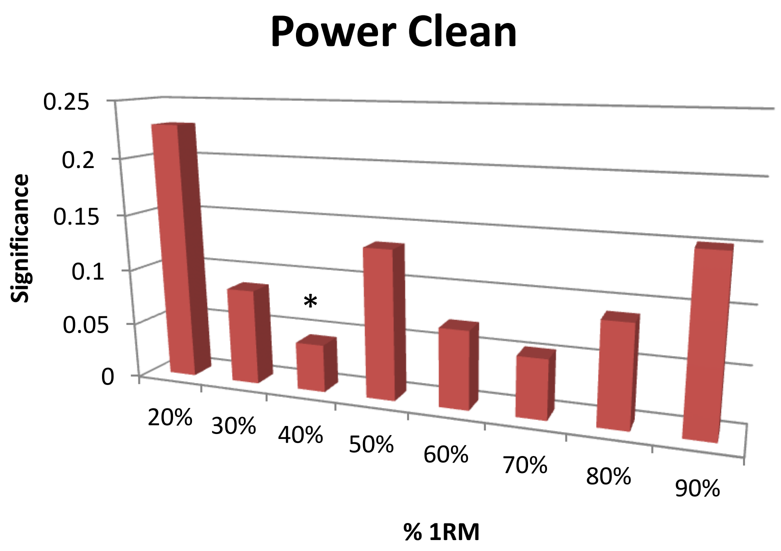


*= Significant difference in bar speed and weight lifted.

Figure4.6.1

Figure illustrates level of significance between bar speed and weight lifted in the squat.

Figure4.6.2: A Pearson Correlation Sig. (2-tailed) test showed a non-significant difference (p>0.05) between bar speed and weight lifted in the power clean at 20%1RM (0.229, p>0.05), 30%1RM (0.086, p>0.05), 50% 1RM (0.133, p>0.05), 60% 1RM (0.07, p>0.05), 70% 1RM (0.053, p>0.05), 80%1RM (0.09, p>0.05) and 90%1RM (0.151, p>0.05). The test showed a significant (p<0.05) difference between bar speed and weight lifted in the power clean at 40% 1RM (0.043, p<0.05). Overall there is a poor correlation between bar speed and weight lifted in the power clean.



*= Significant difference in bar speed and weight lifted.

Figure4.6.2

Figure4.6.1 illustrates level of significance between bar speed and weight lifted in the power clean.

4.7 Research Question4

Is there a relationship between bar speed and weight lifted?

Table4.7.1: below sloes a Pared Samples T-Test was computed to assess the relationship between weight lifted (%1RM) and bar speed in the squat and power clean. The test showed that there was a negative correlation between bar speed and weight lifted in the squat when 20% 1RM load was applied (r= -0.38), 30% 1RM (r= -0.76), 40% 1RM (r= -0.182), 50% 1RM (r= -0.247), 60% 1RM (r= -0.408), 70% 1RM (r= -0.221), 80% 1RM (r= -0.58) and when 90% 1RM load is applied (r= -0.636). The test showed that there is a negative relationship between bar speed and weight lifted in the power clean when a 20% 1RM load is applied (r= -0.299), 30% 1RM (r= -0.475), 40% 1RM (r= -0.548), 50% 1RM (r= -0.421), 60% 1RM (r= -0.498), 70% 1RM (r= -0.526), 80% 1RM (r= -0.47) and when 90% 1RM load is applied (r= -0.405). Overall there was a strong negative correlation between weight lifted (%1RM) and bar speed. Increases in load in the squat and power clean were correlated with a reduction in bar speed.

Table4.7.1

Table4.7.1 displays negative (R-Values) between bar speed and weight lifted.

Squat	R Values	Power Clean	R Values
%1RM		**%1RM**	
20%	-0.38*	**20%**	-0.299*
30%	-0.76*	**30%**	-0.475*
40%	-0.182*	**40%**	-0.548*
50%	-0.247*	**50%**	-0.421*
60%	-0.408*	**60%**	-0.498*
70%	-0.221*	**70%**	-0.526*
80%	-0.58*	**80%**	-0.47*
90%	-0.636*	**90%**	-0.405*

*= represents a negative correlation between bar speed and weight lifted (R=<1).

5.0 Discussion

5.1 Introduction

The aim of this investigation was to determine what the optimal load for developing muscular power in the squat and power clean. This study used bar speed as a method of collecting data on the squat and power clean, it aimed to identify at what load (%1RM) was there a decrease in bar speed across the spectrum in the squat and power clean exercise. Athletes who are focused on bar power and bar speed during the concentric phase of the lift should not train above this spectrum, as the bar speed will be too slow (McBride, 2002). Fast bar speed was categorised as the midpoint speed between the fastest and slowest repetition speed recorded at different percentages of a participants 1RM, in order for a bar speed to be considered fast it had to be at or above this threshold speed. This classification of fast bar speed is in line with previous research by Rhea et al. (2009). The author also aimed to identify at what loads (%1RM) did the fastest bar movements occur in the squat and power clean. Additionally the author wanted to identify if there was a significant difference between bar speed across different percentages of the participants 1RM. Finally this investigation aimed to determine was there a significant relationship between bar speed and weight lifted in the squat and power clean.

Results obtained indicate that the optimal load for developing muscular power in the squat is at or below a 60% 1RM load, and the optimal load for developing muscular power in the power clean is at or below a 56% 1RM load, beyond these loads bar speed was slower than the midpoint. The fastest bar speed was recorded when a 20% 1RM load was applied in both the squat and power clean exercise. This investigation identified that there is a negative relationship between bar speed and weight lifted, as the load (%1RM) increased there was a reduction in bar speed (m/s).

5.2 Optimal Load for Developing Muscular Power in the Squat

Results from this investigation demonstrated that the optimal load for developing muscular power in the squat exercise was 60% 1RM, beyond this load there was a decrease in bar speed below the midpoint. Cormie et al. (2007) carried out research on a similar population size, the investigation tested (N=12) division one male athletes for the optimal load in the squat, the research found that the optimal load in the squat was 56% 1RM. Izquirdo et al. (2002) incorporated a similar methodology to this investigation, the research looked at the optimal load for developing muscular power in the squat during the concentric phase of the lift in middle distance runners, handball players, and cyclists. Similarly to Cormie et al. (2007), Izquirdo et al. (2002) found that 60% 1RM was the optimal load for developing muscular power in the squat. Siegel et al.(2002) carried out research on (N=10) un-trained volunteers to assess at what percentage of your 1RM does maximal power output occur in the squat, peak power outputs occurred between 50-70% 1RM loads. In Siegel et al. (2002) investigation given the population samples limited weightlifting experience and differences in the methodology's, such as the use of a Smith machine instead of a squat rack, all could have attributed to the higher optimal load for developing muscular power found in that investigation.

The optimal load for developing muscular power in the squat for the (N=4) powerlifters (45% 1RM) was lower than the optimal load found in the (N=10) rugby players. Izquirdo et al. (2002) had similar findings when (N=11) weightlifters where tested for their optimal load for developing muscular power in the squat. The results showed that the weightlifters optimal load was 45% 1RM, in comparison to other population groups being tested in the investigation; (N=19) handball players, (N=8) cyclists and (N=10) middle distance runners which optimal loads were all 60% 1RM. A number of elements could have attributed to these differences in loads between athletes, Izquirdo et al. (2002) found that weightlifters had higher maximal strength and power output in the squat. These different levels of maximal strength and power could be attributed to training adaptations that could have occurred as a result of the weightlifters taking part in heavy-resistance training programmes. Whereas other participants in the study such as middle distance runners and handball players perform low-resistance training programmes in preparation for competition. Previous research in this area found that athletes that specialized in endurance events have a higher percentage of slow twitch muscle fibres, while strength and power athletes such as weightlifters and powerlifters have a higher percentage of fast twitch muscle fibres when compared to an untrained subject (Costill, 1976 & Saltin, 1977).

Swinton et al. (2009) conducted a survey of (N=28) elite powerlifter in the United Kingdom, results showed that 46% of participants perform power sets as fast as possible, while 82% of participants performed speed repetitions with submaximal loads applied. Training with submaximal loads during speed sets along with performing power sets as fast as possible could have caused muscular adaptations in the (N=4) powerlifters, which could account for the faster bar speeds and lower optimal load achieved by the powerlifters in this investigation. Slower bar speeds in the (N=10) rugby players could be attributed to training elements of a rugby player, during the playing season rugby players take part in large amounts of aerobic and anaerobic team practices (Baker, 1998; Remedios, 1985 & Fleck 2004). Research suggests that this large amount of aerobic and anaerobic training and the reduced number of strength and power sessions throughout the season can cause a reduction in strength and power output, which would lead to slower bar speeds (Legg, 1999 & Scheidner, 1998).

5.3 Optimal Load for Developing Muscular Power in the Power Clean

Results from this investigation suggest that the optimal load for developing muscular power in the power clean is 60% 1RM, as the load increased beyond this point there was a significant ($p>0.05$) reduction in bar speed below the midpoint. Previous research by Cormie et al. (2007) found that 80% 1RM was the load that maximises power output during the power clean in (N=12) division one male athletes. This calculation by Cormie et al. (2007) was based on the system (bar + body), whereas results in this study were strictly based on bar speed. McBride et al. (2011) conducted similar research using force plates to determine the optimal load in (N=9) males with a minimum of 2 years' experience with the power clean exercise. McBride et al. (2011) had similar recommendations to Cormie et al. (2007), the research found that there was little or no alteration in the optimal load between bar, body and system calculations. Maximal bar and body peak power output was observed at 90% 1RM during the power clean.

Wallace et al. (2006) looked at power output during the power clean with 50, 70 & 90% 1RM loads applied, results showed that maximal power output was achieved at 70% 1RM. An additional study by Haff et al. (2003) used a similar methodology to this investigation. Their research investigated power output during the mid-thigh pull of the hang power clean, excluding the catch a hang power clean involves the same segments as a power clean so results are comparable. Haff et al. (2003) found that the optimal load for the mid-thigh pull to be 80% 1RM, however the credibility of this result was limited as only 80, 90, 100% 1RM loads were assessed and no significant differences between different loads found. The optimal load of 80% 1RM for the mid-thigh pull found by Haff et al. (2003), and its similarity's to power outputs achieved with a 50-90% 1RM loads applied, suggests that the optimal load for developing muscular power for the power clean occurs within this loading range with the use of submaximal loads.

Cormie et al. (2007) concluded their research by saying that such a high peak power achieved by the (N=12) division one athletes would not be a representation of the general population's optimal load, as participants were elite athletes who were specifically trained for power. Similarly McBride et al. (2011) used participants who had two years' minimum experience with the power clean exercise. In this study the participants had limited experience with the power clean exercise, it is a very complex exercise which can take years to master (McBride, 2011). This inexperience with the lift along with the amateur sporting backgrounds of the participants in this study, could have attributed to the low optimal load found for the power clean. Differences in methodologies could have impacted on results, previous research by Cormie et al. (2007) measured peak force, velocity and power during mid-thigh pulls in the power clean, McBride et al. (2011) used force plates and a three-dimensional videography system to measure peak force, velocity and power. Their recommendations were based on a combination of peak force, velocity and power, whereas this investigations recommendation was based on bar speed alone.

5.4 Is Bar Speed an Accurate Method for Collecting Data in the Squat?

Results gathered in this investigation would suggest that bar speed is an accurate method for determining the optimal load for developing muscular power in the squat. Results found are in line with previous research (Izquirdo, 1999; Izquirdo, 2002; Baker, 2001; Cormie, 2007; McBride, 1999 & Siegel, 2002) which all identified 60% 1RM to be the optimal load for developing muscular power in the squat. This investigation also had similar findings to Izquirdo et al. (2002) who found that weightlifters had a lower optimal load than other athletes tested, this was similar to this investigation as the (N=4) powerlifters optimal load was found to be 45% 1RM. Their findings show that there is consistency between measurements of bar speed in this investigation and previous alternative methods of measuring power output in the squat.

5.5 Is Bar Speed an Accurate Method for Collecting Data in the Power Clean

Results gathered from this investigation would suggest that bar speed is not an accurate method for collecting data for power output in the power clean, as there is large variance in results found in this study which found the optimal load to be 60% 1RM and results from previous research which found the optimal load to be 80% 1RM (Cormie, 2007; Haff, 2003 & McBride, 2011). However you cannot dismiss bar speed as a method for collecting data in the power clean based on this investigation alone. There were significant differences in methodologies and population samples between this investigation and previous research conducted on the optimal load in the power clean. The athletes tested in Cormie et al. (2007) and in McBride et al. (2011) investigations were elite athletes who were experienced with the power clean exercise, when compared to the participants in this investigation who were semi-professional. Prior to testing participants outlined they had a certain level of training experience, however their technique did not reflect this in the power clean. Cormie et al. (2007) concluded in her investigation that the optimal load achieved by participants in the study was a representation of an elite athlete who specifically trains to be a power athlete, and would not reflect the same capabilities of a non elite athlete. As a result in order to accurately know if bar speed is an accurate method for determining the optimal load for developing muscular power in the power clean, this methodology would need to be carried out on elite athletes so that the results would be comparable.

Aside from the differences in population between this and previous studies, potentially bar speed alone does not supply enough information to determine the optimal load in the power clean. Data collection of other variables would have allowed for a more comprehensive set of results. This would potentially lead to a more accurate set of recommendations on what is the optimal load for developing muscular power in the power clean. Previous studies by Cormie et al. (2006) measured peak force, velocity and power during mid-thigh pulls in the power clean, while more recently McBride et al. (2011) used a force plate and a three-dimensional videography system to measure peak force, velocity and power.

5.6 Conclusion

The objective of this research was to determine what is optimal load for developing muscular power in the squat and power clean exercises, by assessing bar speed in meters per second in (N=14) male college athletes. Additionally this investigation compared the potential variance in optimal loads between (N=10) semi-professional rugby players and (N=4) semi-professional powerlifters.

It was established that the optimal load for developing muscular power in the squat is 60% 1RM; increases in load beyond this percentage 1RM resulted in a reduction in bar speed below the midpoint. However the optimal load for developing muscular power in (N=4) powerlifters occurred at a lower percentage 1RM load at 45% 1RM. This lower optimal load found in powerlifters is not uncommon, previous research by Izquirdo et al. (2002) on power output in (N=11) weightlifters had similar findings. Izquirdo et al. (2002) put this down to being involved in heavy resistance training programmes and having different levels of maximal strength and power outputs when compared with other population samples. Additionally this difference in optimal loads between population samples could be attributed to possible muscular adaptations that occur as a result of training for powerlifting, Swinton et al. (2009) survey showed that almost 50% of powerlifters perform power sets as fast as possible. It is possible that the (N=10) rugby players in this investigation had never consciously performed repetition’s in the squat as fast as possible prior to this study, until they were instructed to do so during this investigation. This could have caused some discrepancies in results, such as the slower bar speeds recorded for the (N=10) rugby players. The optimal load for developing muscular power in (N=10) rugby players in the squat was 60% 1RM.

Results from this investigation show that the optimal load for developing muscular power in the power clean is 60% 1RM; increases in load beyond this percentage 1RM resulted in a reduction in bar speed below the midpoint. The optimal load for the two population samples was quite similar, 64% 1RM for the (N=4) powerlifters, and 61% 1RM for the (N=10) rugby players. The optimal load of 60% 1RM found in this investigation is not in line with previous studies (Cormie, 2007 & McBride, 2011). However there was a significant difference in population sample between Cormie et al. (2007) and McBride et al. (2011) studies and this investigation, their investigations were conducted on elite athletes who had two years’ minimum experience performing power cleans. The fact that the participants involved in this investigation were semi-professional athletes who had limited experience of performing power cleans has been identified as a potential reason for participants in this investigation having a lower optimal load than found in previous research (Cormie, 2007 & McBride, 2011). Baker et al. (2002) identified in his investigation that professional athletes have higher levels of strength and power than amateur athletes, this alone could result in a higher optimal load in the power clean. Izquirdo et al. (2002) previous research identified that athletes who have higher strength and power outputs, generally have higher optimal loads.

There was also a notable difference in methodologies between this investigation and previous research by Cormie et al. (2007), and McBride et al. (2011). This investigation made its recommendations based on bar speed, Cormie et al. (2006) recommendations were based on peak force and velocity measurements. More recently recommendations were made by McBride et al. (2011) based on results from force plate and a three-dimensional videography system which measured peak force, velocity and power.

5.7 Recommendations for Future Research

Data collection for this investigation took place in March 2014 which is in the final stages of the rugby season for club players in Ireland. There is some disagreement if preseason levels of strength and power outputs achieved by a player can be achieved during the playing season when large amounts of aerobic and anaerobic team practices take place (Baker, 1998; dos Remedios, 1995; Fleck, 2004; Legg, 1999 & Scheidner, 1998). Several studies have investigated if strength and power output achieved during preseason can be maintained during the competitive season. Fleck et al. (2004) and Baker et al. (1998) reported that strength levels can be maintained for 14-16 weeks in college and professional athletes, however Schneider et al. (1998) reported that there was a significant reduction in strength levels in college football players after 13-14 weeks. Power is the result of two variables; speed and strength (Bompa, 1994), a significant reduction in strength would inherently cause a significant reduction in power output. If this is true the optimal load for developing muscular power in a rugby player should constantly be reassessed as strength levels potentially diminish throughout the season. Further research is needed in this area to track strength and power outputs in rugby players over the course of a season, to identify potential changes in the optimal load.

Based on this research it could be argued that athletes should train using the load that maximises power output, in order to maximise improvements in muscular power and to gain improvements in a range of other performance variables. However an athlete needs to be careful when applying such findings into their own personal training programmes, because power output was only measured for one repetition. Weightlifting movements are often performed using multiple repetitions. If an athlete is performing multiple repetitions at the optimal load which was prescribed for one repetition in the squat or power clean, it is expected that power output will decrease as neuromuscular fatigue sets in (Haff, 2003). As a results the athlete will not been maximising improvements in power output during training as they are using too heavy a load. As a result further research should be carried out to investigate power output during multiple repetitions at various loads. This research would provide more practical information to athletes as to what is the optimal load is for developing muscular power is in multiple repetitions rather than in just once off lifts.

To the best of the author's knowledge this is the first study which has aimed to determine the optimal load for developing muscular power by assessing bar speed. The term bar speed is one that is commonly thrown around in fitness facilities, and is strongly associated with powerlifting or team sports during speed and power sessions. However if bar speed has never been accurately measured before why do people think it's important. Owing to this fact further research should be carried out to discover the effects of training at this load have for sprint speed and power output in athletes. This subsequently could show the world of strength and conditioning research the true value of bar speed.

5.8 Limitations

Following on from the investigation a number of potential limitations occurred which could have impacted on results, the number of subjects (N=14) meant that there was a small sample size. This small sample size arose due to the fact that many of the individuals failed to meet the inclusion criteria of six months weightlifting experience and having previous experience with the squat and power clean exercise. Although previous research by Cormie et al. (2007) and McBride et al. (2011) had (N=12) and (N=9) participants respectively. However in order to increase reliability a larger sample size is needed. Initially the population was to be a random-sample however due to participants dropping out due to academic and sporting commitments the sample became non-random, this further reduced the reliability of the investigation.

This small sample size also means that the results are not generalisable, as the study only tested (N=14) male college students.

Although it was stated in the methodology that participants must have had at least 6 months weightlifting experience prior to testing, with previous experience with the squat and power clean exercise it was clear during testing that some struggled with technique during the power clean. This was especially relevant to the powerlifters who appeared to struggle with the flexibility required to complete the Olympic lift. The (N=4) powerlifters had previous experience of power cleans, but had been concentrating on single plane movement such as the squat, bench and deadlift for competition. This would have caused neuromuscular adaptations which would have made it difficult for them to complete the lift with good technique (Swinton, 2009). This could have impacted on the low optimal load found in this study for the power clean.

Finally one limitation which only became evident once testing had begun, the smallest weight increments available in both Cork Constitution rugby club gym and HPL gym in Waterford Institute of Technology were 2.5kg plates. This impacted on the accuracy of the results, as if a participant's percentage 1RM load was not a multiple of five the correct load could not be applied. In these cases the percentage 1RM load was rounded up to as closest applicable load. In order to improve the accuracy and reliability of the results 0.5kg and 1kg plates should have been available during testing.

6.0 Bibliography

1. Anderson, T., & Kearney, J. T. (1982). Effects of three resistance training programs on muscular strength and absolute and relative endurance. *Research Quarterly for Exercise and Sport*, *53*(1), 1-7.

2. Alexander, M. J. (1989). The relationship between muscle strength and sprint kinematics in elite sprinters. *Canadian journal of sport sciences= Journal canadien des sciences du sport*, *14*(3), 148.

3. Adams, K., O'Shea, J. P., O'Shea, K. L., &Climstein, M. (1992). The effect of six weeks of squat, plyometric and squat-plyometric training on power production. *The Journal of Strength & Conditioning Research*, *6*(1), 36-41

4. Abernethy, P., Wilson, G., & Logan, P. (1995). Strength and power assessment. *Sports medicine*, *19*(6), 401-417.

5. Appleby, B., Newton, R. U., & Cormie, P. (2012). Changes in strength over a 2-year period in professional rugby union players. *The Journal of Strength & Conditioning Research*, *26*(9), 2538-2546.

6. Argus, C. K., Gill, N., Keogh, J., Hopkins, W. G., & Beaven, C. M. (2010). Effects of a short-term pre-season training programme on the body composition and anaerobic performance of professional rugby union players. *Journal of sports sciences*, *28*(6), 679-686.

7. Berger, R. (1962). Effect of varied weight training programs on strength. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *33*(2), 168-181.

8. Baker, D., & Nance, S. (1999). The relation between running speed and measures of strength and power in professional rugby league players. *The Journal of Strength & Conditioning Research*, *13*(3), 230-235.

9. Bompa, T. O. (1994). *Theory and methodology of training: the key to athletic performance*. Kendall Hunt Publishing Company.

10. Baker, D. (1998). Applying the in-season periodization of strength and power training to football. *Strength & Conditioning Journal*, *20*(2), 18-27.

11. BAKER, D., NANCE, S., & MOORE, M. (2001). The load that maximizes the average mechanical power output during jump squats in power-trained athletes. *The Journal of Strength & Conditioning Research*, *15*(1), 92-97.

12. BAKER, D. (2002). Differences in strength and power among junior-high, senior-high, college-aged, and elite professional rugby league players. *The Journal of Strength & Conditioning Research*, *16*(4), 581-585.

13. Bret, C., Rahmani, A., Dufour, A. B., Messonnier, L., & Lacour, J. R. (2002). Leg strength and stiffness as ability factors in 100 m sprint running. *Journal of Sports Medicine and Physical Fitness*, *42*(3), 274-281.

14. BOURQUE, J. P. Determinants of load at peak power during maximal effort squat jumps in endurance and power trained athletes [dissertation]. Fredericton, Canada: Department of Kinesiology, University of New Brunswick, 2003

15. Baker, D and Newton, R. Adaptations in upper-body maximal strength and power output resulting from long-term resistance training in experienced strength-power athletes. J Strength Cond Res 20: 541–546, 2006.

16. Costill, D. L., Daniels, J., Evans, W., Fink, W., Krahenbuhl, G., & Saltin, B. (1976). Skeletal muscle enzymes and fiber composition in male and female track athletes. *J Appl Physiol*, *40*(2), 149-154.

17. Coyle EF, Feiring DC, Rotkis TC, Cote III RW, Roby FB, Lee W, Wilmore JH (1980) Specificity of power improvements through slow and fast isokinetic training. J Appl Physiol 51: 1437–1442

18. Caiozzo, V. J., Perrine, J. J., & Edgerton, V. R. (1981). Training-induced alterations of the in vivo force-velocity relationship of human muscle. *Journal of Applied Physiology*, *51*(3), 750-754.

19. Cronin, J., & Sleivert, G. (2005). Challenges in understanding the influence of maximal power training on improving athletic performance. *Sports Medicine*,*35*(3), 213-234.

20. Cormie, P., McCaulley, G. O., Triplett, N. T., & McBride, J. M. (2007). Optimal loading for maximal power output during lower-body resistance exercises. *Medicine and science in sports and exercise*, *39*(2), 340.

21. Cormie, P., McGuigan, M. R., & Newton, R. U. (2011). Developing maximal neuromuscular power. *Sports medicine*, *41*(1), 17-38.

22. Comfort, P., Udall, R., & Jones, P. A. (2012). The Effect of Loading on Kinematic and Kinetic Variables During the Midthigh Clean Pull. *The Journal of Strength & Conditioning Research*, *26*(5), 1208-1214.

23. Delorme, T. L., Schwab, R. S., & Watkins, A. L. (1948). The response of the quadriceps femoris to progressive-resistance exercises in poliomyelitic patients. *The Journal of Bone & Joint Surgery*, *30*(4), 834-847.

24. dos Remedios, K. A., dos Remedios, R. L., Loy, S. F., Holland, G. J., Vincent, W. J., Conley, L. M., & Heng, M. (1995). Physiological and field test performance changes of community college football players over a season. *The Journal of Strength & Conditioning Research*, *9*(4), 211-215.

25. Fleck, S., & Kontor, K. (1986). Soviet strength and conditioning: Complex training. *Strength & Conditioning Journal*, *8*(5), 66-72.

26. Fleck, S. J. (2004). *Designing resistance training programs*. Human Kinetics.

27. Guilich, A., Schmidtbleicher, D. (1996) MVC-induced short-term potentiation of explosive force. *New Studies in Athletics*, 11, 67-81

28. HAFF, G. G., M. H. STONE, H. S. O `BRYANT, et al. Force-time dependent characteristics of dynamic and isometric muscle actions. J. Strength Cond. Res. 11:269–272, 1997.

29. Harris, G. R., Stone, M. H., O'Bryant, H. S., Proulx, C. M., & Johnson, R. L. (2000). Short-term performance effects of high power, high force, or combined weight-training methods. *The Journal of Strength and Conditioning Research*, 14-20.

30. Haff, G. G., WHITLEY, A., MCCOY, L. B., O'BRYANT, H. S., Kilgore, J. L., HAFF, E. E., ... & STONE, M. H. (2003). Effects of different set configurations

on barbell velocity and displacement during a clean pull. *The Journal of Strength & Conditioning Research*, *17*(1), 95-103.

31. Heinecke, M, Jovick, B, Cooper, Z, and Wiechert, J. Comparison of strength gains in variable resistance bench press and isotonic bench press [Abstract]. J Strength Cond Res 18: e10, 2004.

32. Hori, N., Newton, R. U., Andrews, W. A., Kawamori, N., McGuigan, M. R., & Nosaka, K. (2007). Comparison of four different methods to measure power output during the hang power clean and the weighted jump squat. *The Journal of Strength & Conditioning Research*, *21*(2), 314-320.

33. Izquierdo, M., Aguado, X., Gonzalez, R., Lopez, J. L., & Häkkinen, K. (1999). Maximal and explosive force production capacity and balance performance in men of different ages. *European Journal of Applied Physiology and Occupational Physiology*, *79*(3), 260-267.

34. Izquierdo, M., Häkkinen, K., Gonzalez-Badillo, J. J., Ibanez, J., & Gorostiaga, E. M. (2002). Effects of long-term training specificity on maximal strength and power of the upper and lower extremities in athletes from different sports.*European Journal of Applied Physiology*, *87*(3), 264-271.

35. Kaneko, A., & Saito, T. (1983). Ionic mechanisms underlying the responses of off-center bipolar cells in the carp retina. II. Studies on responses evoked by transretinal current stimulation. *The Journal of general physiology*, *81*(4), 603-612.

36. KAWAMORI, N., A. J. CRUM, P. A. BLUMERT, et al. Influence of different relative intensities on power output during the hang power clean: identification of the optimal load. J. Strength Cond. Res. 9:698–708, 2005.

37. Kilduff, L. P., Bevan, H. R., Kingsley, M. I., Owen, N. J., Bennett, M. A., Bunce, P. J., ... & Cunningham, D. J. (2007). Postactivation potentiation in professional rugby players: Optimal recovery. *The Journal of Strength & Conditioning Research*, *21*(4), 1134-1138.

38. LEGG, D., & BURNHAM, R. (1999). In-season shoulder abduction strength changes in football players. *The Journal of Strength & Conditioning Research*, *13*(4), 381-383.

39. Moffroid, M. T., & Whipple, R. H. (1970). Specificity of speed of exercise.*Physical Therapy*, *50*(12), 1692.

40. Meckel, Y., Atterbom, H., Grodjinovsky, A., Ben-Sira, D., & Rotstein, A. (1995). Physiological characteristics of female 100 metre sprinters of different performance levels. *Journal of sports medicine and physical fitness*, *35*(3), 169-175.

41. McBride, J. M., TRIPLETT-MCBRIDE, T. R. A. V. I. S., DAVIE, A., & NEWTON, R. U. (1999). A comparison of strength and power characteristics between power lifters, Olympic lifters, and sprinters. *The Journal of Strength & Conditioning Research*, *13*(1), 58-66.

42. MCBRIDE, J. M., T. TRIPLETT-MCBRIDE, A. DAVIE, and R. U. NEWTON. A comparison of strength and power characteristics between power lifters, Olympic lifters and sprinters. J. Strength Cond. Res. 13:58–66, 1999.

43. McBride, J.M., Triplett-McBride, T., Davie, A., & Newton, R.U. (2002). The effect of heavy- vs. light-load jump squats on the development of strength, power, and speed. Journal of Strength and Conditioning Research, 16, 75–82.

44. Markovic, G. (2007). Does plyometric training improve vertical jump height? A meta-analytical review. *British journal of sports medicine*, *41*(6), 349-355.

45. McBride, J. M., Haines, T. L., & Kirby, T. J. (2011). Effect of loading on peak power of the bar, body, and system during power cleans, squats, and jump squats. *Journal of sports sciences*, *29*(11), 1215-1221.

46. NEWTON, R., W. KRAEMER, K. HAKKINEN, B. HUMPHRIES, AND A. MURPHY. Kinematics, kinetics and muscle activation during explosive upper body movements. J. Appl. Biomech. 12:31–43. 1996.

47. O'Shea, P. (1966). Effects of selected weight training programs on the development of strength and muscle hypertrophy. *Research Quarterly.*

American Association for Health, Physical Education and Recreation, *37*(1), 95-102.

48. Pipes, T. V. (1979). High intensity, not speed. *Athletic. J*, *59*, 60-62.

49. Promoli, F., & Holt, L. E. (1979). Effects of isotonic and isokinetic exercise, at a fast repetition rate, on jumping and running. *Reh. Med*, *28*, 175-181.

50. Palmieri, G. A. (1987). Weight training and repetition speed. *The Journal of Strength & Conditioning Research*, *1*(2), 36-38.

51. Rhea, M. R., Ball, S. D., Phillips, W. T., & Burkett, L. N. (2002). A comparison of linear and daily undulating periodized programs with equated volume and intensity for strength. *The Journal of Strength & Conditioning Research*, *16*(2), 250-255.

52. Rhea, M. R., & Kenn, J. G. (2009). The effect of acute applications of whole-body vibration on the iTonic platform on subsequent lower-body power output during the back squat. *The Journal of Strength & Conditioning Research*, *23*(1), 58-61.

53. Rhea, M. R., Kenn, J. G., & Dermody, B. M. (2009). Alterations in speed of squat movement and the use of accommodated resistance among college athletes training for power. *The Journal of Strength & Conditioning Research*, *23*(9), 2645-2650.

54. Saltin, B., Henriksson, J., Nygaard, E., Andersen, P., & Jansson, E. (1977). Fiber types and metabolic potentials of skeletal muscles in sedentary man and endurance runners*. *Annals of the New York Academy of Sciences*,*301*(1), 3-29.

55. Stone, M. H., O'Bryant, H., & Garhammer, J. (1981). A hypothetical model for strength training. *The Journal of sports medicine and physical fitness*, *21*(4), 342.

56. SIEGEL, J. A., R. M. GILDERS, R. S. STARON, and F. C. HAGERMAN. Human muscle power output during upper- and lower-body exercises. J. Strength Cond. Res. 16:173–178, 2002.

57. Schneider, V., Arnold, B., Martin, K., Bell, D., & Crocker, P. (1998). Detraining effects in college football players during the competitive season. *The Journal of Strength & Conditioning Research*, *12*(1), 42-45.

58. Swinton, P. A., Lloyd, R., Agouris, I., & Stewart, A. (2009). Contemporary training practices in elite british powerlifters: survey results from an international competition. *The Journal of Strength & Conditioning Research*,*23*(2), 380-384.

59. Withers, R. T. (1970). Effect of varied weight-training loads on the strength of university freshmen. *Research Quarterly. American Association for Health, Physical Education and Recreation*, *41*(1), 110-114.

60. WOOD, G. A. Data smoothing and differentiation procedures in biomechanics. Exercise. Sport Sci. Rev. 10:308–362, 1982.

61. Wilson, G. J., Newton, R. U., Murphy, A. J., & Humphries, B. J. (1993). The optimal training load for the development of dynamic athletic performance. *Medicine and Science in Sports and Exercise*, *25*(11), 1279.

62. Wallace, B. J., Winchester, J. B., & MCGUIGAN, M. R. (2006). Effects of elastic bands on force and power characteristics during the back squat exercise. *The Journal of Strength & Conditioning Research*, *20*(2), 268-272.

63. Young, W., Benton, D., & John Pryor, M. (2001). Resistance training for short sprints and maximum-speed sprints. *Strength & Conditioning Journal*, *23*(2), 7.

64. Young, W. B. (2006). Transfer of strength and power training to sports performance. *International Journal of Sports Physiology and Performance*, *1*(2), 74.

65. Zatsiorsky, V. M., & Kraemer, W. J. (1995). *Science and practice of strength training* (pp. 251-255). Champaign: Human Kinetics.

7.0 Appendix

7.1 Summary Chart of Loads

Author	Sample (Sport)	Exercise	Optimal %1RM
Baker (2001)	Rugby League	Jump Squats	0%1RM
McBride (2002)	Athletic Men	Jump Squats	60%1RM
Argus (2011)	Rugby League	Jump Squats	0%1RM
Izquirdo (1999)	Handball / weightlift-ers / cyclists	Squat	60%1RM
Siegel (2002)	Male Volunteers	Squat	60%1RM
Haff (1997)	Weightlifters	Power Clean	70-80%1RM
Wood (1982)	Weightlifters	Power Clean	70-80%1RM
Baker (2001)	Power Trained ath-letes	Squat	60%1RM
Cormie (2007)	Div.1 Athletes	Squat	60%1RM
McBride (2011)	Athletic Men	Squat	60%1RM
Siegel (2002)	Male Volunteers	Squat	60%1RM
Cormie (2007)	Div.1 Athletes	Hang Power Clean	80%1RM
Haff (1997)	Weightlifters	Hang Power Clean	80%1RM
Kawamori (2005)	Men	Hang Power Clean	70%1RM
Kilduff (2007)	Rugby Union	Hang Power Clean	80%1RM
Cormie (2012)	Long Jumpers / Sprinters	Squat	56%1RM
Cormie (2012)	Long Jumpers / Sprinters	Jump Squat	0%1RM
Cormie (2012)	Long Jumpers / Sprinters	Power Clean	80%1RM

7.2 Informed Consent Form

Informed Consent Form

I Fionn Mc Swiney state that I premeditated to participate in this investigation which aims to determine the optimal load for developing muscular power in the squat and power clean exercise, by assessing bar speed. This being a component of my final year dissertation submitted in part fulfilment of the requirement for a B.A (Hons) degree in Exercise and Health in Waterford Institute of Technology.

I willingly approve to take part in this investigation which will require me to perform a one rep maximum (1RM) test in the squat and power clean exercise, and perform repetitions of the squat and power clean at percentages of my 1RM.

I am fully aware that I must instantly notify the investigator of any pain, discomfort, distress or irregularities that I feel during or directly after testing. I am aware that I can terminate my involvement in this investigation at any point. The investigator holds the right to terminate my involvement in this at investigation at any point without question.

I state that I have read, studied, and understood and consent to the contents of this informed consent arrangement in its totality.

Signature: ____

Investigator Signature: ____________________________________

Date: ____