# Rubber based resistance and the bench press exercise: Force and power outputs

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Godfrey, A. E., Harris, N. K. and Cronin, J. B. (2010). Repetition, set and total session kinematic and kinetic analysis of rubber based resistance during the bench press exercise (submitted to Journal of Strength and Conditioning Research).

Godfrey, A. E., Harris, N. K. and Cronin, J. B. (2010). Repetition, set and total session kinematic and kinetic analysis of rubber based resistance during the bench press exercise. *NZ Sports Medicine and Science Conference*, Wellington, New Zealand, November 2010 (abstract submitted to Sports Medicine New Zealand).

# ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university of other institute of higher learning.

Adam Godfrey ________________________________________

Date ____________________________________________

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# DEDICATION

This thesis is dedicated to each member of my family. Dad, Mum, Ben, Michael, Troy, Colleen, Paul, Helaina, Andre and Nikki. You each inspire and motivate me in your own unique way. Thank you all for your support and belief in me throughout this journey, I could not have done this without you!

## INTELLECTUAL PROPERTY RIGHTS

**ABSTRACT**

The application of rubber based resistance (RBR) to traditional isoinertial resistance exercises as a method of manipulating exercise kinematics and kinetics has gained popularity within the strength and conditioning fraternity. However, the tensile properties of RBR have not been thoroughly quantified and practitioners cannot prescribe loading parameters with absolute certainty given the inconsistencies in research methodologies. It was the purpose of this research to a) report the tension-deformation (T-D) characteristics for several sizes of RBR bands and b) determine whether differences exist between free weight (FW) and RBR bench press repetition, set and total set kinematics and kinetics. The T-D and fatigue characteristics of six sets of RBR bands were determined by measuring pre- and post-intervention mean vertical ground reaction forces. Force platform data was sampled at 200Hz for 5 seconds over a range of ascending and descending displacements. Subsequent to the establishment of the T-D relationship, fourteen well-trained male rugby players performed three sets of six bench press repetitions under three conditions, in a randomised crossover manner. A 50% 1RM load was equated between conditions at the apex of the concentric phase. RBR resistance contributed to either 0% (FW), 20% (RBR20) or 40% (RBR40) of the total apex resistance. A customised bench, force platform and linear position transducer were used in conjunction with a power rack fitted with sliding safety bars. A pair of RBR bands were attached to either end of a barbell and anchored by the safety bars, accounting for the anthropometrical differences between participants. The force- and displacement-time data were sampled at 200Hz by a computer based data acquisition and analysis programme. Descriptive data were presented as means ± SD, and the magnitudes of the observed differences, 90% confidence limits and clinical inferences were interpreted qualitatively. Results showed the T-D relationships exhibited curvilinear properties most appropriately fitted by second-order polynomial functions ($R^2 > 0.99$). Analysis of repetition kinematics and kinetics revealed greater force values for both RBR conditions during the middle stages (30-70%) of the concentric phase compared to FW. Total set peak force was greater for RBR20 than for FW (110 ± 90% confidence limits, 71 N). However, mean force was greater for FW than for RBR40 (57 ± 30 N). Repetition power was greater for RBR40 than for FW and RBR20 from 10-50% and from 90-100% of the relative concentric displacement. Total set peak power was greater for RBR40 than for FW (42 ± 58 W) but mean power was greater for FW than RBR40 (34 ± 39 W). The magnitudes of these effects were considered to be likely (≥92.4%) meaningful. This investigation indicates that the application of RBR to an isoinertial bench press leads to decreased concentric force and increased power values during the middle stages and increased force values at the end stages of a repetition. Over multiple sets, RBR increased peak power outputs but decreased mean force and mean power outputs. RBR training may be most appropriate for athletes required to produce power characterised by high velocities such as shot putters compared to those required to produce power characterised by high force outputs such as rugby props. RBR training may be an appropriate periodisation tool to increase power outputs as athletes approach competition.

# CHAPTER ONE: INTRODUCTION

The power producing capabilities of an athlete are widely considered as an important determinant contributing toward the successful performance of many athletic movements. Consequently, strength and conditioning programmes designed to enhance these qualities have become an integral component of an athletes' training regime. Various forms of resistance and training techniques intended to maximise power generating capabilities of muscles have been theorised and the efficacy of these techniques have subsequently been examined in scientific research studies (Frost, Cronin & Newton, 2010). One such technique, the application of RBR to traditional isoinertial resistance exercises has gained popularity despite a lack of conclusive scientific evidence concerning its ability to maximise mechanical power output. RBR products provide tensile force relative to the magnitude of the applied stretch. It has been proposed that the substitution of a proportion of the isoinertial resistance for RBR provides a method of manipulating the acute kinematic and kinetic profiles of an exercise (Behm, 1988; Cronin, McNair & Marshall, 2003a; Israetel, McBride, Nuzzo, Skinner, & Dayne, 2010). However, the understanding of the influence of RBR training on the muscular qualities of athletes and the transference to athletic performance is far from complete. The available research is fraught with methodological inconsistencies making valid comparisons between results problematic. The recommendations for the use of RBR training as a technique to maximise mechanical power outputs seem to be based on misguided interpretations and anecdotal rather than valid and reliable empirical evidence. Consequently, ambiguity affects the accurate prescription of RBR loading parameters including intensity (% 1RM), volume, repetition tempo, frequency, rest periods, the inclusion or exclusion of stretch-shortening cycle (SSC) and the relative contribution of isoinertial and RBR towards the total resistance. The uncertainty surrounding the application of RBR application compromises the monitoring and subsequent progression of athlete training loads. A more comprehensive understanding of RBR as a modality to manipulate the kinematic and kinetic profiles of resistance training exercises is imperative before accurate and meaningful recommendations can be made.

There is currently no research investigating the effects of RBR application over multiple sets or on any upper body exercises. It is thought that by determining and reporting the T-D relationship of commercially available RBR products, strength and conditioning practitioners will be able to identify the magnitude of tensile force acting upon an athlete throughout the range of motion for a given exercise, reducing the ambiguity surrounding the prescription of RBR training. Moreover, investigating the influence of RBR application on repetition kinematic and kinetic profiles over multiple sets will provide insight as to the mechanical stimuli afforded during RBR training.

***PURPOSE STATEMENT***

The purpose of this thesis was to provide an overview of knowledge regarding the effects RBR on traditional isoinertial resistance training exercises, to quantify the T-D relationship and to investigate the acute kinematic and kinetic effects of the application of RBR during the traditional isoinertial bench press exercise. Firstly, the literature surrounding RBR was critically reviewed and discussed (Chapter Two). Next, the T-D relationships and fatigue characteristics of RBR were quantified and discussed (Chapter Three). Subsequently, the acute effects of RBR application on the traditional isoinertial bench press exercise were investigated with respect to repetition, set and total session kinematic and kinetic profiles (Chapter Four). Chapter Five summarised the findings of Chapters Two, Three and Four, and provided recommendations for future research designs and practical applications for the use of RBR by strength and conditioning practitioners.

***AIMS***

The primary aim of this thesis was to determine whether repetition, set or total session kinematic or kinetic differences exist between traditional isoinertial and RBR bench press exercises. The secondary aim of this thesis was to quantify the T-D relationship before and after repetitive loading in order to determine the fatigue characteristics of RBR. The final aim of this thesis was to critically review and discuss the literature concerning RBR and its application to traditional resistance training exercises.

### *SIGNIFICANCE OF THE THESIS*

Traditional isoinertial resistance training exercises are widely accepted as a method of enhancing muscular strength qualities. Recently, several techniques have been implemented in an effort to manipulate the kinematics and kinetics of isoinertial exercises. One such technique, the application of RBR, has been increasingly utilised by strength and conditioning practitioners. However, the forces provided by RBR have not been thoroughly quantified, thus practitioners are unable to prescribe RBR loading parameters with absolute certainty. Little empirical evidence concerning the influence of RBR on the kinematics and kinetics of resistance training is available. Furthermore, of the few peer-reviewed research studies that are available, it is evident that methodological discrepancies make it difficult to compare research and construct concise conclusions about the efficacy of RBR. It seems that those strength and conditioning professionals who advocate the use of RBR, do so on the basis of anecdotal evidence.

It is the intent of this thesis to determine the T-D relationships for several sizes of RBR bands commonly used in the field of strength and conditioning. In doing so, practitioners will be provided with formulas to quantify the forces provided by RBR, allowing the accurate prescription of RBR loading parameters. Moreover, this research will investigate the effects RBR has on the kinematic and kinetics of a traditional isoinertial bench press exercise, and may potentially provide insight as to the most effective manner of applying RBR in order to enhance the desired muscular qualities of athletes. Conclusions and recommendations will be made regarding future research and the practical application of RBR on resistance training exercises.

### *LIMITATIONS AND DELIMITATIONS*

The reader should be cognizant of the following limitations when interpreting the results of this thesis.

1. The inclusion criteria (well trained, semi professional rugby players with a minimum 12 months resistance training experience, including previous experience with RBR training) dictates that the results of this research may only be applicable to this population.
2. In an effort to minimise any potential burden to player's and any disruption to player's training programmes, all data acquisition sessions were conducted in conjunction with regularly scheduled squad training session. This combined with the time constraints associated with testing athletes approaching the start of an in-season campaign, resulted in a relatively small sample size, and thus relatively low statistical power.
3. This research investigated the effect of RBR during an explosive rebound free weight bench press. Therefore the results may be limited to this exercise and training modality.
4. The T-D data were determined statically, whereas the kinematic and kinetic analysis utilised dynamic movements. It may be postulated that tension provided statically may not replicate that of dynamic movements.
5. Calculating the appropriate load to be used throughout the duration of the research involved the athletes statically holding a barbell at the apex of the bench press movement. A dynamic bench press movement may potentially involve greater protraction of the scapula, and thus increased

barbell displacement, resulting in greater than anticipated tension during the RBR conditions.

6. Although much effort was made to ensure kinematic and kinetic data acquisition was performed as close as possible to regularly scheduled strength testing sessions, the fact that the athletes continued to train, it may be speculated that the athletes increased in strength throughout the duration of the research.

***AUTHORSHIP CONTRIBUTION***

The contribution of authorship for the literature review and two experimental studies are as follows:

1. Literature review: The characteristics of rubber based resistance and its application to traditional isoinertial resistance training exercises.

   Godfrey, A. E. (90%), Harris, N. K. and Cronin, J. B. (10%)

2. Experimental paper one: The quantification of the tension-deformation characteristics of rubber based resistance.

   Godfrey, A. E. (90%), Harris, N. K. and Cronin, J. B. (10%)

3. Experimental paper two: the kinematic and kinetic analysis of rubber based resistance: Application to the bench press exercise.

   Godfrey, A. E. (90%), Harris, N. K. and Cronin, J. B. (10%)

***NOTE TO READER***

Chapter two of this thesis is a review of the literature concerning the biomechanical principles of RBR and its application to traditional resistance training. The chapter also serves as a general introduction for the two ensuing experimental chapters (three and four). Chapters three and four are presented in the format appropriate for the journals they have been submitted to, except that brief explanatory preludes replace the introductions to link the thesis as a cohesive whole. Finally, chapter five summarises with conclusions and recommendations for strength and conditioning practitioners. References and appendices have been assembled at the end of the final chapter. For consistency, all referencing is in APA format.

# CHAPTER TWO: THE CHARACTERISTICS OF RUBBER BASED RESISTANCE AND ITS APPLICATION TO TRADITIONAL ISOINERTIAL RESISTANCE TRAINING EXERCISES.

## *INTRODUCTION*

The ability to produce high power outputs is generally recognised as being an important determinant of many successful athletic movements. As such, strength and conditioning practitioners have manipulated traditional resistance training exercises in an attempt to maximise power outputs (Baker & Newton, 2009). The influence of various resistance types (isoinertial, accommodating, variable resistance) and techniques (SSC, ballistics, complex/contrast training, inter-repetition rest periods) on exercise kinematic and kinetic profiles have been well-documented (Baker & Newton, 2009; Frost et al., 2010). The use of RBR has gained popularity within the strength and conditioning fraternity because of its low cost, portability, versatility and non-reliance on gravity for resistance (Hughes & Page, 2003). It has also been theorised that the application of RBR to traditional isoinertial resistance training exercises alters the kinematic and kinetic profiles of the lift to augment power production. As a consequence, there has been an increase in the incidence of research concerning the efficacy of RBR training as a method of maximising strength and power in athletes (Ebben & Jensen, 2002; Wallace, Winchester, & McGuigan, 2006) and enhancing sport-specific movements of athletes (Jakubiak & Saunders, 2008; Page et al., 1993; Treiber, Lott, Duncan, Slavens, & Davis, 1998). However, the understanding of the influence of RBR training on the muscular qualities of athletes and the transference to athletic performance is far from complete. The available research is fraught with methodological inconsistencies making comparisons between results problematic. As a consequence recommendations for the use of RBR as a training technique seem to be based on misguided interpretations and anecdotal rather than a sufficient body of empirical evidence. It is the intent of this review to: a) introduce the concept of RBR training along with the biomechanical rationale for its use; b) critically review the literature concerning RBR including research pertaining to the tensile properties of RBR, the acute effect of RBR application to exercise kinematics and kinetics and the training effect of RBR on the performance of sport-specific movements; and c) to identify the methodological limitations affecting the interpretation of research in attempt to provide a framework from which future RBR research can be based. It is thought that standardising certain aspects of research methodologies will promote a greater understanding of RBR and its influence on athletic training and performance.

In order to comprehend the influence of RBR on athletic performance, an understanding of biomechanical principles is imperative. Newton's second law of motion states that the acceleration (a) of an object is directly proportional to the magnitude and in the same direction as the net force ($F_{net}$) applied and inversely proportional the mass (m) of the object:

$$F_{net} = m \times a \qquad \text{(Equation 1)}$$

In training terms, the ability to accelerate oneself or equipment such as a barbell is determined by the strength of an athlete and the mass of the athlete or barbell.

Acceleration, measured in metres per second squared ($m.s^{-1}$) can also be described as a derivative of velocity (v):

$$a = (v_f - v_i) / (t_f - t_i) \quad \text{(Equation 2)}$$

where $v_f$ is final velocity, $v_i$ is initial velocity, $t_f$ is final time and $t_i$ is initial time. Velocity, measured in metres per second ($m.s^{-1}$), can be described as a derivative of displacement (s) data:

$$v = (s_f - s_i) / (t_f - t_i) \quad \text{(Equation 3)}$$

where $s_f$ is final displacement and $s_i$ is initial displacement. Displacement, measured in metres can be defined as a change in position over time. The interaction between an external load and subsequent F and v profiles has been termed the force-velocity or load-velocity relationship. Cronin, McNair and Marshall (2003b) demonstrated that as the load increases, the maximal velocity that load can achieve decreases. Power (P) is defined as the product of an applied force on an object and the subsequent velocity attained by that object, and is measured in Watts (W):

$$P = F \times v \quad \text{(Equation 4)}$$

Considering that the mass (load) impacts the F-v relationship, the mass of an object must impact on the power producing capabilities of the system. In a training context, the power of an athlete - the ability to impart high forces on an object which results in high velocities – is dictated by the mass of that object.

Newton's first law of motion states that an object at rest will remain at rest or an object in motion will remain in motion in the same direction and with the same velocity until acted upon by an unbalanced force. This resistance to a change in motion is referred to as objects inertia and is proportional to the mass of that object. If a force great enough to overcome inertia is applied to an object, the object will acquire velocity. This object can now be described as having momentum (p), which is the product of the mass and the velocity of that object ($kg \cdot m.s^{-1}$):

$$p = m \times v \qquad \text{(Equation 5)}$$

Impulse (*I*) is defined as the magnitude and duration of the $F_{net}$ on an object and is proportional to the change in momentum of an object. This is referred to as the impulse-momentum relationship:

$$F_{net} \times t = m \times v \qquad \text{(Equation 6)}$$

The subsequent review of the influence of RBR training will be discussed with reference to the kinematic and kinetic variables mentioned above.

### *Types of resistance*

In an attempt to maximise the musculoskeletal adaptation of resistance training, various forms of resistance have become common place within the strength and conditioning fraternity. These can be categorised into isoinertial resistance, accommodating resistance or variable resistance. Each category provides distinct mechanical stimuli and therefore presents distinct hormonal and metabolic responses of the musculoskeletal system. Isoinertial resistance also referred to as isotonic or constant external resistance training involves movement of a constant load, and most free weight exercises are considered isoinertial resistance. Accommodating resistance also known as isokinetic resistance refers to movements in which velocity remains constant throughout the entire range of motion. This requires the use of an isokinetic dynamometer to ensure segment motion occurs at a preset and controlled velocity. The use of RBR does not display the characteristics of the above mentioned categories. Commonly referred to as variable resistance training, the change in tension which is evident as the RBR is elongated contradicts the definition provided for isoinertial exercise. Additionally, the change in velocity which accompanies the change in tension contradicts the definition of isokinetic exercise (Page & Ellenbecker, 2003). Other forms of variable resistance include the use of chains, cams and lever systems (McMaster, Cronin, & McGuigan, 2009). RBR is sometimes referred to as elastic resistance, the term RBR will be used throughout this thesis because elastic resistance does not accurately describe the application of tension provided by these products.

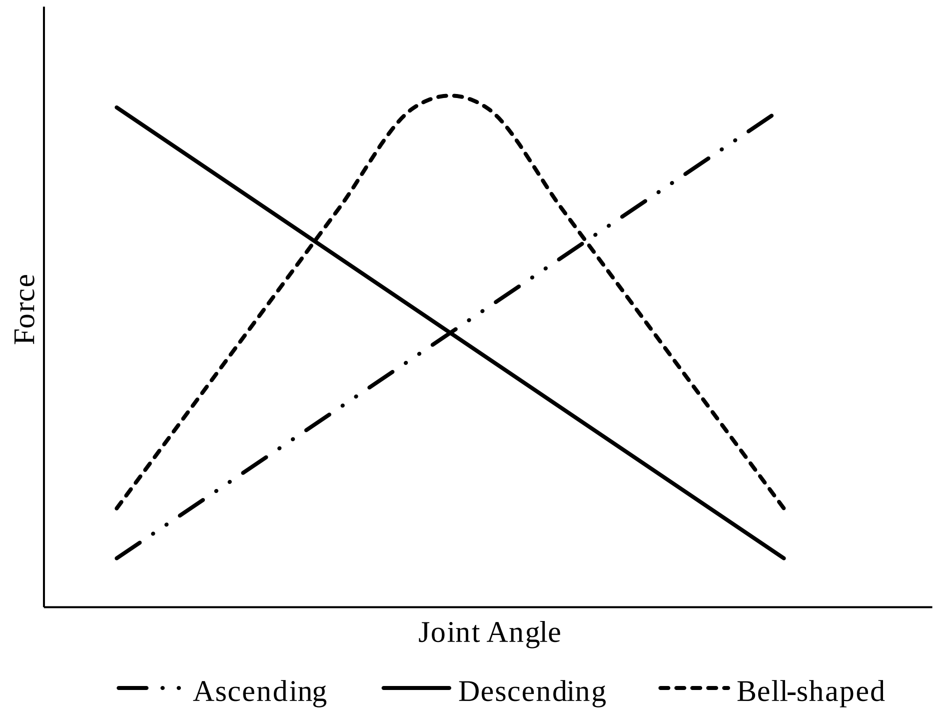
### *Biomechanical rationale for RBR training*

Muscular strength can be defined as the ability to generate maximum external force (Zatsiorsky & Kraemer, 2006). Biomechanically, maximum force is muscular tension that experiences two transformations; muscle forces transform into joint moments and joint moments transform into external force (Zatsiorsky, 2003). Certain features determine the force, velocity and power capabilities of muscles, including the cross-sectional area of muscle, pennation angle, fibre length (number of sarcomeres in series), the number and type of motor units recruited, the discharge rate of motor neurons, contraction type as well as the anatomical joint configuration (Enoka & Fuglevand, 2001; MacIntosh & Holash, 2000). The influence of joint configuration on muscular strength is pertinent to the rationale for RBR training. For a given exercise, the maximal force capabilities of the contractile entity or the maximal strength of a muscle or muscle group may vary as a function of joint configuration. Muscular forces that do not intersect the line of force create a rotational effect (torque) about an axis (joint). The magnitude of the torque (T) is a product of contraction force (F) and the perpendicular distance from the line of action of the force to the joint centre, known as the moment arm (r) (MacIntosh & Holash, 2000):

$$T = F \times r \qquad \text{(Equation 7)}$$

When a joint angle varies, the external force changes due to two reasons; 1) the muscles produce different tensions, 2) the muscle forces act through different moment arms (Zatsiorsky, 2003). A plot which describes the maximal muscular capabilities at a joint as a function of joint angle is referred to as a strength curve (Kulig, Andrews, & Hay, 1984). Human strength curves generally fall into one of three categories; a) ascending, b) descending, or c) ascending-descending (Fleck & Kraemer, 1997; Kulig et al., 1984; Zatsiorsky & Kraemer, 2006). An ascending strength curve is one in which the strength measure increases as the joint angle increases. Exercises with ascending strength curves include bench press, squat, deadlift and shoulder press. The greatest forces during arm or leg extension are exerted when the extremity is almost completely extended (Zatsiorsky, 2003). Conversely, a descending strength curve is one in which the strength measure decreases as the joint angle increases. Exercises with descending strength curves generally include pull type exercises such as pull-ups, chin-ups, bent over row and lat pull-downs. Single joint exercises commonly have ascending-descending strength curves. During these exercises the maximum force production occurs during the midpoint of the lift and includes exercises such as biceps curls, triceps extension, leg curls and leg extensions (Kulig et al., 1984).

**Figure 3.1. Three major strength curves: force production versus joint angle**




Due to the nature of the human body's lever systems, the maximal load that can be lifted during free weight resistance exercises is limited to the point at which mechanical advantage is the lowest, known as the sticking point (Elliott, Wilson, & Kerr, 1989). The regions each side of the sticking point are not allowing maximum muscular tension to be generated (Behm, 1988), which adversely affects the kinetics and kinematics of the movement. For instance, the closer the legs to full extension during a squat movement, the smaller the knee joint moment and the greater the amount of resistance that can be tolerated (Zatsiorsky, 2003). With the addition of RBR bands, the amount of tension (or force) acting on the body increases as the legs approach full extension providing increased muscle stimulation, motor unit recruitment and firing rates (McMaster, Cronin, & McGuigan, 2010). It has been theorised that the benefits of RBR training are most obvious when combined with free weight resistance (Behm, 1988). Free weights provide the greatest amount of mechanical overload at the beginning of the concentric phase, whereas RBR provides the greatest amount of overload at the end range of motion.

### *Physical and mechanical properties of RBR*

RBR products are made of polymers (thermoplastics and elastomers) which have varying physical and mechanical properties. The composition of these properties during manufacturing affects the modulus of elasticity, density, yield and tensile strengths of the product (Askeland, 1990). Viscoelastic materials exhibit time-dependent behaviour (Ozkaya & Nordin, 1991). The response of the viscoelastic material to an applied stress depends on the magnitude of the stress and the rate at which the stress is applied. Greater total deformation or an increased rate of deformation requires an increased applied stress (Askeland, 1990). Elastic material has a T-D relationship which is independent of time or strain rate. Therefore, the amount of tensile force produced by RBR is dependent on the physical and mechanical makeup, the cross-sectional area and the magnitude and rate of deformation (Askeland, 1990; Mott, 2008; Ozkaya & Nordin, 1991). The equation to determine the amount of force provided by RBR is:

$$F_{band} = -k \times l \qquad \text{(Equation 8)}$$

where k = the stretch coefficient of the band and l = the amount of deformation applied to the band (Frost et al., 2010). When used in conjunction with free weight resistance, the equation to determine the amount of force provided by the load ($F_{load}$) becomes:

$$F_{load} = F_{band} + F_{mass} \qquad \text{(Equation 9)}$$

where $F_{mass}$ is the gravitational force of the load (N) and $F_{band}$ is the tensile force produced by the RBR (N).

***TENSION-DEFORMATION RESEARCH***

There is a paucity of empirical evidence available to shape our understanding of the tensile properties and behaviour of RBR materials under different conditions. Research investigating the quantification of RBR tension has yielded equivocal results (McMaster et al., 2009; Page, Labbe, & Topp, 2000; Patterson, Stegink Jansen, Hogan, & Nassif, 2001). McMaster et al. (2009) reported that RBR bands displayed curvilinear properties which were best fitted by second order polynomial functions ($R^2 \geq 0.99$). Conversely, Page et al. (2000) reported RBR bands which displayed consistent and linear tensile properties across all colours tested which were best fitted by linear function equations ($R^2 \geq 0.95$). Various other scientific studies have reported viscoelastic tensile properties of RBR products, specifically a curvilinear region followed by a linear, elastic region (Patterson et al., 2001; Simoneau, Bereda, Sobush, & Starsky, 2001; Thomas, Müller, & Busse, 2005). Thomas et al. (2005) suggested that deformations greater than 25% of the resting length are characterised by linear tensile properties ($R^2 = 0.99$). Patterson et al. (2001) stated the transition from curvilinear to linear behaviour appears after a deformation of 50% above that of the products resting length, however the goodness of fit ($R^2$) was not presented.

The integrity of RBR over time will affect its tensile properties. Simoneau et al. (2001) reported a decrease in tension provided by Thera-band bands and tubing of 9-12% after 501 deformation cycles of 100% of the resting length. The decrease in tension (10-15%) was greater after 501 deformation cycles of 200%. Conversely, Patterson et al. (2001) concluded that no significant difference was observed after over 5000 cycles at 100% and 200% deformations when using Thera-band tubing.

Researchers have suggested that viscoelastic materials exhibit time-dependent behaviour (Ozkaya & Nordin, 1991). However, Patterson et al. (2001) investigated the effects of loading rate on RBR T-D characteristics and observed no statistically significant differences in tensile behaviour when deformed at rates of 5.1cm/min and 50.8cm/min. In the same study, the authors reported a significant difference in tensile behaviour between the directions of deformation (loading versus unloading). At the same deformation length, the tension produced during loading was greater than that during unloading.

***Methodological concerns***

Comparison between research outputs and the development of valid conclusions as to the tensile properties of RBR used during resistance training is difficult considering the methodological inconsistencies presented in the fore mentioned studies. It is apparent that each study examined different RBR products from varying manufacturers. Each variation (bungy’s, tubing and bands) has distinct physical and mechanical characteristics which influence its tensile properties. Patterson et al. (2001) used tubing and Simoneau et al. (2001) bands and tubing from different manufacturers which are commonly associated with rehabilitative exercises. McMaster et al. (2009) used large RBR bands of approximately 1 metre in length, which are more commonly used to augment isoinertial exercises.

Inconsistencies also appear in terms of magnitude of deformation, the rate of deformation and the inclusion or exclusion of pre-stretching. Patterson et al. (2001) loaded the RBR sinusoidally from 100%-200% at rates of 5.1- and 50.8cm per minute, Simoneau et al. (2001) loaded the RBR from 0%-100% and 0%-200% at a rate of 0.018m per second and McMaster et al. (2009) measured T-D statically.

Although definitive's regarding the tensile properties of RBR products under different conditions may not be available, it is evident that each type and brand of RBR will possess unique tensile properties, even different batches of the same brand will be unique. Therefore, it is recommended that all research pertaining to RBR training and its influence on athletic performance should calculate and report the T-D relationship independent of manufacturer's claims or previous research. The magnitude of deformation should reflect the intended use of the product and the rate of deformation should replicate the rate of deformation expected during resistance training exercises. Although, Patterson et al. (2001) reported no significant difference between the tensile properties at different deformation rates, the authors did report significantly greater forces during loading compared to that seen during unloading at the same deformation lengths. The loss of energy during unloading is known as hysteresis and is typical of viscoelastic material (Hamill & Knutzen, 2003). This result may provide some insight as to whether static loading accurately represents the T-D characteristics of RBR products when used in conjunction with traditional resistance training exercises. If there are discrepancies in the magnitude of tension provided during the concentric and eccentric phases of an exercise, surely static loading does not accurately replicate the tensions seen during one cycle, if not both of these phases. If this is in fact the case, then one could speculate that research investigating the acute (Cronin et al., 2003a; Newton et al., 2002; Wallace et al., 2006) and training (Cronin et al., 2003a) effects of RBR are methodologically flawed, because static loading was used to determine the T-D relationship. It seems most appropriate to measure the tensile properties in a manner that replicates the use of RBR during training.

### *KINEMATIC AND KINETIC RESEARCH*

In the following section, the application of RBR will be investigated with respect to the acute influence on repetition kinematic and kinetic. The short-term training effect of RBR will be investigated with respect to repetition kinematic and kinetic profiles and the execution of sport-specific movements.

#### *Acute research*

*Within repetition*

Cronin, McNair and Marshall (2003a) studied the effect of RBR on kinematic variables and EMG activity during an isoinertial supine squat. EMG activity, duration of contraction, mean and peak velocities and time to peak velocity were measured during traditional squats, non-RBR jump squats and RBR jump squats of ten trained males. The kinematic variables were calculated using a linear position transducer and averaged over 10% intervals for the eccentric and concentric movements. It was reported that vastus lateralis EMG activity was significantly greater for the RBR and non-RBR jump squats compared to the traditional squat throughout the entire concentric phase. Greater EMG activity was observed for both RBR and non-RBR jump squats during the first 60% of the eccentric phase compared to the traditional squat. The final 30% of the eccentric phase, EMG activity was significantly greater for the RBR condition compared to the non-RBR conditions. The greater EMG activity recorded during the final stages of the eccentric phase for the RBR jump squat indicated that a greater braking force was required with the addition of RBR.

The ballistic techniques were significantly different from the traditional squat for all of the variables measured. The only significant difference between the two ballistic conditions was that the time to peak velocity occurred much earlier in the RBR condition (83%) compared to the non-RBR condition (91.3%) during the concentric phase. The authors suggested the application of RBR offered a similar training stimulus to that of ballistic training. Unfortunately, Cronin et al. (2003a) did not directly assess the influence of RBR on a traditional squat, and the notion that the two techniques offer a similar training stimulus is speculative. There were no significant differences observed between RBR and non-RBR conditions for the majority of variables tested. It may be the act of projecting the load has created the difference between the RBR jump squat and the traditional squat conditions, not the application of RBR. Furthermore, the variables which did incur a difference between RBR and non-RBR jump squats (vastus lateralis EMG activity during the final phase of the eccentric contraction and time to peak concentric velocity) may have done so because of a combination of jumping and application of RBR. There is nothing to suggest that a traditional squat with additional RBR would induce the same changes.

Israetel, McBride, Nuzzo, Skinner and Dayne (2010) investigated the effects of RBR on free weight squat kinematics and kinetics with the load equated by work done. Ten recreationally trained men completed one set of five squat repetitions with a load of ~100kg. The contribution of resistance at the apex of the lift comprised of ~20% from FW and the remaining ~80% from RBR. The participants then performed five repetitions with a free weight load equivalent to the average force exerted during the RBR condition. Averaged force, velocity and power outputs were compared based on relative time to complete the lift. The authors reported significantly greater FW force values for the final 5% of the eccentric phase and the first 5% of the concentric phase. FW F values were also significantly higher from 68% to 72% of the movement compared to RBR. Higher RBR velocity values were recorded during the first ~30% of the eccentric phase and the last 10% of the concentric phase. FW velocity values were greater from 75% to 80% of the movement. Power-time curves revealed greater RBR values during the first 20% of the eccentric phase and from 85% to 95% of the movement. FW power outputs were greater during 50% to 60% and 75% to 80% of the movement. Vastus lateralis IEMG analysis showed greater activation for the first 20% of the eccentric phase, the last 5% of the concentric phase and from 85% to 95% relative time of the entire movement.

Newton, Robertson, Dugan et al., (2002) reported the effects of RBR on the force, velocity and power output produced during the back squat exercise using ten collegiate powerlifters. Three experimental conditions were assessed; no bands (NB), bands top (BT) and bands bottom (BB). The 6RM squat load was determined for each lifter. During the NB condition the load was provided by the barbell alone. For the BT condition, the bands were attached to each end of the barbell. Using a force platform beneath the lifter, the weight on the barbell was decreased until the total load on the subject was equal to that of the 6RM load as the lifter stood erect. For the BB condition, the total load was equal to that of the 6RM load when the subject was in a parallel squat position. Force, velocity and power output were calculated and averaged every 10% of concentric bar movement. Force during the BT condition was significantly lower for the initial 80% of concentric bar movement compared to NB and BB conditions. The velocity of the barbell was greater for the BT condition during the first 50% of the concentric movement by 0.209 and $0.295 m.s^{-1}$ for the NB and BB conditions, respectively. Additionally, relative power outputs were greater for the first 50% of the lift for the BT condition compared to the BB condition by between 0.37 and 0.72W/kg. No significant differences were observed for force, velocity or power outputs between the NB and BB conditions.

*Whole repetitions*

Wallace, Winchester and McGuigan (2006) examined the effects of RBR on force and power characteristics during the back squat on a Smith machine. Ten trained subjects performed 2 sets of 3 repetitions at 85% 1RM and 60% 1RM with and without RBR. The RBR loading schemes were further divided into conditions (B1 and B2). No bands (NB) represented all of the resistance was accounted for by free weights. B1 equated to approximately 20% for the resistance being provided by bands and the remaining 80% provided by FW. B2 equated to approximately 35% of the resistance being provided by bands and the remaining 65% provided by FW. The contribution from RBR was calculated via the apex load method, in which the bands and NB loads are equal at the apex of the exercise. Peak force, peak power and rate of force development were recorded using a force platform.

It was reported that there were significant differences between the 85%1RM condition with respect to peak force and peak power. An increase of 11% was observed for peak force between the NB and B1 conditions. A further increase of 5% in peak force was observed between B1 and B2. The results suggest that the addition of bands to the barbell during a back squat increased the peak force at a relatively high percentage of 1RM. A significant increase of 24% was observed between NB and B1 for peak power. In contrast, a 13% decrease was observed between B1 and B2 for peak power. No significant difference was observed during the 60% 1RM condition for any variable assessed and no significant differences were apparent for the RFD variable across the conditions. The addition of RBR resulted in increased peak power however, there seems to be a ceiling effect for the relative contribution of resistance from bands before a decline in power output becomes evident.

Ebben and Jensen (2002) examined the EMG and kinetic variables associated with traditional, chain and RBR back squats in eleven collegiate athletes. Mean vertical ground reaction forces (MVGRF) and peak vertical ground reaction forces (PVGRF) were assessed using a force platform for the eccentric and concentric phases. Mean integrated electromyography (I-EMG) values for the quadriceps and hamstring muscle groups were measured with surface electrodes. The relative contribution of bands and chains equalled 10% of the total resistance. However, Ebben and Jensen (2002) failed to include the methodology used to determine the relative contribution of the bands and chains. Significantly greater mean PVGRF (~12%) coupled with significantly greater hamstring IEMG (~20%) activity were observed for the concentric phase compared to the eccentric phase. No significant difference was observed between the traditional, chain and band back squat for any variable assessed. It may be postulated that the relative contribution of chains or bands to free weights (10%) was not great enough to elicit significant changes in EMG activity or VGRF. It may be that there is a threshold which needs to be surpassed in order for a difference to become evident.

*Potentiation*

Surprisingly, there has been only one study examining the acute effects of combined RBR and FW resistance on an upper body exercise. Bellar, Ryan, Muller et al. (2008) compared the acute influence of training with RBR on power output during two 50% 1RM maximum effort bench presses. Four collegiate male shot putters performed two trials of 3 sets of 5 repetitions at 85% 1RM. The shot putters used either FW bench press or RBR bench press with 15% contribution from RBR. Immediately after each trial, two maximal effort 50% 1RM bench presses were performed and power measured using a potentiometer. Significantly greater power output (13%) was observed for the RBR condition (639 W) compared to the FW condition (556 W) for the first maximal effort.

When the first and second trials were averaged, there was no significant difference between testing conditions. The point of difference of this study was that power output was not measured with the use of RBR, rather it attempted to assess whether the use of RBR produced a greater potentiation effect than the traditional bench press. However, the reader should be cognizant of the small sample size (*n* =4) and low statistical power of the study.

### ***Training studies***

Recent research has attempted to determine the efficacy of RBR as a training technique to improve athletic performance. These studies can be broadly categorised into examining the influence of RBR training on either general muscular function such as lower body strength or the execution of sport-specific movements such as the tennis serve.

#### *Muscular function*

Anderson, Sforzo and Sigg (2008) examined the effects of RBR application on upper body strength and lower body strength and power. Thirty nine collegiate athletes performed a resistance training programme three times per week for seven weeks. The loading parameters included 3-6 sets of 2-10 repetitions at an intensity of 72-98% 1RM. The training programmes were matched except for the application RBR to the bench press and back squat exercises. The RBR contribution was 20% of the athletes 1RM and was normalised using the average force method. 1RM strength measures were extrapolated from observed 1-3RM values and mean power and peak power outputs were estimated using an unloaded countermovement vertical jump (CVJ). Both conditions (RBR and FW) significantly increased bench press 1RM values by 8% and 4%, and back squat 1RM values by 16% and 6% from baseline measurements, respectively. mean power improved by 4.5% for the RBR condition, and by 1.5% for the FW condition compared to baseline measurements. Between-condition analysis revealed the strength and mean power improvements as significantly different. Non-significant peak power outputs improvements were observed between conditions.

Cronin et al. (2003a) examined the effects of ten weeks of ballistic weight training on muscle function and functional performance. Forty athletes performed a periodised strength and power training programme two times per week for the duration of 10 weeks. The training programmes were differentiated between conditions by the application of RBR during supine jump squats. The effects on lower body unilateral performance were measured by a concentric-only 1RM supine squat, concentric-only supine jump squat with a 50% 1RM load, countermovement jump (CMJ), lunge ability and a modified agility test. mean velocity, peak velocity, mean force, peak force, time to peak force, mean power and peak power outputs were calculated from displacement-time data during the 50% 1RM supine jump squat via a linear position transducer. Analysis revealed that 10 weeks of RBR and non-RBR jump squat training were found to be equally effective in producing improvements in a variety of concentric strength and power measures. RBR jump squat training lead to a significant improvement in lunge performance (21.5%) compared to the non-RBR training group (12.7%).

The kinematic and kinetic findings suggest that RBR and non-RBR jump squat training offer a similar training stimulus and are equally effective in improving lower body maximal strength, relative strength, peak velocity, peak force, mean power and peak power. The functional performance findings illustrated that no significant changes occurred in single leg jump performance after training despite improvements in leg power and relative strength, qualities thought to be important predictors of jump performance. Cronin et al. (2003a) offer several suggestions as to why this may have occurred. Firstly, joint configuration associated with the supine squat machine (90º knee angle) differed to those angles associated with running and jumping movement (120-150º knee angle). The relatively deep squat used throughout the training involved greater eccentric and concentric loading compared to those experienced during running and jumping. This type of loading is more likely to enhance lunge performance because of the slow SSC compared to the running, jumping or agility which involves shorter duration SSC movements.

Cronin et al. (2003a) also proposed that the improvements seen from utilising the supine squat machine did not translate into single leg jump performance because of differences in posture. The two exercises differed in terms of the plane of movement (horizontal versus vertical) and trunk angle. The supine squat machine does not allow trunk flexion/extension. Finally, Cronin et al. (2003a) thought that the improvements in strength and power were not tuned to the jumping skill because of the absence of specific jump training. Bobbert and van Soest (1994) concluded that training exercises should be accompanied by specific exercises in which the athlete can practice with their changed muscle properties. The temporal, kinematic and EMG characteristics of RBR and non-RBR squat jumps revealed that the addition of bungy resulted in greater EMG activity during the final stages of the eccentric contraction (70-100%) compared to the non-bungy training group. The greater resistive force may have attributed to shorter eccentric loading and a quicker eccentric-concentric transition. This may have resulted in potentiation of the concentric phase (Bosco et al. 1981; Komi 1984) and thus quicker lunge performance.

Rhea, Kenn and Dermody (2009) investigated the effects of movement speed and variable resistance training on strength development and peak power outputs. Forty eight well-trained athletes were randomly assigned to one of three training groups: heavy resistance and slow movement (Slow), lighter resistance and fast movement (Fast), or fast movement with accommodating resistance (FACC). Accommodating resistance refers to movements in which velocity remains constant throughout the entire range of motion, whereas variable resistance indicates a change in resistance throughout the range of motion. Rhea, Kenn and Dermody (2009) use the terms variable resistance and accommodated resistance interchangeably when referring to RBR. It should be noted that the Fast and Slow groups accommodated the resistance by controlling the velocity, whereas the FACC group used a combination of accommodating and variable resistance. The intervention consisted of compound lower body resistance training with a load of ~75-85% 1RM as well as sprint and plyometric training. Conditions were differentiated by back squat repetition velocity and the application of RBR. Squat repetitions were performed with a maximum load that allowed for velocities to remain between 0.2m/s and 0.4 m/s for the Slow group and 0.6m/s and 0.8 m/s for the Fast group. The FACC group trained within the same velocity range as the Fast group but with 50% 1RM FW load plus the addition of RBR bands. Percent increases and effect sizes (ES) were calculated for back squat strength values and CVJ peak power outputs pre- and post-intervention.

Peak power improvements of 17.8% for the FACC group, 11% for the Fast group and 4.8% for the slow group were reported. The magnitude of the effects were considered to be large for the FACC group (ES = 1.06), moderate for the Fast group (ES = 0.80) and small for the Slow group (ES = 0.28). 1RM squat improvements were similar between the FACC (9.44%, ES = 1.10) and Slow groups (9.59%, ES = 1.08). 1RM squat values for the Fast group improved by 3.2% (ES = 0.38). However, the only significantly different between-group improvement was observed between FACC and Slow groups for peak power ($p$ = 0.02).

Although Rhea et al. (2009) have equated the training programmes with regard to the loading parameters of the secondary exercises, the independent variable which differentiated the experimental conditions did not have the volume of work equated. The force-velocity relationship described at the beginning of this review dictates that the maximum load a participant can move at speeds of 0.2 to 0.4 $m.s^{-1}$ (Slow group) is greater than the maximum load a participant can move at speeds of 0.6 to 0.8 $m.s^{-1}$ (Fast group). Moreover, Rhea et al. (2009) did not report the T-D relationship of the RBR bands added for the FACC group. Without first determining the amount of force the RBR bands provide throughout the repetition, it is impossible to determine the loading parameters of the participants in the FACC group. Furthermore, it should be asked whether the anthropometric variables of participants such as height and limb length were accounted for. Rhea et al. (2009) have not reported adjusting the amount of tension provided by RBR bands to accommodate for any discrepancy in athlete body size. It could then be speculated that not only do the three conditions not equate in training volume but the loading parameters of the experimental group FACC are not even equated. These omissions confound the results of the present study and make replication or generalisation problematic.

Ghigiarelli, Nagle, Gross, Robertson, Irrgang and Myslinski (2009) investigated the effects of a 7 week rubber and chain based resistance training programme on upper body strength and power of 36 division 1-AA football players. Experimental groups were differentiated by the application of rubber- (RBR) or chain based resistance (WC) to a traditional (FW) speed bench press exercise. Upper body strength was determined from 5-7 RM bench press. mean velocity, peak velocity, mean power and peak power values were recorded during a speed bench press with a load of 50% 1RM using a Fitrodyne device. Two sets of five repetitions were performed, the mean values from both sets used for analysis. Results revealed significantly greater (5% - 8%) post-intervention 1RM strength test scores for all conditions with no significant difference between groups compared to pre-intervention scores. No significant differences for between- or within-group effects were observed from the 50% 1RM speed bench press tests.

To date only one study has investigated the influence of RBR training on skeletal muscle adaptation. Holster, Schwirian, Campos, Toma, Crill, Hagerman, Hagerman and Staron (2001) assessed the fibre-type composition, cross-sectional area, myosin heavy chain content and capillarity along with 1RM and maximum repetitions at 60% 1RM for squat and leg extension exercises. It was reported that performing two sets of single leg squats and leg extensions until failure at a rate of 50 repetitions per minute for 8 weeks lead to an increase in type IIAB fibres for both men and women with a concomitant decrease in type IIB fibres for men. Women showed a similar but non-significant trend decrease in type IIB fibres. These data suggest that RBR training induced minor changes in fibre-type composition however, Holster et al. (2001) note that the magnitude of the changes observed during this study are less than those observed during short-term FW training studies from the same laboratory.

To summarise, the training effect of RBR may have the potential to alter muscle function leading to improvements in the power producing capabilities of muscle which may transfer into improved functional performance. Holster et al. (2001) reported changes in fibre-type composition after RBR training, Anderson et al. (2008) reported improved mean power outputs and Cronin et al. (2003a) reported improved lunge performance after RBR training. However, methodological discrepancies still confound our ability to draw definitive conclusions.

*Sport-specific performance*

Strength and conditioning practitioners typically use RBR in isolation rather than in combination with FW resistance when attempting to enhance sport-specific movements. Execution of multi-planar movements at velocities more representative of those experienced during performance and RBR's non-reliance on gravity to provide resistance allows a greater ability to manipulate the direction of resistance. The focus of this section is the application of RBR to isoinertial resistance nevertheless, research concerning the use of RBR in isolation will be examined.

Jakubiak and Saunders (2008) examined the efficacy of RBR training on the velocity of an Olympic Taekwondo (TKD) turning kick. Twelve elite TKD athletes were assigned to either a control group, which performed four weeks of regular kick training, or an experimental group which performed a progressive, TKD-specific, RBR training protocol in addition to regular kick training. Mean kick velocity was assessed using a digital timer, a floor-mounted pressure sensor and a second pressure sensor housed within a TKD kick-training target. The intervention comprised of six turning kicks, resisted by RBR attached to the kicking foot and anchored to the ground directly behind the athlete. The starting protocol used three sets of six repetitions and deformation of the RBR was 100% of the resting length. Each week the protocol increased by one set and the RBR band was stretched by a further 30cm. The RBR kick-training protocol resulted in greater mean kick velocities of 7% for the experimental group, which was significantly greater than the 0.1% improvement observed in the control group.

Treiber, Lott, Duncan, Slavens and Davis (1998) examined the effects of a resistance training programme on concentric shoulder rotator strength and service velocity in elite tennis players. The experimental group performed formal practice sessions in addition to shoulder internal and external rotation exercises with RBR tubing followed by the 'empty can' exercise using a lightweight dumbbell. The control group continued with only formal practice sessions. Exercises were performed for two sets of 20 repetitions, three times per week for four weeks. Analysis revealed the experimental group increased service mean velocity by 7.9% and peak velocity 6%, whereas the control condition experienced a decline in service mean velocity by 2.3% and peak velocity by 1.0%. The experimental group displayed greater post-intervention peak internal rotation torque at 300º/s by 23.8% and peak external rotation torque at 300º/s by

17%. The control also improved but to a lesser degree, 1.0% and 1.2% respectively.

Page, Lambert, Abadie, Boling, Collins and Linton (1993) assessed the effects of a six week posterior rotator cuff strengthening programme on collegiate baseball pitchers. Participants performed a series of isoinertial dumbbell exercises either with or without a functional diagonal pattern exercise using RBR. Isokinetic dynamometry measured eccentric mean force at 60º/s and 180º/s while performing the functional diagonal movement. Eccentric mean force at 60º/s improved by 19.8% for the experimental group and 1.6% decrement for the control group. At 180º/s, eccentric mean force declined by 14.8% for the experimental group and by 8.1% for the control group. The authors proposed that the testing order (60º/s followed by 180º/s) and greater time under tension associated with the slower 60º/s condition may have induced muscular fatigue negatively impacting the results of the 180º/s condition.

Consensus as to the training effect of RBR on the execution of sport-specific movements may not be possible because of the unique characteristics of each movement. However, from the above mentioned research, a theme of improved sport-specific performance is apparent when regular skills training is supplemented by some form of RBR training.

### ***Methodological concerns***

*Subjects*

Research regarding the acute effects of combined RBR and FW resistance on kinematic and kinetic variables is limited to six studies with a total sample size of 55 subjects. No one study has had any more than 11 participants, therefore one must be cognizant of the low statistical power afforded by each of the studies. Moreover, the training status of these subjects' ranges from recreationally trained to well-trained athletes. It has been suggested that generalising findings from participants with different level of resistance training experience is problematic (Harris, Cronin, & Hopkins, 2007).

*Exercise selection*

The research studies investigating the effects of RBR application on exercise kinematic and kinetics have employed a variety of different squats and a bench press exercise. Of the studies utilising the squat, three have used FW back squats, one has used a Smith machine squat and the other used a supine squat machine. The Smith machine and supine squat machine eliminate any horizontal barbell displacement. It might also be argued that the use of the supine squat changes the way a participant activates the musculature considered important for balance and stability. The differences associated with each piece of equipment alone may affect kinematics and kinetics. Hence, the results found using the supine squat or the Smith machine may not replicate those observed during FW squats.

*Loading parameters*

An array of different loading parameters have been used in an attempt to determine the influence of RBR on exercise kinematics and kinetics. The intensities have ranged from bodyweight (Cronin et al., 2003a), 50% 1RM (Bellar et al. 2008), 60% 1RM (Wallace et al., 2006) to 85% 1RM (Wallace et al., 2006; Ebben & Jensen, 2002; Newton et al. 2002). In the case of Israetel et al. (2010) an absolute load of ~100kg was used for all participants. Assuming that every participant had different 1RM squat values, the load used throughout this study was not equated between subjects. If we consider the biomechanical principles stated in the introduction of this review (equations 1-5), it is evident that the magnitude of the load (mass) effects the resultant kinematic and kinetic outputs. The resistive force or inertia of an object is directly proportional to the mass of that object. That is, for a given participant, the forces required to accelerate a load of 85% 1RM (Wallace et al., 2006; Ebben & Jensen, 2002; Newton et al. 2002) are substantially greater than the forces required to accelerate a 50% 1RM load (Bellar et al. 2008). The force-velocity relationship dictates that for a given force, the velocity achieved by an object is inversely proportional to the mass of the object. A participant is able to achieve greater velocity values with a 50% 1RM load compared to that of an 85% 1RM load because the magnitude of force required to overcome inertia is reduced.

Considering that both force and velocity outputs are dependent on the mass of an object, power, the product of force and velocity is also dependent of the mass of the object. There is a great deal of literature that has investigated the load which optimised the contribution of force and velocity to produce maximum mean and peak power (Pmax). The power-load curve is considered relatively flat for a range of upper (Pearson, Cronin, Hume, & Slyfield, 2009) and lower body exercises (Harris, Cronin, & Hopkins, 2008). Harris et al. (2008) concluded that a change in load of up to 20% either side of the Pmax load resulted in a 9.9% (90% confidence limits ± 2.4%) decrement in Pmax. Although the authors considered the decrease in power output either side of Pmax as unsubstantial, a 20% difference in load, similar to the difference in loads of 60% 1RM (Wallace et al., 2006) and 85% 1RM (Ebben & Jensen, 2002; Newton et al., 2002) may be enough of a difference to confound the interpretations of RBR research outputs. In fact, Wallace et al. (2006) found significant differences in peak force and peak power values between RBR and FW Smith machine squats, while concurrently concluding that no significant differences were observed for any variable measured when the load was decreased by 15%. The discrepancies in the magnitude of the load make comparisons between RBR research outputs problematic. With RBR research still in its infancy, perhaps it may be appropriate to suggest a framework from which future research might be based, allowing for valid comparisons. If the concept of RBR has been theorised to promote an increase in power outputs, then one could speculate then an appropriate load to begin investigating would be one which is considered to maximise the power output (Pmax) for a given exercise.

*Equation of load*

The method used to equate the loads between experimental conditions will substantially impact the tension provided by RBR. Several methods have emerged throughout the literature. The apex force method involves determining the resistive forces at the end range of the concentric phase of an ascending strength curve movement. This method seems appropriate for testing purposes if we consider that it replicates current training practices. A proportion of the FW resistance is removed and replaced with RBR. The proportion of the resistance provided by RBR needs to be great enough to elicit the proposed benefits, while at the same time allowing the athlete or participant to successfully execute the lift. Two different procedures have been used to determine the apex load, each with its advantages and disadvantages. The first variation involves calculating the resistive forces by multiplying the mass of the FW load by the acceleration provided by gravity. For instance, a 100kg barbell held statically at the apex of a concentric contraction would theoretically produce 981 N of force. In fact, Frost et al., (2008) reported this to be true for FW loads within an acceptable range of error. If the T-D relationship has been accurately established, then one can compute the appropriate deformation length and the relative contributions of RBR for a given exercise and participant. Alternatively, instead of working out the forces mathematically, a force platform can be used to determine the VGRF of the RBR condition at full extension. Subsequently, an equivalent apex FW load can be measured without the need to modify the relative contribution provided by the RBR bands. The other method used to equate the loads between conditions is the average force method. It requires a participant to first perform the exercise with one of the experimental conditions. The mean forces exerted throughout the movement, repetition or set are quantified and therefore load equated.

There is a lack of consistency in the methods used to equate loads of different resistance types. Cronin et al., (2003a), Wallace et al., (2006) and Newton et al., (2002) used the apex method to equate loads. Newton et al., (2002) utilised the force platform to measure and equate VGRF for back squats at the apex, and also when the participant was in a parallel squat position. Ebben and Jensen (2002) failed to report how conditions were equated. Israetel et al. (2010) has reported the use of a force platform and the average force method to equate loads. The authors state that the subjects performed one set of five repetitions with a FW load equal to the average force exerted during the RBR condition. The authors failed to report whether the forces exerted during the RBR conditions were averaged over five repetitions or over one repetition, further complicating the issue. The authors did state that the FW condition was performed with a load equivalent to the average of force exerted during the RBR condition, but neglected to report how the FW force was determined. We have already established the inter-relatedness force, mass and acceleration (Equation 1), it seems apparent that attempting to equate loads by applying the same average force over the course of a dynamic movement, then the acceleration of the movement must be controlled.

*Kinematic and kinetic measurement techniques*

Linear position transducers and force platforms are the most commonly used devices in the collection and analysis kinematic and kinetic data and are valid and reliable measures of mechanical power output (Chiu, Schilling, Fry, & Weiss, 2004; Cronin, Hing & McNair, 2004). However, each measurement technique has limitations which will impact power outputs if not accounted for. Linear position transducer devices involve the advancing and retracting of a spool of wire which emits a voltage signal proportional to the distance the wire is advanced (Harman, 2006). The resulting displacement-time data can be doubled differentiated (equations 2 and 3) to calculate velocity- and acceleration-time data (Cormie, McBride, & McCaulley, 2007). Manipulating data amplifies noise in the raw data  increasing the risk of error and reducing the reliability and validity of the measured power output (Dugan, Doyle, Humphries, Hasson, & Newton, 2004). Techniques involving a single LPT fail to account for any horizontal displacement and tend to overestimate power values (Cormie, Deane, & McBride, 2007). Force platforms measure GRF and provide voltage signals proportional to the forces exerted on the surface of the platform (Harman, 2006). Acceleration and velocity data can be calculated using equation 1 and equation 6, respectively. Power data is then calculated by multiplying the measured force by the calculated velocity (Hori, Newton, Nosaka, & McGuigan, 2006). Akin to linear position transducers, manipulation of data can lead to noise amplification and the subsequent risk of erroneous data restricts the force platforms ability to reliably assess power output (Wood, 1982). The integration of the force platform and linear position transducer reduces data manipulation but still does not account for horizontal displacement (Cormie, McBride et al., 2007; Dugan et al., 2004; Hori et al., 2006; McBride, Triplett-McBride, Davie, & Newton, 2002; Newton, Kraemer, & Hakkinen, 1999). Restricting the movement to a purely vertical plane by using a Smith machine or similar apparatus eliminates horizontal displacement but is considered to translate to few athletic movements (Cormie, McBride et al., 2007).

Of the five research outputs studying the acute effects of RBR application reviewed in this paper; Ebben and Jensen (2002), Newton et al. (2002) and Wallace et al. (2006) used a force platform to account for a variety of kinematic and kinetic measures. The use of a supine squat machine to investigate the effects of RBR application by Cronin et al. (2003a), allowed only for the acquisition of kinematic data from a linear position transducer. Israetel et al. (2010) adopted the most scientifically sound method for the assessment of kinematic and kinetic variables. The authors used a force platform in combination with two linear position transducers, which were mounted above the power rack, anterior and posterior to the subject.

***SUMMARY***

The application of RBR has been theorised to enhance EMG activity of associated muscle groups, increase velocity and power outputs during the initial stages of the concentric phase and increase resistive braking forces during the eccentric contraction.  Research pertaining to the acute and training effects of RBR application on the kinematic and kinetic profiles of resistance exercises are characterised by methodological inconsistencies which confound our ability to draw conclusions. Future research should quantify the T-D relationships of RBR products and report the results along with the methods used to determine the relationship. Where possible the determination of T-D relationship should replicate the deformation rates of the exercise or movement in question. Current strength and conditioning training practises involve substituting a proportion of the FW resistance with RBR so that the total resistance at the apex of the movement is similar enabling athletes to fully execute the lift. The method of equating loads should replicate current training practise. Measuring the apex load rather than the average load method with the use of a force platform is recommended. Further research investigating the load parameters which maximises power output, including the relative intensity of the load (% 1RM) and the contribution of RBR to total resistance is warranted. Despite conjecture surrounding load which maximises a given exercises power output, it seems appropriate to investigate the effects of RBR training power profiles with Pmax load.

# CHAPTER THREE: THE QUANTIFICATION OF THE TENSION-DEFORMATION CHARACTERISTICS OF RUBBER BASED RESISTANCE

***PRELUDE***

The literature review established that the tensile properties of RBR products have not yet been thoroughly quantified and the paucity of RBR research is fraught with methodological inconsistencies confounding interpretations. The lack of understanding has lead to strength and conditioning practitioners prescribing RBR loading parameters with uncertainty.

The purpose of this study therefore, is to establish the tension-deformation and fatigue characteristics of several commercially available RBR bands. Subsequently, polynomial function equations and reference charts will be developed, which can afford strength and conditioning practitioners a greater understanding of the tensions provided by RBR for a given displacement thus enabling the accurate prescription of RBR loading parameters during training. Moreover, in order to establish the potential influence of RBR training on the kinematic and kinetic profiles of resistance training exercises, an accurate representation of the tensile properties is essential.

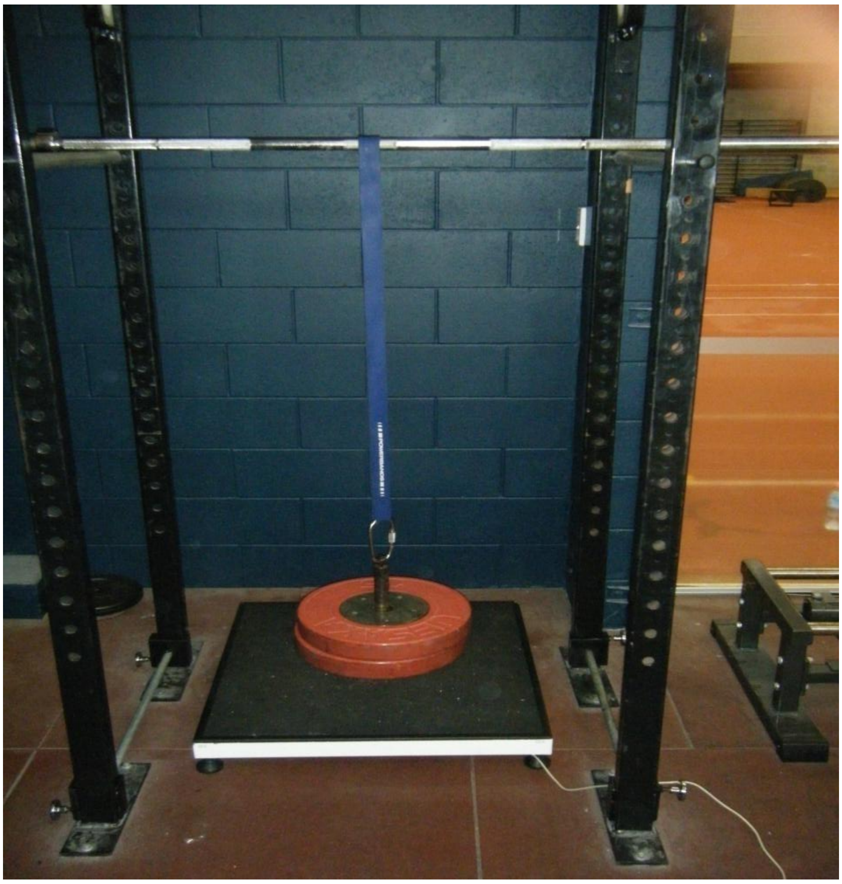
## *METHODS*

### *Procedures*

Six types of RBR bands (Power Bands, Australian Kettlebells, Victoria) with widths of 14, 21, 31, 48, 64 and 84mm (see Figure 3.1) were used to determine the tension provided over a range of displacements for each size band. A power rack (Fitness Works, Auckland) with Olympic barbell and safety bars was used in conjunction with a carabiner, Force Platform (Fitness Technology, Adelaide, Australia), data acquisition programme (Ballistic Measurement System 2009.1.4, Adelaide, Australia), and a known weight to determine VGRF (see Figure 3.2).

**Figure 3.2. Rubber based resistance bands**

**Figure 3.3. Tension-deformation testing setup**



The resting lengths of the bands were determined with a tape measure by laying the bands flat on the ground. The bands were looped around two barbells to replicate the setup of the force platform testing procedures. Safety bars suspended the barbell within the power rack. Directly below, the force platform was centred inside the power rack. Olympic plates were placed on top of the force platform with a steel tube inserted through the centre of the plates which allowed for the attachment of a karabiner (see Figure 3.4). The force provided by the plates was greater than that expected to be provided from the RBR. The plates acted as an anchor from which the bands could be elongated, as well as providing a calibration tool. The system was offset by zeroing the force platform before each trial. The band which was looped over the suspended barbell was attached to the karabiner and plate stack. VGRF was recorded for 5 seconds at a sampling frequency of 200Hz. By offsetting the force platform before each trial, the static tension provided by the bands was measured as a negative VGRF.

**Figure 3.4. Tension-deformation testing setup: RBR attachment**

The procedure was repeated with increased elongation lengths until the deformation reached approximately 190% of the bands resting length. During the same testing session, the procedures were replicated starting from ~190% back down to ~110% of resting length. This was performed in order to determine whether differences existed in the T-D properties during loading and unloading of the bands. Each testing session was performed on two separate occasions to determine the reliability of the testing procedures. The procedures were again replicated post-intervention (Chapter 4) to determine the fatigue characteristics after repetitive loading.

### *Statistical analysis*

Coefficient of variation (CV) and intra-class correlation coefficients (ICC) were calculated to determine the within and between trial reliability of the testing procedures. The differences between testing sessions (loading versus unloading; band set one versus band set two; and pre-intervention versus post intervention) are presented as means ± SD, and the magnitude and confidence limits were interpreted qualitatively (Hopkins, 2007). The pre-intervention data were fitted with trend lines and goodness of fit ($R^2$) was determined by applying polynomial regression equations (Microsoft Excel, 2007). The standard error (SE) of the quadratic equation coefficients was calculated using SPSS (17.0).

***RESULTS***

The mean tensions provided over a range of ascending and descending displacements both before and after the repetitive loading (see Chapter 4) can be observed in Figure 3.4. The mean resting length of the bands equalled 1.01 m (±0.01). The T-D values are presented as a percentage of resting length because of the discrepancies in resting lengths of each of the RBR bands.

**Figure 3.4. Mean tension-deformation relationships of six types of RBR bands**

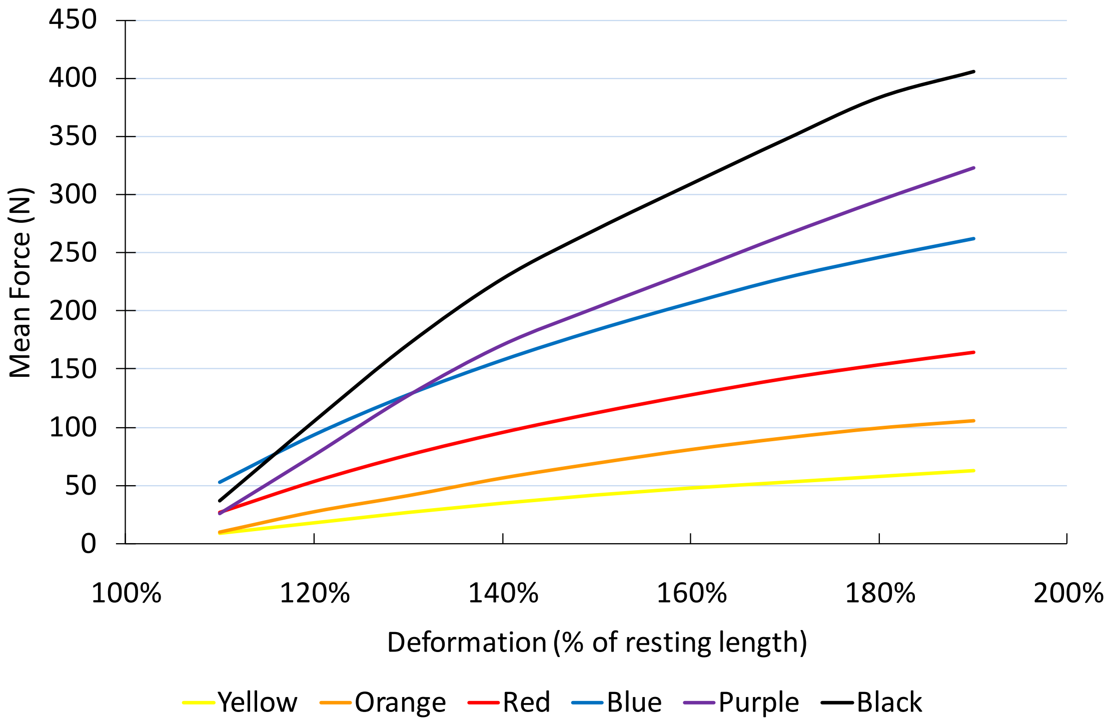


**Table 3.1. Mean tension-deformation values of six types of RBR bands**

| Deformation | | Yellow | Orange | Red | Blue | Purple | Black |
|---|---|---|---|---|---|---|---|
| % RL | (cm) | Kilograms | | | | | |
| 110% | 110 | 0.9 | 1.0 | 2.8 | 5.5 | 2.9 | 4.0 |
| 120% | 120 | 1.9 | 2.7 | 5.3 | 9.3 | 7.9 | 10.8 |
| 130% | 130 | 2.7 | 4.3 | 7.6 | 12.8 | 12.6 | 17.1 |
| 140% | 140 | 3.5 | 5.7 | 9.7 | 16.0 | 16.8 | 22.7 |
| 150% | 150 | 4.3 | 7.0 | 11.5 | 18.7 | 20.7 | 27.7 |
| 160% | 160 | 4.9 | 8.2 | 13.1 | 21.2 | 24.3 | 32.0 |
| 170% | 170 | 5.5 | 9.2 | 14.5 | 23.3 | 27.4 | 35.7 |
| 180% | 180 | 5.9 | 10.1 | 15.7 | 25.1 | 30.2 | 38.8 |
| 190% | 190 | 6.3 | 10.8 | 16.7 | 26.5 | 32.5 | 41.2 |

% RL = percent of resting length

The T-D relationships of the six RBR sets displayed curvilinear properties and were best represented by a second order polynomial function ($R^2 > 0.99$). The widths, quadratic polynomial equations ($y = ax^2 + bx + c$), goodness of fit ($R^2$) and SE's for each size band are presented in Table 3.2.

**Table 3.2. Polynomial function equations for six types of RBR bands**

| | Width (mm) | Quadratic Equation $y = ax^2 + bx + c$ | $R^2$ (%) | SE (±) |
|---|---|---|---|---|
| Yellow | 1.4 | $y = -39.575x^2 + 185.11x - 146.85$ | 1.00 | 6.0 |
| Orange | 2.1 | $y = -70.643x^2 + 332.57x - 270.81$ | 1.00 | 3.9 |
| Red | 3.1 | $y = -107.06x^2 + 490.89x - 382.52$ | 1.00 | 2.9 |
| Blue | 4.8 | $y = -165.59x^2 + 754.36x - 575.07$ | 1.00 | 4.5 |
| Purple | 6.4 | $y = -186.12x^2 + 922.52x - 761.58$ | 1.00 | 4.8 |
| Black | 8.4 | $y = -310.16x^2 + 1387.5x - 1112.1$ | 1.00 | 3.1 |

y = tension (N), x = deformation (mm), SE = standard error of coefficients (a, b, and c).

Measurements were reliable across testing sessions (CV = 1.79%; ICC ≥ 0.99). The difference in means across all colours of RBR sets and deformation lengths were ~0.18 N (90% confidence limit ± 2.49 N). All trials compared were considered clear and were at least likely trivial (≥ 95%), except for the yellow and orange sets when compared pre- and post-intervention, which were considered likely trivial (80%) and possibly trivial (71%), respectively. Mean pre- and post-intervention and inter-band T-D differences are detailed in Table 3.3.

**Table 3.3. Mean pre- and post-intervention and inter-band tension-deformation values**

| | Yellow | Orange | Red | Blue | Purple | Black |
|---|---|---|---|---|---|---|
| Band Set One - Pre (N) | 38.4 | 59.5 | 102.7 | 168.8 | 183.6 | 260.9 |
| Band Set One - Post (N) | 35.9 | 55.1 | 101.4 | 168.1 | 181.9 | 263.3 |
| Percent Difference (%) | 2.5 | 4.4 | 1.2 | 0.6 | 1.7 | 2.4 |
| | | | | | | |
| Band Set Two - Pre (N) | 41.3 | 71.5 | 111.2 | 178.1 | 197.2 | 238.7 |
| Band Set Two - Post (N) | 41.0 | 71.5 | 107.8 | 176.4 | 201.4 | 240.0 |
| Percent Difference (%) | 0.3 | 0.1 | 3.5 | 1.7 | 4.2 | 1.2 |
| | | | | | | |
| Mean Band Set One (N) | 37.1 | 57.3 | 102.0 | 168.5 | 182.7 | 262.1 |
| Mean Band Set Two (N) | 41.1 | 71.5 | 109.5 | 177.2 | 199.3 | 239.3 |
| Percent Difference (%) | 4.0 | 14.2 | 7.5 | 8.8 | 16.6 | 22.7 |

***DISCUSSION***

Tension provided by six different types of RBR was quantified over a number of deformations, ranging from 110-190% of the bands resting lengths. It was found that the T-D relationship for each band was curvilinear, which were most appropriately fitted by second order polynomial functions ($R^2 > 0.99$). Previous research has presented equivocal results regarding the tensile properties of RBR products. McMaster et al. (2009) reported that RBR bands from another manufacturer displayed curvilinear properties which were best fitted by second order polynomial functions ($R^2 \geq 0.99$), similar to the results seen in this present study. Conversely, Page et al. (2000) reported RBR products which displayed consistent and linear tensile properties across all colours tested ($R^2 \geq 0.95$). Various other scientific studies have reported viscoelastic tensile properties in RBR products, specifically a curvilinear region followed by a linear, elastic region (Patterson et al., 2001; Simoneau et al., 2001; Thomas et al., 2005). Thomas et al. (2005) suggested that deformations greater than 25% of the resting length are characterised by linear tensile properties ($R^2 = 0.99$). Patterson et al. (2001) stated that the transition from curvilinear to linear behaviour appears after a deformation of 50% above that of the products resting length, however the goodness of fit ($R^2$) was not presented.

RBR products are made of polymers (thermoplastics and elastomers) which have varying physical and mechanical properties. The composition of these properties during manufacturing affects the modulus of elasticity, density, yield and tensile strengths of the product (Askeland, 1990). Viscoelastic materials exhibit time-dependent behaviour (Ozkaya & Nordin, 1991). The response of the viscoelastic material to an applied stress depends on the magnitude of the stress and the rate at which the stress is applied. Greater total deformation or an increased rate of deformation requires an increased applied stress (Askeland, 1990). Elastic material has a T-D relationship which is independent of time or strain rate. The linear elastic region of deformation can be explained by Hookes Law (Ozkaya & Nordin, 1991).

F = k (stiffness) * d (deformation)

Therefore, the amount of tensile force produced by RBR is dependent on the physical and mechanical makeup, the cross-sectional area, the amount of deformation and during curvilinear region, the rate of deformation (Askeland, 1990; Mott, 2008; Ozkaya & Nordin, 1991).

Only Patterson et al. (2001) has investigated the effects of loading rate on T-D characteristics. The authors observed no statistically significant differences in tensile behaviour when deformed at rates of 5.1 and 50.8cm/min ($p \leq 0.05$). Interestingly, in the same study, the authors do report a significant difference in tensile behaviour between the directions of loading (loading versus unloading). At the same deformation length, the tension produced during loading was greater than that during unloading ($p \leq 0.05$). The loss of energy during unloading is known as hysteresis and is typical of viscoelastic material (Hamill & Knutzen, 2003). This revelation may provide some insight as to whether static loading accurately represents the T-D characteristics of RBR products when they are used in conjunction with traditional resistance training exercises. If there are discrepancies in the magnitude of tension provided during the concentric and eccentric phases of an exercise, surely static loading does not accurately replicate the tensions observed during one, if not both of these phases. If this in fact is the case, then one could speculate that research investigating the acute (Cronin et al., 2003a; Newton et al., 2002; Wallace et al., 2006) and training (Cronin et al., 2003a) effects of RBR on traditional resistance exercises are methodologically flawed, because static loading was used to determine the T-D relationship. Further research pertaining to the quantification of the T-D relationships of RBR products is warranted and should examine the association between static and dynamic loading protocols. Future research investigating the effect of RBR application on kinematic and kinetic variables needs to determine the T-D relationship of the product independent of manufacturer's claims or previous research and report the methods used to determine the relationship. Ideally, researchers should look to measure T-D relationships at a rate which replicates the associated movement and/or exercise.

Test-retest reliability suggests the intra-band reliability and the procedures used to assess the T-D relationship in this study were stable over time (CV = 1.79%), similar to that of previous research (Patterson et al., 2001). One limitation of the present study was the amount of data points collected to determine the quadratic functions, which is illustrated by the standard error of the quadratic equation coefficients (2.9 - 6.0 N). The power cage used to suspend the barbell only allowed for deformations every 7.5cm. A greater number of data points should allow for more accurate quadratic equations and thus greater accuracy when interpolating or extrapolating T-D data. Previous research has shown standard error of coefficients of 6.32 - 26.8 N when tensions were measured at intervals of 10cm. (McMaster et al., 2009). The authors suggested that applying linear and quadratic equations to the specific portions of the T-D curve may help reduce the error. While this may be correct, more data points are still needed to accuracy identify where the transition from linear to curvilinear region occurs. Future research should attempt to measure T-D relationship dynamically rather than statically which better represents the conditions observed during RBR training.

The mean resting lengths of the bands equalled 1.01 m (±0.01), which is similar to previous research (McMaster et al., 2009). Practitioners should be cognizant of the discrepancy in the resting length of bands despite some manufacturer's claims. It has become common practice to attach RBR on either side of barbells to augment resistance training with ascending strength curve exercises. If two bands, despite being the same colour, have different resting lengths, at the apex of the lift, the RBR will be providing different forces at either end of the barbell. The nature of the stresses imposed during training will affect the specific training adaptations experienced (Wilson, Murphy, & Giorgi, 1996) and as such, the application of RBR bands with different resting lengths may potentially result in musculoskeletal imbalances after prolonged use depending on the magnitude of the imbalance.

Data for this study was collected at increasing and decreasing deformation lengths in an attempt to identify any differences in the tension produced during loading and unloading of the RBR bands. The results suggest that the differences were likely trivial, however, it should be noted that data was sampled statically for five seconds in order to determine the mean tension at each deformation length. Upon completion of one deformation length, the barbell was moved to the next deformation length. The researcher estimates that the recording of each deformation length was separated by approximately ten to fifteen seconds. It could be postulated that this method is not truly representative of the behaviour exhibited of RBR products during resistance training exercises.

Differences in pre- and post-intervention tensions ranged from possibly (71%) trivial to likely (≥95%) trivial. Interestingly, the sets of RBR bands which displayed lower magnitudes of chance (yellow and orange) were not those used during the repetitive loading of Chapter 4. The combination of peak displacement and 1RM bench press values determined the colour of the band used by each participant in Chapter 4. All participants used either red or blue bands, therefore the only deformations experienced by the yellow and orange bands were those described within this chapter. Potentially, the functionality of smaller sized bands is less than that of the larger bands and may need replacing more often. However, at this stage, this is still speculative. Previous research has reported a decrease in tension provided by Thera-band bands and tubing by 9-12% after 501 cycles of deformation at 100% of resting length. The decrease in tension was further evident (10-15%) at 200% elongation (Simoneau et al., 2001). On the contrary, Patterson et al. (2001) reported no significant difference between tensions provided by Thera-Band tubing before and after 5000 cycles at 100% and 200% of resting length. Deformation lengths during this present study are comparable to that of Simoneau et al. (2001) and Patterson (2001), however the unique physical and mechanical properties of each style of RBR and methodological differences make comparison between each study problematic.

## *PRACTICAL APPLICATIONS*

The methodology used in this study seemed a simple and reliable approach to determining the tensile properties of RBR bands. The T-D data provided from this research allows the strength and conditioning fraternity to prescribe RBR loading parameters with greater accuracy. For a given displacement, the forces imparted by RBR can be established. Trainers, coaches and athletes must be aware of the discrepancies in resting band lengths and the implications on musculoskeletal development. Despite the manufacturer's specifications, variations in resting band lengths, even in bands of the same colour, will alter the force production at a given deformation. Loading a pair of RBR bands on either end of a barbell may potentially provide greater resistance on one side than the other. The reader should be aware that the physical and mechanical properties of RBR differ between manufacturers and between products (bands, bungy's and tubing), thus the results of this research can only be accurately applied to Power Band (Australian Kettlebells, Victoria) brand products. RBR bands are a cost-effective, portable tool, which do not rely on gravity to provide resistance, allow multi-planar movements and have the potential to alter the kinetics and kinematics of various exercises to augment strength and power qualities of athletes.

# CHAPTER FOUR: THE KINEMATIC AND KINETIC ANALYSIS OF RUBBER BASED RESISTANCE: APPLICATION TO THE BENCH PRESS EXERCISE

***PRELUDE***

The application of RBR to traditional isoinertial resistance training exercises has gained popularity as a method of manipulating the kinematic and kinetic profiles of various strength training exercises. The literature review established that advocacy for the use of RBR is primarily based on anecdotal rather than empirical evidence. The previous chapter quantified the T-D relationship, affording practitioners with a greater understanding of the characteristics possessed by RBR and the ability to prescribe RBR loading parameters with greater accuracy. However, the knowledge concerning the efficacy of RBR as a tool to alter the kinematics and kinetics of resistance training exercises is in its infancy and even less is understood about the transference of these alterations to enhancing athletic performance. It was considered that an analysis of the kinematic and kinetic differences between RBR and isoinertial resistance bench press exercises would provide insight into the effectiveness of each in enhancing upper body muscular performance. A randomised crossover design was used to determine whether repetition, set and total session kinetics and kinematics differed between traditional free weight bench press and RBR bench press exercises corresponding to 20% and 40% of the load when equated at 100% concentric displacement.

## *METHODS*

### *Subjects*

Fourteen subjects volunteered to participate in this study. The mean age, mass of the subjects were 24.6 ± 3.6 years, 102.9 ± 14.5 kg, respectively. All subjects were semi-professional rugby players with a minimum of 12 months resistance training experience as well as experience with RBR loading. All participants were required to undergo a pre-screen for any previous or current injuries. The participants signed an informed participant consent form prior to data collection. Participants were instructed that they were able to withdraw without prejudice at any time. Ethical approval was granted by the AUT University Ethics Committee.

### *Equipment*

RBR bands (Power Bands, Australian Kettlebells, Victoria) with widths of 14, 21, 31, 48, 64 and 84 mm were used to add variable resistance to the bench press exercise. A power rack (Fitness Works, Auckland) fitted with sliding safety bars was used to anchor the RBR bands at a position which allowed the contribution of RBR to be either 20% or 40% of the total resistance at 100% concentric displacement. A linear position transducer (Fitness Technology, South Australia – mean sensitivity 0.499mV/V/mm, linearity 0.05 full scale) was attached to one end of the barbell to measure displacement with an accuracy of 1.0 mm. A force platform (Fitness Technology, South Australia) and custom made bench (Fitness Works, Auckland) were centred beneath the power rack (Figure 4.1). The custom made bench was adjustable in height to ensure that the RBR bands were loaded at the peak concentric displacement during the repetition for each player. The bench also had adjustable legs which allowed all parts of the bench to fit onto the force platform. A foot stand was attached to one end of the bench to ensure subjects' feet were in contact with the bench and all of the force could be accounted for by the force platform. Displacement and force data were sampled at 200Hz by a computer based data acquisition and analysis programme (Ballistic Measurement System, version 2009.1.4).

**Figure 4.1. Kinematic and kinetic data collection setup**

***Procedures***

To minimise disruption to the athletes' current strength and power training programme all testing sessions were performed prior to a regularly scheduled squad training session. Each testing session was preceded by a standardised warm-up procedure consisting of five minutes of rowing on an indoor rowing ergometer (Concept 2 Model D, Tauranga, NZ) at a pace of ~2.30 minutes per

500m, on a resistance level of 10. Dynamic stretches and sets of 6-12 repetition of press-ups were performed in a self-selected manner. One practice set at the load to be lifted during testing was performed as a part of the warm up and also to reiterate the testing procedures. 1RM bench press values were determined according to standard accepted protocols (Bloomfield, Ackland, & Elliott, 1994) so traditional and RBR loading could be quantified. This 1RM load testing occurred during a regular squad strength testing session. Participants completed the first of three data acquisition testing sessions within 2 weeks of 1RM strength testing and the loads determined were used throughout the duration of the study. Data acquisition was performed on three separate occasions, at least two days apart. Participants performed 3 sets of 6 repetitions of a bench press exercise at 50% of their 1RM for each experimental condition. A 50% 1RM load was considered the optimal load for developing maximal power (Pmax) outputs during the bench press (Jidovtseff et al., 2006). Each set was separated by a 3 minute rest period. The conditions included; traditional free weight bench press (FW), 20% contribution from RBR bands (RBR20) and 40% contribution of total apex load from RBR bands (RBR40). The RBR bands were attached to either end of the barbell, inside the plates and were anchored by the sliding safety rack. During the first data acquisition session, subjects had their peak barbell displacement recorded in order to determine the correct apex load for each condition. Depending on the athlete's limb length and thus displacement of the barbell, the sliding safety bars were positioned so that at peak concentric displacement, the RBR bands provided either 20% or 40% of the total apex load according to the T-D relationship of each band.

The athletes' were well versed with the bench press exercise and with the use of RBR bands. The athletes' were instructed to adopt a self-selected grip width throughout the testing sessions. Once positioned ready, the athletes were instructed to remain still with their feet positioned on the foot stand and hands off the barbell. The force platform was zeroed at this point, removing the mass of the bench and participant from data analysis calculations. Data acquisition started before the athlete was instructed to unload the barbell, hold still for approximately 3 seconds at 100% concentric displacement before performing 6 repetitions as explosively as possible. The number of repetitions was counted aloud by the researcher. At the end of the $6^{th}$ repetition, the participant was instructed to hold the barbell still at the 100% concentric displacement for approximately 3 seconds before replacing the barbell back on the safety hooks. The linear position transducer and force platform equipment was calibrated before every data acquisition session.

### *Data analysis*

The displacement-time data from the linear position transducer and force-time data from the force platform was filtered using a low (second order) pass Butterworth filter with a cut-off frequency of 5Hz. The derived velocity data and force data were multiplied to provide power outputs. The following variables were recorded and analysed for the concentric phase of the lift: duration of contraction, peak displacement, peak velocity, peak and mean acceleration, peak and mean force, peak and mean power.

Comparisons were made between repetitions using three different methods. Firstly, within the same condition and within the same set, in order to determine if intra-set differences existed. Secondly, within the same condition but between the corresponding repetition of each set, to determine whether differences existed from set to set. Finally, comparisons were made between repetitions and the corresponding repetition and set number between each of the experimental groups to determine whether differences existed with the application of RBR. Furthermore, the mean values of each repetition were combined using a statistical excel spreadsheet (Hopkins, 2007) to determine whether differences existed within and between the sets of each condition. This procedure was repeated with the mean values of each set, in order to determine whether differences existed between the total session kinematic and kinetics. In addition to the repetition, set and total session comparisons, the second repetition of the first set of each condition was divided into 10% intervals relative to total barbell displacement. Temporal data as well as instantaneous displacement, velocity, acceleration, force and power values were compared. The first set was selected to ensure that the influence of muscular fatigue was minimised. The second repetition was selected to reduce the variability associated with the loading and unloading of the barbell during free weight bench press as observed in previous research.

The end of the concentric phase was determined by maximum displacement in order to remain consistent with previous research (Asci & Acikada, 2007; Frost et al., 2008; Jidovtseff et al., 2006). The initiation of the eccentric phase was defined as the first instance of negative displacement (Frost et al., 2008). The body mass of the participant was excluded from subsequent data analysis calculations.

***Statistical analysis***

A randomised crossover design was used to determine whether differences existed between repetition, set and total session kinetics and kinematics of traditional free weight bench press and RBR bench press exercises corresponding to 20% and 40% of the apex load. Means and standard deviations were used throughout as a measure of centrality and spread of data. One-Way Repeated Measures ANOVA post-hoc tests of means were applied by conducting pair-wise comparisons using SPSS 17.0. Confidence limits and magnitude-based inferences were then calculated by entering the p values, the value of the effect statistic (the observed difference in means), the degrees of freedom and the smallest practically important positive and negative values of effect into a Microsoft Excel statistical spreadsheet and were interpreted qualitatively (Hopkins, 2007). The smallest practically important positive and negative values of effect also referred to as the standardised differences of the means were calculated by dividing the difference in condition means by the standard deviation of the predictor variable (Hopkins, 2007). This was performed to illustrate the precision of the outcome statistics as the likely range of the true value in the population. The magnitudes of the effect statistic were interpreted using the following scale: most unlikely (0.0-0.5), very unlikely (0.5-5), unlikely (5-25), possibly (25-75), likely (75-95), very likely (95-99.5), or most likely (99.5-100). Inferences about a true value were based on the uncertainty in its magnitude, that is, if the 90% confidence limits overlapped the smallest positive and negative value, the magnitude of the effect statistic was considered unclear; otherwise the magnitude was interpreted as meaningful or trivial. *P* values have also been reported to allow comparisons to previous research and potentially contribute to future meta-analyses, but were not used to determine significance.

## *RESULTS*

### *Repetition kinematics and kinetics*

Descriptive statistics for the concentric repetition kinematic and kinetic outputs are detailed in Table 4.1. The difference in means, 90% confidence limits and *P* values for each pair-wise comparison are depicted in Table 4.2.

FW displayed greater force values at the 10% interval (98 N ± 87 N, $P = 0.066$) compared to RBR20 and (98 N ± 65 N, $P = 0.019$) compared with RBR40. The magnitudes of these effects were considered a very likely chance (≥96.6%) of being meaningful. From 20% to 70% forces values were greater for the RBR conditions ranging from 63 ± 32 N ($P = 0.004$) to 100 ± 60 N ($P = 0.01$). Each of the pair-wise comparisons (refer to Table 4.3) were considered at least a very likely chance (≥ 97.2%) of being meaningful. Comparisons between the two RBR conditions were practically unclear from 10%-80%. The greater force displayed by RBR40 of 170 ± 120 N ($P = 0.029$) and 230 ± 150 N ($P = 0.017$) over RBR20 for the 90% and 100% interval was very likely (≥98.5%) meaningful.

**Figure 4.2. Mean force and power outputs relative to concentric displacement**

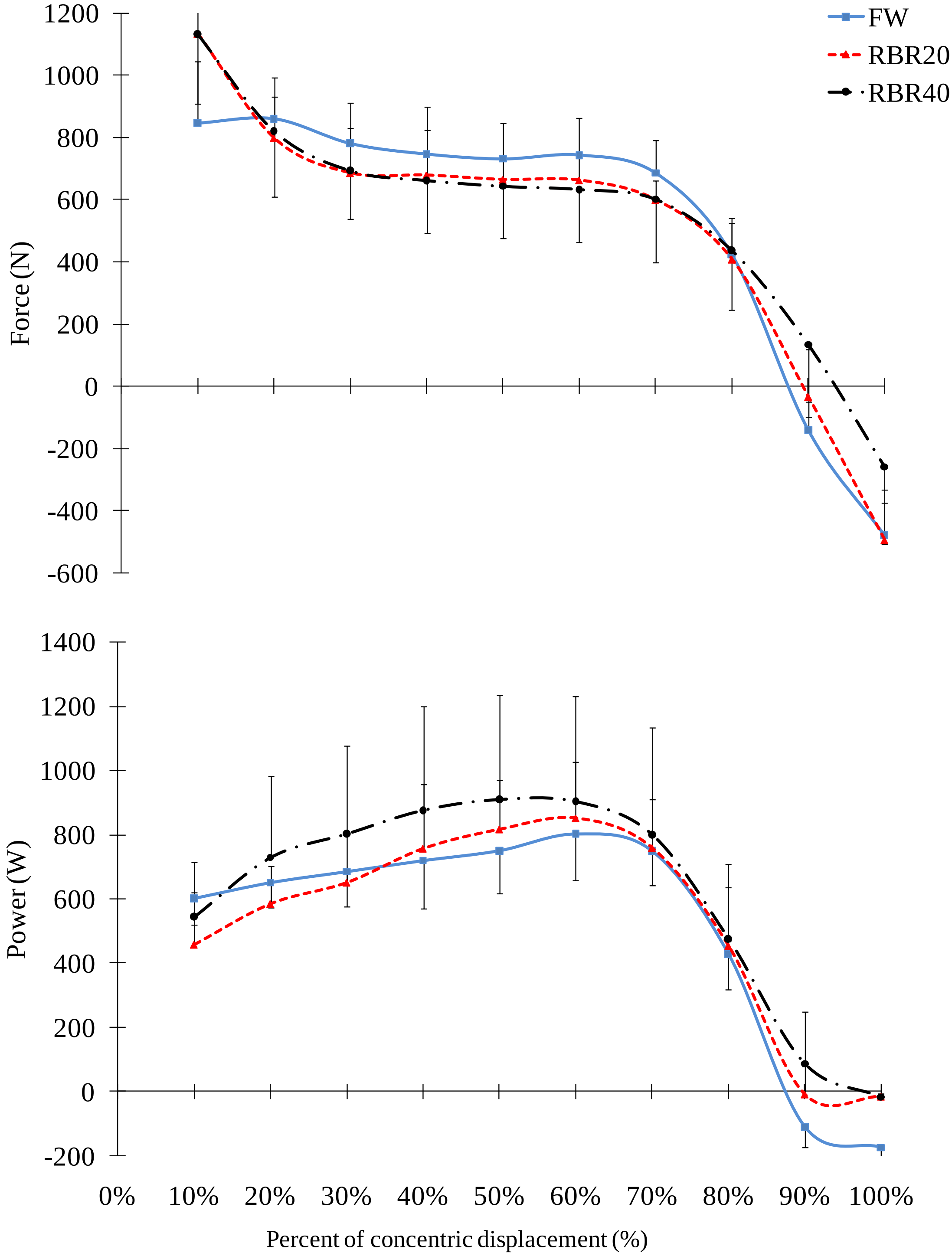


**Figure 4.3. Mean FW, RBR20 and RBR40 velocity and acceleration outputs relative to concentric displacement**

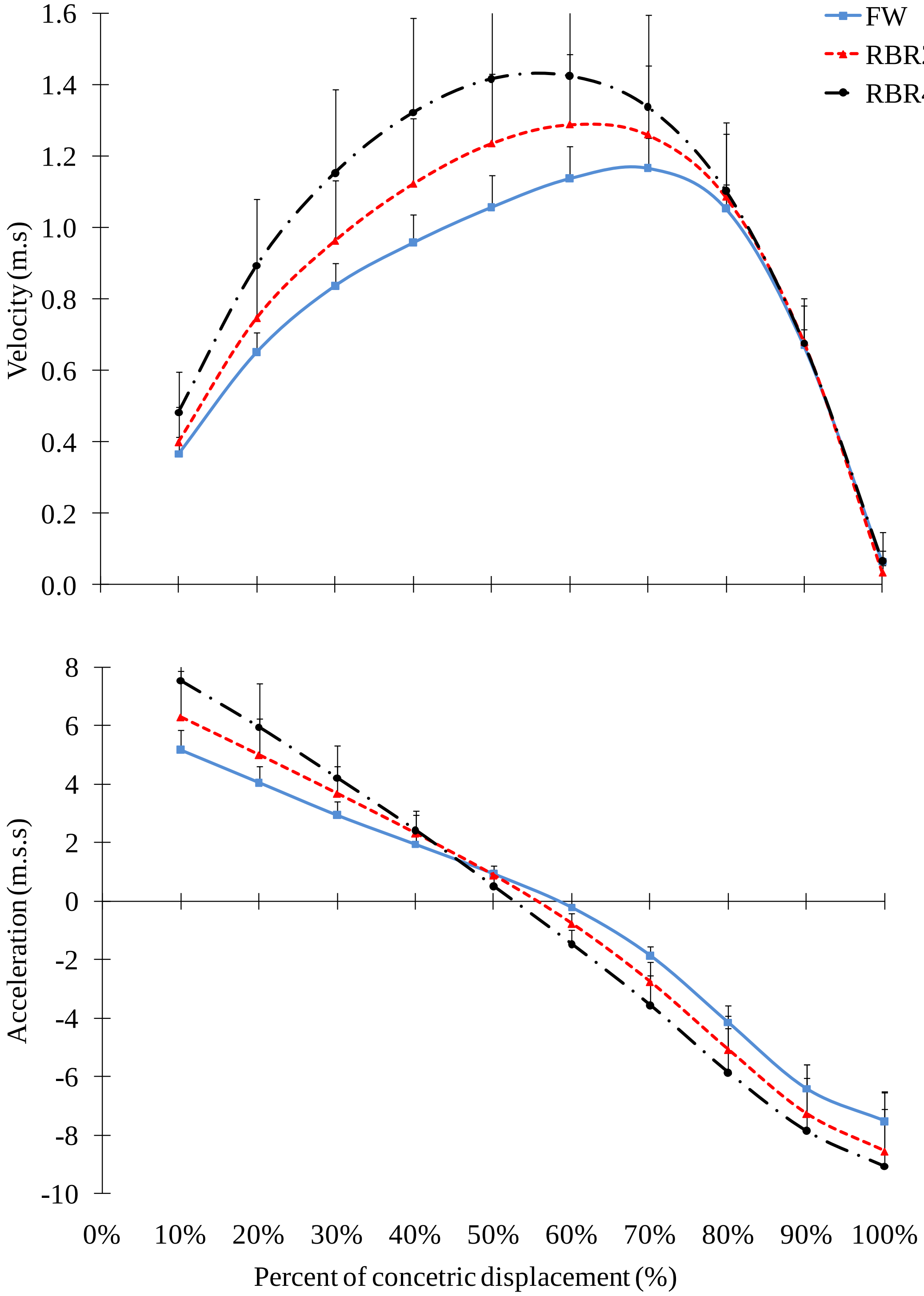


**Table 4.1. Concentric repetition kinematic and kinetic outputs**

| | n | TIME (s) | DISPLACEMENT (m) | VELOCITY ($m.s^{-1}$) | ACCLERATION ($m.s^{-2}$) | FORCE (N) | POWER (W) |
|---|---|---|---|---|---|---|---|
| FW 10% | 14 | 0.047 ± 0.00 | 0.03 ± 0.04 | 0.37 ± 0.0 | 5.2 ± 0.7 | 1035 ± 197 | 385 ± 82 |
| RBR20 | 14 | 0.038 ± 0.00 | 0.05 ± 0.04 | 0.40 ± 0.1 | 6.3 ± 1.6 | 1133 ± 207 | 456 ± 165 |
| RBR40 | 14 | 0.034 ± 0.01 | 0.04 ± 0.02 | 0.48 ± 0.1 | 7.5 ± 1.9 | 1133 ± 224 | 544 ± 171 |
| FW 20% | 14 | 0.099 ± 0.01 | 0.06 ± 0.03 | 0.67 ± 0.1 | 4.2 ± 0.5 | 870 ± 133 | 578 ± 78 |
| RBR20 | 14 | 0.083 ± 0.01 | 0.08 ± 0.04 | 0.75 ± 0.1 | 5.0 ± 1.3 | 797 ± 136 | 585 ± 118 |
| RBR40 | 14 | 0.074 ± 0.01 | 0.07 ± 0.03 | 0.89 ± 0.2 | 6.0 ± 1.5 | 821 ± 211 | 729 ± 254 |
| FW 30% | 14 | 0.152 ± 0.01 | 0.11 ± 0.03 | 0.86 ± 0.1 | 3.0 ± 0.5 | 775 ± 131 | 665 ± 110 |
| RBR20 | 14 | 0.127 ± 0.01 | 0.12 ± 0.04 | 0.96 ± 0.2 | 3.7 ± 0.9 | 685 ± 145 | 651 ± 157 |
| RBR40 | 14 | 0.114 ± 0.02 | 0.12 ± 0.03 | 1.15 ± 0.2 | 4.2 ± 1.1 | 694 ± 156 | 803 ± 273 |
| FW 40% | 14 | 0.203 ± 0.02 | 0.16 ± 0.03 | 0.98 ± 0.1 | 2.0 ± 0.3 | 749 ± 152 | 736 ± 149 |
| RBR20 | 14 | 0.173 ± 0.01 | 0.17 ± 0.04 | 1.12 ± 0.2 | 2.3 ± 0.6 | 678 ± 145 | 757 ± 203 |
| RBR40 | 14 | 0.153 ± 0.02 | 0.17 ± 0.03 | 1.32 ± 0.3 | 2.4 ± 0.7 | 662 ± 170 | 876 ± 322 |
| FW 50% | 14 | 0.257 ± 0.02 | 0.21 ± 0.03 | 1.09 ± 0.1 | 0.9 ± 0.2 | 727 ± 114 | 789 ± 133 |
| RBR20 | 14 | 0.218 ± 0.01 | 0.23 ± 0.04 | 1.24 ± 0.2 | 0.9 ± 0.3 | 664 ± 79 | 816 ± 154 |
| RBR40 | 14 | 0.195 ± 0.03 | 0.23 ± 0.04 | 1.42 ± 0.3 | 0.5 ± 0.3 | 644 ± 168 | 910 ± 326 |
| FW 60% | 14 | 0.309 ± 0.03 | 0.27 ± 0.03 | 1.16 ± 0.1 | -0.3 ± 0.1 | 736 ± 118 | 855 ± 145 |
| RBR20 | 14 | 0.261 ± 0.02 | 0.29 ± 0.04 | 1.29 ± 0.2 | -0.8 ± 0.4 | 662 ± 87 | 851 ± 178 |
| RBR40 | 14 | 0.234 ± 0.03 | 0.29 ± 0.04 | 1.42 ± 0.3 | -1.5 ± 0.5 | 633 ± 169 | 903 ± 327 |
| FW 70% | 14 | 0.360 ± 0.03 | 0.33 ± 0.03 | 1.18 ± 0.1 | -2.0 ± 0.3 | 671 ± 105 | 789 ± 107 |
| RBR20 | 14 | 0.307 ± 0.02 | 0.35 ± 0.05 | 1.26 ± 0.2 | -2.8 ± 0.7 | 599 ± 63 | 757 ± 151 |
| RBR40 | 14 | 0.273 ± 0.04 | 0.35 ± 0.04 | 1.34 ± 0.3 | -3.6 ± 1.0 | 602 ± 204 | 801 ± 333 |
| FW 80% | 14 | 0.413 ± 0.03 | 0.40 ± 0.04 | 1.05 ± 0.1 | -4.3 ± 0.6 | 394 ± 102 | 413 ± 109 |
| RBR20 | 14 | 0.351 ± 0.02 | 0.41 ± 0.05 | 1.09 ± 0.2 | -5.1 ± 1.2 | 407 ± 134 | 451 ± 182 |
| RBR40 | 14 | 0.314 ± 0.04 | 0.41 ± 0.05 | 1.10 ± 0.2 | -5.9 ± 1.5 | 436 ± 191 | 477 ± 234 |
| FW 90% | 14 | 0.465 ± 0.04 | 0.45 ± 0.04 | 0.66 ± 0.0 | -6.5 ± 0.8 | -156 ± 91 | -103 ± 61 |
| RBR20 | 14 | 0.396 ± 0.03 | 0.46 ± 0.05 | 0.68 ± 0.1 | -7.3 ± 1.7 | -35 ± 152 | -12 ± 89 |
| RBR40 | 14 | 0.354 ± 0.05 | 0.46 ± 0.05 | 0.68 ± 0.1 | -7.9 ± 1.8 | 133 ± 233 | 87 ± 164 |
| FW 100% | 14 | 0.518 ± 0.04 | 0.47 ± 0.04 | 0.05 ± 0.1 | -7.6 ± 1.0 | -482 ± 106 | -24 ± 33 |
| RBR20 | 14 | 0.443 ± 0.03 | 0.48 ± 0.05 | 0.03 ± 0.0 | -8.6 ± 2.0 | -495 ± 164 | -17 ± 11 |
| RBR40 | 14 | 0.396 ± 0.05 | 0.48 ± 0.05 | 0.04 ± 0.0 | -9.1 ± 2.0 | -269 ± 249 | -9 ± 10 |

## Table 4.2. Concentric repetition kinematic outputs

| | | TIME (s) | | DISPLACEMENT (m) | | VELOCITY (m.s) | |
|---|---|---|---|---|---|---|---|
| | | MDiff ± 90% CL | *P* | MDiff ± 90% CL | *P* | MDiff ± 90% CL | *P* |
| FW - RBR20 | 10% | 0.0089 ± 0.0037 | 0.001 | -0.013 ± 0.018 | 0.218 | -0.026 ± 0.034 | 0.198 |
| FW - RBR40 | | 0.013 ± 0.0055 | 0.001 | -0.0078 ± 0.013 | 0.308 | -0.11 ± 0.055 | 0.004 |
| RBR20 - RBR40 | | 0.0043 ± 0.0032 | 0.034 | 0.0057 ± 0.017 | 0.560 | -0.083 ± 0.047 | 0.008 |
| FW - RBR20 | 20% | 0.016 ± 0.0066 | 0.001 | -0.015 ± 0.019 | 0.177 | -0.08 ± 0.057 | 0.029 |
| FW - RBR40 | | 0.025 ± 0.01 | 0.001 | -0.011 ± 0.012 | 0.125 | -0.23 ± 0.095 | 0.001 |
| RBR20 - RBR40 | | 0.0093 ± 0.0056 | 0.011 | 0.0037 ± 0.016 | 0.692 | -0.15 ± 0.081 | 0.007 |
| FW - RBR20 | 30% | 0.025 ± 0.01 | 0.001 | -0.014 ± 0.019 | 0.236 | -0.1 ± 0.069 | 0.020 |
| FW - RBR40 | | 0.038 ± 0.016 | 0.001 | -0.014 ± 0.012 | 0.061 | -0.29 ± 0.12 | 0.001 |
| RBR20 - RBR40 | | 0.013 ± 0.0078 | 0.012 | -0.0004 ± 0.012 | 0.956 | -0.19 ± 0.11 | 0.007 |
| FW - RBR20 | 40% | 0.03 ± 0.013 | 0.001 | -0.017 ± 0.021 | 0.176 | -0.14 ± 0.081 | 0.010 |
| FW - RBR40 | | 0.05 ± 0.021 | 0.001 | -0.018 ± 0.012 | 0.019 | -0.34 ± 0.14 | 0.001 |
| RBR20 - RBR40 | | 0.02 ± 0.011 | 0.006 | -0.0017 ± 0.017 | 0.860 | -0.2 ± 0.13 | 0.015 |
| FW - RBR20 | 50% | 0.039 ± 0.016 | 0.001 | -0.017 ± 0.021 | 0.181 | -0.15 ± 0.089 | 0.011 |
| FW - RBR40 | | 0.062 ± 0.026 | 0.001 | -0.023 ± 0.011 | 0.004 | -0.33 ± 0.16 | 0.003 |
| RBR20 - RBR40 | | 0.023 ± 0.013 | 0.008 | -0.0056 ± 0.017 | 0.562 | -0.18 ± 0.14 | 0.038 |
| FW - RBR20 | 60% | 0.047 ± 0.02 | 0.001 | -0.019 ± 0.023 | 0.181 | -0.13 ± 0.091 | 0.029 |
| FW - RBR40 | | 0.074 ± 0.031 | 0.001 | -0.025 ± 0.012 | 0.003 | -0.26 ± 0.16 | 0.014 |
| RBR20 - RBR40 | | 0.027 ± 0.015 | 0.008 | -0.0063 ± 0.018 | 0.543 | -0.14 ± 0.15 | 0.122 |
| FW - RBR20 | 70% | 0.053 ± 0.022 | 0.001 | -0.019 ± 0.025 | 0.186 | -0.079 ± 0.09 | 0.144 |
| FW - RBR40 | | 0.087 ± 0.036 | 0.001 | -0.022 ± 0.013 | 0.010 | -0.16 ± 0.15 | 0.090 |
| RBR20 - RBR40 | | 0.034 ± 0.018 | 0.005 | -0.0023 ± 0.02 | 0.846 | -0.078 ± 0.14 | 0.351 |
| FW - RBR20 | 80% | 0.061 ± 0.026 | 0.001 | -0.015 ± 0.026 | 0.332 | -0.033 ± 0.079 | 0.476 |
| FW - RBR40 | | 0.099 ± 0.053 | 0.001 | -0.014 ± 0.014 | 0.115 | -0.05 ± 0.11 | 0.430 |
| RBR20 - RBR40 | | 0.038 ± 0.016 | 0.006 | 0.0011 ± 0.023 | 0.936 | -0.018 ± 0.12 | 0.802 |
| FW - RBR20 | 90% | 0.069 ± 0.029 | 0.001 | -0.01 ± 0.026 | 0.488 | -0.022 ± 0.057 | 0.502 |
| FW - RBR40 | | 0.11 ± 0.06 | 0.001 | -0.0048 ± 0.016 | 0.597 | -0.019 ± 0.059 | 0.578 |
| RBR20 - RBR40 | | 0.042 ± 0.018 | 0.006 | 0.0056 ± 0.022 | 0.661 | 0.0034 ± 0.082 | 0.942 |
| FW - RBR20 | 100% | 0.075 ± 0.031 | 0.001 | -0.011 ± 0.026 | 0.457 | 0.019 ± 0.045 | 0.475 |
| FW - RBR40 | | 0.12 ± 0.067 | 0.001 | -0.0038 ± 0.016 | 0.674 | 0.013 ± 0.038 | 0.564 |
| RBR20 - RBR40 | | 0.046 ± 0.019 | 0.007 | 0.0076 ± 0.024 | 0.579 | -0.0061 ± 0.022 | 0.634 |

**Table 4.3. Concentric repetition kinetic outputs**

| | | ACCLERATION (m.s.s) | | FORCE (N) | | POWER (W) | |
|---|---|---|---|---|---|---|---|
| | | MDiff ± 90% CI | *P* | MDiff ± 90% CL | *P* | MDiff ± 90% CL | *P* |
| FW - RBR20 | 10% | -1 ± 0.59 | 0.008 | -98 ± 87 | 0.066 | -71 ± 65 | 0.074 |
| FW - RBR40 | | -2.3 ± 0.96 | 0.001 | -98 ± 65 | 0.019 | -160 ± 67 | 0.001 |
| RBR20 - RBR40 | | -1.3 ± 0.99 | 0.043 | 0.45 ± 77 | 0.992 | -88 ± 61 | 0.024 |
| FW - RBR20 | 20% | -0.84 ± 0.49 | 0.010 | 73 ± 34 | 0.002 | -7.7 ± 51 | 0.793 |
| FW - RBR40 | | -1.8 ± 0.83 | 0.002 | 49 ± 75 | 0.264 | -150 ± 98 | 0.017 |
| RBR20 - RBR40 | | -0.96 ± 0.82 | 0.058 | -24 ± 74 | 0.577 | -140 ± 91 | 0.015 |
| FW - RBR20 | 30% | -0.66 ± 0.38 | 0.009 | 90 ± 51 | 0.008 | 14 ± 82 | 0.774 |
| FW - RBR40 | | -1.2 ± 0.63 | 0.005 | 82 ± 69 | 0.055 | -140 ± 130 | 0.083 |
| RBR20 - RBR40 | | -0.54 ± 0.62 | 0.145 | -8.5 ± 72 | 0.839 | -150 ± 100 | 0.022 |
| FW - RBR20 | 40% | -0.34 ± 0.26 | 0.037 | 71 ± 49 | 0.023 | -21 ± 96 | 0.708 |
| FW - RBR40 | | -0.45 ± 0.42 | 0.075 | 87 ± 71 | 0.050 | -140 ± 59 | 0.123 |
| RBR20 - RBR40 | | -0.12 ± 0.44 | 0.641 | 16 ± 75 | 0.714 | -120 ± 130 | 0.112 |
| FW - RBR20 | 50% | 0.04 ± 0.13 | 0.602 | 63 ± 32 | 0.004 | -27 ± 28 | 0.608 |
| FW - RBR40 | | 0.41 ± 0.19 | 0.002 | 83 ± 61 | 0.030 | -120 ± 410 | 0.184 |
| RBR20 - RBR40 | | 0.37 ± 0.23 | 0.013 | 20 ± 61 | 0.564 | -94 ± 120 | 0.223 |
| FW - RBR20 | 60% | 0.46 ± 0.19 | 0.001 | 74 ± 49 | 0.019 | 3.9 ± 5.4 | 0.950 |
| FW - RBR40 | | 1.2 ± 0.48 | 0.001 | 100 ± 60 | 0.010 | -49 ± 1300 | 0.588 |
| RBR20 - RBR40 | | 0.7 ± 0.29 | 0.001 | 28 ± 64 | 0.444 | -53 ± 170 | 0.541 |
| FW - RBR20 | 70% | 0.77 ± 0.33 | 0.001 | 72 ± 49 | 0.022 | 32 ± 90 | 0.572 |
| FW - RBR40 | | 1.6 ± 0.66 | 0.001 | 69 ± 78 | 0.139 | -11 ± 35 | 0.884 |
| RBR20 - RBR40 | | 0.79 ± 0.47 | 0.011 | -2.7 ± 78 | 0.952 | -43 ± 520 | 0.624 |
| FW - RBR20 | 80% | 0.8 ± 0.49 | 0.013 | -13 ± 99 | 0.821 | -39 ± 140 | 0.573 |
| FW - RBR40 | | 1.6 ± 0.85 | 0.006 | -42 ± 91 | 0.425 | -64 ± 200 | 0.240 |
| RBR20 - RBR40 | | 0.77 ± 0.82 | 0.118 | -29 ± 98 | 0.603 | -25 ± 36 | 0.751 |
| FW - RBR20 | 90% | 0.78 ± 0.64 | 0.050 | -120 ± 91 | 0.035 | -91 ± 500 | 0.019 |
| FW - RBR40 | | 1.4 ± 0.97 | 0.027 | -290 ± 120 | 0.001 | -190 ± 130 | 0.002 |
| RBR20 - RBR40 | | 0.59 ± 1.1 | 0.366 | -170 ± 120 | 0.029 | -98 ± 45 | 0.058 |
| FW - RBR20 | 100% | 0.98 ± 0.81 | 0.052 | 14 ± 60 | 0.692 | -7 ± 6 | 0.487 |
| FW - RBR40 | | 1.5 ± 1.1 | 0.024 | -210 ± 130 | 0.015 | -15 ± 38 | 0.116 |
| RBR20 - RBR40 | | 0.54 ± 1.3 | 0.473 | -230 ± 150 | 0.017 | -8.4 ± 8.9 | 0.105 |

***Set kinematics and kinetics***

Mean (± SD) values for the concentric set kinematic and kinetics outputs can be observed in Table 4.3. The between-condition paired difference kinematic and kinetic outputs can be viewed in Table 4.4.

Mean (± SD) peak velocity values ranged from 1.14 (± 0.1 $m.s^{-1}$) to 1.15 (± 0.09 $m.s^{-1}$); 1.25 (± 0.15 $m.s^{-1}$) to 1.28 (± 0.15 $m.s^{-1}$) and 1.41 (± 0.24 $m.s^{-1}$) to 1.46 (± 0.26 $m.s^{-1}$) for the FW, RBR20 and RBR40 conditions, respectively. The between- and within-condition differences for peak displacement and peak velocity were very likely to be trivial (≥98.1%)

The mean (± SD) peak force values ranged from 1405 (± 238 N) to 1442 (± 245 N), 1479 (± 388 N) to 1577 (± 314 N) and 1479 (± 322 N) to 1491 (± 421 N) over three sets for the FW, RBR20 and RBR40 conditions, respectively. The between-condition comparisons for set one were practically unclear. The set two difference in mean peak force values between RBR20 and FW was 110 (± 74 N, $P$ = 0.024) and 140 (± 110 N, $P$ = 0.039) between RBR20 and RBR40. The effect was even greater when compared to the RBR40 condition. A difference in mean peak force values of 140 (± 98 N, $P$ = 0.028) between RBR20 and FW was observed for set three. These results all showed a very likely chance (≥ 98%) that the magnitudes of the effects were meaningful.

mean force values ranged from 639 (± 100 N) to 649 (± 97 N), 604 (± 76 N) to 611 (± 84 N) and 576 (± 106 N) to 623 (± 165 N) for the FW, RBR20 and RBR40 conditions, respectively. The between-condition comparison of set one showed FW with a difference in mean force of 36 (± 22 N, $P = 0.015$) over the RBR20 condition. Other between-condition set one results were unclear. Set two revealed greater mean force values for the FW condition by 38 (± 28 N, $P = 0.034$) and 73 (± 31 N, $P = 0.001$) compared to RBR20 and RBR40, respectively. Set three showed similar findings – greater FW mean force values by 33 (± 20, $P = 0.011$) compared to RBR20 and by 57 (± 26, $P = 0.002$) compared to RBR40. The chance that the magnitudes of the effects were practically meaningful was at least very likely (98.2%). The difference between RBR20 and RBR40 means were also deemed at least likely (93.3%) meaningful.

Peak power ranged from 846 (± 140 W) to 911 (± 191 W), 932 (± 213 W) to 1076 (± 539 W) and 931 (± 207 W) to 1015 (± 310 W) for FW, RBR20 and RBR40, respectively. Set one saw clear and likely-very likely (≥ 90%) chances of meaningful effects of 86 (± 110 W, $P = 0.196$) for RBR20 over FW and 140 (±130 W, $P = 0.088$) for RBR40 over FW. Set three saw a likely (91.7%) chance of a meaningful effect of 160 (± 200 W, $P = 0.163$) for RBR20 over FW. The magnitudes of the remaining between-condition effects were considered practically unclear.

Mean power values ranged from 505 (± 83 W) to 518 (± 84 W), 520 (±100 W) to 536 (± 112 W) and 541 (± 157 W) to 597 (± 158 W) for the FW, RBR20 and RBR40 conditions, respectively. A likely (89.1%) meaningful effect of 77 (± 100 W, $P$ = 0.214) was observed for RBR40 over RBR20 during set one. The effect was greater (91 ± 87 W, $P$ = 0.086) between RBR40 and FW and very likely (95.5%) meaningful. All remaining between conditions effects were regarded as unclear.

**Table 4.4. Concentric set kinematic and kinetic outputs**

| | | n | Mean ± SD | | Condition | n | Mean ± SD |
|---|---|---|---|---|---|---|---|
| PD (m) | FW 1 | 14 | 0.453 ± 0.04 | PV ($m.s^{-1}$) | FW 1 | 14 | 1.14 ± 0.10 |
| | FW 2 | 14 | 0.450 ± 0.04 | | FW 2 | 14 | 1.15 ± 0.11 |
| | FW 3 | 14 | 0.452 ± 0.04 | | FW 3 | 14 | 1.15 ± 0.09 |
| | RBR20 1 | 14 | 0.449 ± 0.04 | | RBR20 1 | 14 | 1.26 ± 0.19 |
| | RBR20 2 | 14 | 0.452 ± 0.05 | | RBR20 2 | 14 | 1.29 ± 0.15 |
| | RBR20 3 | 14 | 0.447 ± 0.04 | | RBR20 3 | 14 | 1.28 ± 0.16 |
| | RBR40 1 | 14 | 0.452 ± 0.04 | | RBR40 1 | 14 | 1.42 ± 0.25 |
| | RBR40 2 | 14 | 0.444 ± 0.05 | | RBR40 2 | 14 | 1.46 ± 0.27 |
| | RBR40 3 | 14 | 0.444 ± 0.04 | | RBR40 3 | 14 | 1.43 ± 0.27 |
| PF (N) | FW 1 | 14 | 1405 ± 239 | MF (N) | FW 1 | 14 | 640 ± 100 |
| | FW 2 | 14 | 1442 ± 245 | | FW 2 | 14 | 650 ± 97 |
| | FW 3 | 14 | 1441 ± 304 | | FW 3 | 14 | 642 ± 96 |
| | RBR20 1 | 14 | 1480 ± 388 | | RBR20 1 | 14 | 604 ± 76 |
| | RBR20 2 | 14 | 1549 ± 322 | | RBR20 2 | 14 | 612 ± 85 |
| | RBR20 3 | 14 | 1578 ± 314 | | RBR20 3 | 14 | 609 ± 88 |
| | RBR40 1 | 14 | 1479 ± 323 | | RBR40 1 | 14 | 624 ± 166 |
| | RBR40 2 | 14 | 1412 ± 284 | | RBR40 2 | 14 | 576 ± 106 |
| | RBR40 3 | 14 | 1492 ± 421 | | RBR40 3 | 14 | 585 ± 105 |
| PP (W) | FW 1 | 14 | 847 ± 140 | MP (W) | FW 1 | 14 | 506 ± 84 |
| | FW 2 | 14 | 909 ± 166 | | FW 2 | 14 | 518 ± 84 |
| | FW 3 | 14 | 911 ± 191 | | FW 3 | 14 | 514 ± 75 |
| | RBR20 1 | 14 | 933 ± 213 | | RBR20 1 | 14 | 521 ± 100 |
| | RBR20 2 | 14 | 970 ± 215 | | RBR20 2 | 14 | 537 ± 113 |
| | RBR20 3 | 14 | 1076 ± 540 | | RBR20 3 | 14 | 529 ± 103 |
| | RBR40 1 | 14 | 984 ± 329 | | RBR40 1 | 14 | 597 ± 233 |
| | RBR40 2 | 14 | 932 ± 208 | | RBR40 2 | 14 | 548 ± 159 |
| | RBR40 3 | 14 | 1015 ± 310 | | RBR40 3 | 14 | 542 ± 158 |

PD = peak displacement, PV = peak velocity, PF = peak force,
MF = mean force, PP = peak power, MP = mean power

**Table 4.5. Between condition differences in kinematic and kinetic outputs, their confidence limits and P-values**

| | | MDiff ± 90% CL | *P* | | | MDiff ± 90% CL | *P* |
|---|---|---|---|---|---|---|---|
| PD (m) | FW 1 - RBR20 1 | 0.0031 ± 0.016 | 0.729 | PV ($m.s^{-1}$) | FW 1 - RBR20 1 | -0.11 ± 0.095 | 0.051 |
| | FW 1 - RBR40 1 | 0.00064 ± 0.022 | 0.959 | | FW 1 - RBR40 1 | -0.28 ± 0.13 | 0.003 |
| | RBR20 1 - RBR40 1 | -0.0025 ± 0.016 | 0.792 | | RBR20 1 - RBR40 1 | -0.16 ± 0.15 | 0.075 |
| | FW 2 - RBR20 2 | -0.0018 ± 0.015 | 0.834 | | FW 2 - RBR20 2 | -0.14 ± 0.062 | 0.002 |
| | FW 2 - RBR40 2 | 0.0053 ± 0.014 | 0.516 | | FW 2 - RBR40 2 | -0.31 ± 0.13 | 0.001 |
| | RBR20 2 - RBR40 2 | 0.0071 ± 0.013 | 0.341 | | RBR20 2 - RBR40 2 | -0.17 ± 0.13 | 0.033 |
| | FW 3 - RBR20 3 | 0.0047 ± 0.015 | 0.598 | | FW 3 - RBR20 3 | -0.12 ± 0.074 | 0.011 |
| | FW 3 - RBR40 3 | 0.0083 ± 0.015 | 0.347 | | FW 3 - RBR40 3 | -0.28 ± 0.13 | 0.002 |
| | RBR20 3 - RBR40 3 | 0.0036 ± 0.022 | 0.773 | | RBR20 3 - RBR40 3 | -0.16 ± 0.15 | 0.088 |
| PF (N) | FW 1 - RBR20 1 | -75 ± 130 | 0.332 | MF (N) | FW 1 - RBR20 1 | 36 ± 22 | 0.015 |
| | FW 1 - RBR40 1 | -74 ± 110 | 0.269 | | FW 1 - RBR40 1 | 16 ± 54 | 0.606 |
| | RBR20 1 - RBR40 1 | 0.36 ± 130 | 0.996 | | RBR20 1 - RBR40 1 | -19 ± 59 | 0.567 |
| | FW 2 - RBR20 2 | -110 ± 74 | 0.024 | | FW 2 - RBR20 2 | 38 ± 28 | 0.034 |
| | FW 2 - RBR40 2 | 31 ± 110 | 0.638 | | FW 2 - RBR40 2 | 73 ± 31 | 0.001 |
| | RBR20 2 - RBR40 2 | 140 ± 110 | 0.039 | | RBR20 2 - RBR40 2 | 35 ± 31 | 0.067 |
| | FW 3 - RBR20 3 | -140 ± 98 | 0.028 | | FW 3 - RBR20 3 | 33 ± 20 | 0.011 |
| | FW 3 - RBR40 3 | -50 ± 170 | 0.608 | | FW 3 - RBR40 3 | 57 ± 26 | 0.002 |
| | RBR20 3 - RBR40 3 | 86 ± 180 | 0.418 | | RBR20 3 - RBR40 3 | 24 ± 26 | 0.127 |
| PP (W) | FW 1 - RBR20 1 | -86 ± 110 | 0.196 | MP (W) | FW 1 - RBR20 1 | 0.0036 ± 0.017 | 0.611 |
| | FW 1 - RBR40 1 | -140 ± 130 | 0.088 | | FW 1 - RBR40 1 | 0.00069 ± 0.023 | 0.086 |
| | RBR20 1 - RBR40 1 | -51 ± 170 | 0.601 | | RBR20 1 - RBR40 1 | -0.0029 ± 0.015 | 0.214 |
| | FW 2 - RBR20 2 | -62 ± 100 | 0.304 | | FW 2 - RBR20 2 | 0.00085 ± 0.014 | 0.521 |
| | FW 2 - RBR40 2 | -23 ± 110 | 0.724 | | FW 2 - RBR40 2 | 0.0071 ± 0.016 | 0.371 |
| | RBR20 2 - RBR40 2 | 39 ± 160 | 0.678 | | RBR20 2 - RBR40 2 | 0.0062 ± 0.014 | 0.821 |
| | FW 3 - RBR20 3 | -160 ± 200 | 0.163 | | FW 3 - RBR20 3 | 0.0046 ± 0.016 | 0.581 |
| | FW 3 - RBR40 3 | -100 ± 190 | 0.343 | | FW 3 - RBR40 3 | 0.0026 ± 0.016 | 0.365 |
| | RBR20 3 - RBR40 3 | 61 ± 340 | 0.755 | | RBR20 3 - RBR40 3 | -0.002 ± 0.021 | 0.81 |

PD = peak displacement, PV = peak velocity, PF = peak force, MF = mean force, PP = peak power, MP = mean power, Mdiff = difference in means, CL = confidence limits

### *Total session kinematics and kinetics*

Table 4.5 displays the total session kinematic and kinetic outputs. The mean (± SD) values for peak velocity were 1.15 (± 0.1 $m.s^{-1}$), 1.27 (± 0.16 $m.s^{-1}$) and 1.33 (± 0.26 $m.s^{-1}$) for FW, RBR20 and RBR40, respectively. The difference observed between FW and RBR20 means of 0.12 (± 0.07 $m.s^{-1}$, $P = 0.011$) was considered a possibly (73.1%) meaningful. The difference between FW and RBR40 means of 0.18 (± 0.08 $m.s^{-1}$, $P = 0.002$) was considered most likely (100%) trivial. The RBR20 and RBR40 comparison was considered unclear.

The mean (± SD) values for mean force were 643 (± 97 N), 608 (± 79 N) and 586 (± 112 N) for FW, RBR20 and RBR40, respectively. FW showed greater mean force values than RBR40 (57 ± 30 N, $P = 0.005$), these differences were most likely (99.7%) a meaningful effect. The difference between FW and RBR20 (35 ± 19 N, $P = 0.007$) was most likely (100%) trivial and comparisons between RBR conditions were unclear. The mean (± SD) values for peak force were 1249 (± 242 N), 1541 (± 319 N) and 1388 (± 319 N) for FW, RBR20 and RBR40, respectively. The only effect deemed clear was the most likely (99.7%) trivial difference of 110 (± 71 N, $P = 0.015$) seen between the RBR20 condition over the FW condition.

The mean (± SD) values for mean power were 512 (± 79 W), 527 (± 102 W) and 478 (± 168 W) and the peak power values were 888 (± 156 W), 987 (± 279 W) and 930 (± 237 W) for FW, RBR20 and RBR40, respectively. RBR20 displayed greater mean power values of 15 (± 44 W, $P = 0.55$) and greater peak power values of 99 (± 100 W, $P = 0.108$) than FW, which were considered at least very likely (≥ 98.8%) trivial. FW resulted in greater mean power outputs compared to RBR40 (34 ± 39 W, $P$ = 0.148), but RBR40 had greater peak power outputs than FW (42 ± 58 W, $P$ = 0.226). The differences were considered most likely (99.7%) meaningful for mean power and likely (92.4%) meaningful for peak power. The magnitudes of the differences between peak displacement values for all conditions were considered most likely (100%) trivial.

**Figure 4.4. Total session mean and peak force and power outputs**

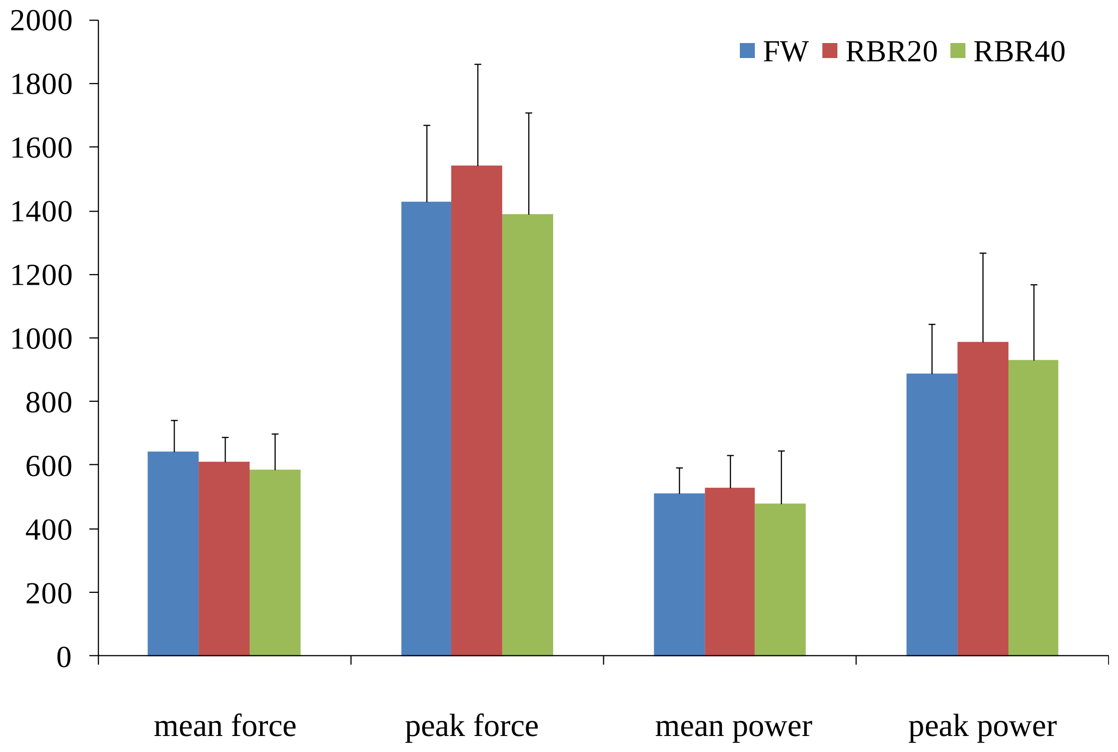


**Table 4.6. Total session concentric kinematic and kinetic outputs**

| | | Mean | ± | SD | | MDiff ± 90% CL | *P* |
|---|---|---|---|---|---|---|---|
| PD (m) | FW | 0.45 | ± | 0.04 | FW - RBR20 | 0.001 ± 0.0056 | 0.743 |
| | RBR20 | 0.45 | ± | 0.04 | FW - RBR40 | 0.0049 ± 0.016 | 0.589 |
| | RBR40 | 0.45 | ± | 0.04 | RBR20 - RBR40 | 0.0039 ± 0.022 | 0.762 |
| PV (m.s) | FW | 1.15 | ± | 0.10 | FW - RBR20 | -0.12 ± 0.073 | 0.011 |
| | RBR20 | 1.27 | ± | 0.16 | FW - RBR40 | -0.18 ± 0.081 | 0.002 |
| | RBR40 | 1.33 | ± | 0.26 | RBR20 - RBR40 | -0.055 ± 0.047 | 0.058 |
| MF (N) | FW | 644 | ± | 97 | FW - RBR20 | 35 ± 19 | 0.007 |
| | RBR20 | 609 | ± | 80 | FW - RBR40 | 57 ± 30 | 0.005 |
| | RBR40 | 587 | ± | 112 | RBR20 - RBR40 | 22 ± 43 | 0.380 |
| PF (N) | FW | 1430 | ± | 242 | FW - RBR20 | -110 ± 71 | 0.015 |
| | RBR20 | 1542 | ± | 320 | FW - RBR40 | 41 ± 130 | 0.588 |
| | RBR40 | 1389 | ± | 320 | RBR20 - RBR40 | 150 ± 220 | 0.240 |
| MP (W) | FW | 513 | ± | 79 | FW - RBR20 | -15 ± 44 | 0.550 |
| | RBR20 | 528 | ± | 103 | FW - RBR40 | 34 ± 39 | 0.148 |
| | RBR40 | 478 | ± | 169 | RBR20 - RBR40 | 49 ± 130 | 0.501 |
| PP (W) | FW | 889 | ± | 156 | FW - RBR20 | -99 ± 100 | 0.108 |
| | RBR20 | 987 | ± | 280 | FW - RBR40 | -42 ± 58 | 0.226 |
| | RBR40 | 930 | ± | 237 | RBR20 - RBR40 | 57 ± 700 | 0.888 |

***DISCUSSION***

Analysis of single repetitions revealed greater RBR concentric F values at 10% displacement relative to the FW condition. When we consider that the net force required for an object to overcome inertia is directly proportional to the mass of the object, one might expect the FW condition to elicit greater force values at the 10% interval compared to the RBR condition due to its greater mass. Cronin et al. (2003a) observed greater concentric muscle activation at the 10% interval for ballistic RBR and non-RBR supine squats compared to the FW counterpart. It is conceivable that the greater muscle activation late during the eccentric contraction impacts the initial stage of the concentric phase however the authors reject this contention. The enhanced muscle activation and greater forces associated with RBR conditions early in the concentric phase may be the result of greater acceleration through the early stages of the concentric phase. The acceleration of an object is directly proportional to the magnitude of the net force applied and is inversely proportional to the mass of the object. The removal of plates from the barbell reduces the inertial properties of the system, even though loads are equated at the apex. The smaller mass of the RBR conditions may allow for greater rates of acceleration during the early stages of the concentric phase. However, it should be noted that the magnitude of the effect statistic for the acceleration variables in the present study were considered very likely trivial. Israetel et al. (2010) reported greater forces for FW compared to RBR at 5% of the concentric phase, in contrast to the results of this present study. The authors equated the conditions by work done (force x displacement) by first determining the average force exerted by the RBR condition and then applying an equivalent mass. A potential reason for the divergent results observed between the present study and that of Israetel et al. (2010) may be attributed to the intensity of the load being lifted. In the present study, a relative load of 50% 1RM was used to normalise between subjects, whereas Israetel et al. (2010) opted for an absolute load of approximately 100 kg for the RBR condition. The load did not differ between the ten recreationally trained subjects. The force-velocity relationship states that the velocity possessed by an object is proportional to the net forces applied to it, that is, the heavier an object the slower one can move it and that acceleration is a derivative of velocity-time data. It is possible that the subjects involved in the study of Israetel et al. (2010) were unable to produce the rates of acceleration seen in this study due to the higher relative intensity of the load. Unfortunately, the strength of the participants was not reported, so at this stage, the reasoning is purely speculative.

Throughout the middle ranges of the concentric phase (30% - 60%) FW force values were greater than that of the RBR conditions, which was expected and is consistent with previous research (Newton et al., 2002). The 90% interval was the only stage at which recorded force values for RBR20 were considered practically greater than those of the FW condition. RBR40 showed greater force values for the 90% and 100% intervals compared to FW resistance. The gradient of T-D relationship of the RBR may influence where throughout the phase force is greatest. For example, a large black band would presumably create a rapid change in force values compared to that of a smaller yellow band which is characterised by a flat T-D curve.

The results showed greater RBR40 repetition power output compared to FW and RBR20 though the ranges of 10% to 50% and again from 90% to 100% of concentric displacement. It was expected that both RBR conditions would result in greater power outputs during the initial stages of the concentric phase, this was not the case. It seems that there is a threshold in terms of the contribution of RBR to the total load, which needs to be surpassed in order for RBR application to be effective in maximising power output. Ebben and Jensen (2002) reported no significant difference in force values or EMG activity between FW and rubber- or chain based resistance back squats when the contribution was 10% of the total load. On the contrary, Wallace et al. (2006) reported greater peak power outputs by 24% from RBR compared to FW when the RBR contribution equalled 20% of apex resistance. An increase in the proportion of RBR to 35% of apex resistance resulted in a decrement in peak power output by 13%. The authors imply that a ceiling exists for the relative contribution of RBR resistance before a decline in power output becomes apparent. The results of the present study do not support this. Finding the RBR load that will maximise repetition power output (RBR Pmax) will be of great benefit to strength and conditioning practitioners and warrants further investigation.

RBR40 power output was greater than FW resistance from 10% to 50% displacement despite greater FW force values at similar percent displacement. This would imply that the increased power outputs were explained by the superior RBR40 velocities. This is not the case. The magnitudes of the differences in velocity outputs were considered trivial for the entire concentric phase. Cronin et al. (2003a) observed greater concentric RBR peak velocity compared to FW throughout the entire range of the repetition. The reasons for the inconsistency in results may be due to the methodological difference between each study. Firstly, the interpretations of Cronin et al. (2003a) may have been confounded due to the fact that the experimental conditions included FW, ballistic RBR and ballistic non-RBR but no non-ballistic RBR condition. The authors suggested that the RBR training provided a similar stimulus to ballistic training techniques. The greater velocities seen throughout the concentric contraction are likely the result of the intent to project the given load. Support for this statement is strengthened when considering that no significant differences in velocity outputs were observed between the ballistic groups. There is no evidence to suggest that a non-ballistic RBR supine squat condition would induce similar kinematic and kinetic profiles as the two ballistic conditions. Alternatively, the statistical analysis used by each study (practical versus statistical significant differences) substantially influences the interpretations of the results. If the current study employed the use of statistical significance, the result interpretations would have been comparable to that of Cronin et al. (2003a) – see Table 4.3.

To date no research has investigated the effects of RBR on set or total session kinematics or kinetics. The results showed that peak force values were greater for the RBR20 condition over that of FW, particularly towards the end of the sets. Conversely, mean force values were greater for the FW compared to RBR20 throughout all sets. The increased mean force values were also observed between FW and RBR40 but only during sets two and three.

Furthermore, the magnitude of the difference between RBR conditions was only practically significant from set three. It seems that the decrement of mean force over the duration of the three sets was most observable for the RBR40 condition (~6%) compared to the relatively stable measures seen for FW and RBR20. Over the course of the total session, the substitution of approximately 20% resistance from FW to RBR during the bench press exercise did not lead to meaningful changes in mean force. However, the increase to 40% did lead to a significant decrease in mean force outputs compared to FW loading. The same effect was observed for mean power values. Previously, it has been suggested that a ceiling exists as to the amount (35%) of RBR that can be applied before a decrement in power is evident (Wallace et al., 2006). The current study did not show a ceiling effect when RBR contribution increased from 20% to 40%, however the differences in the methodology of the each study must be considered.

Whilst references have been made to previous research in an attempt to compare and contrast results, the author would like to highlight the inconsistencies between the studies. The reader should be cognizant that these anomalies which make comparisons difficult. Research concerning the influence of RBR on kinematics and kinetics have examined variations of the squat pattern; free weight back squat (Ebben & Jensen, 2002; Newton et al., 2002), supine squat machine (Cronin et al., 2003) and Smith machine back squat (Wallace et al., 2006). The biomechanical differences of each exercise, namely, the joint configuration and thus joint moments of each exercise as well as the distinct architectural features of the muscles used such as pennation angle and fibre length (number of sarcomeres in series) undoubtedly influence the force, velocity and power outputs of each exercise. The curvilinear nature of the T-D relationship of RBR means that the difference in displacements associated with each exercise would likely result in different kinematic and kinetic characteristics throughout the range of motion of each exercise. In addition to the biomechanical differences between the squat and bench press, loading parameters including the intensity of the load (% 1RM) and the amount of contribution from RBR, the methods used to calculate RBR T-D relationships, the method of data collection and/or data analysis and the statistical analysis.

The reader should also be aware that the method used to quantify RBR T-D properties involved statically measuring the RBR bands at increasing and decreasing lengths. Previous research (Patterson et al., 2001) has reported discrepancies in the amount of tension provided during loading and unloading at the same deformation lengths. The loss of energy during unloading is known as hysteresis and is typical of viscoelastic material (Hamill & Knutzen, 2003). The dynamic nature of the bench press exercise may elicit different tensile properties than those seen with static loading. Future RBR research should quantify the T-D relationships and report the methods used to determine the relationship. Where possible the determination of T-D relationship should replicate the deformation rates and direction of the exercise or movement in question.

***PRACTICAL APPLICATIONS***

The application of RBR affords greater power outputs compared to traditional isoinertial resistance during the first half and again during the late stages of the concentric repetition. Consequently, RBR application leads to a decrease in force outputs at similar percent displacement. This result is also true over multiple sets. The use of RBR training may be more appropriate for athletes who are required to produce power outputs characterised by high velocities such as shot putters compared to those who are required to produce power outputs through high force contribution such as rugby props. When considering the periodisation of athlete training programmes, it seems most appropriate to use FW resistance during the off- or pre-season to promote improvements in strength and hypertrophy, followed by the substitution of a proportion of FW resistance with RBR to augment power outputs as athletes approach competition. The practitioner should be aware of the inherent limitations of RBR, including potential differences in the resting lengths of bands, reduced inertia of the load and the influence of RBR on other determinants considered important in enhancing muscular performance such as rest periods. RBR used in isolation affords a greater ability to manipulate the direction of resistance, allowing the execution of multi-planar movements at velocities more representative of those experienced during performance. RBR is a cost effective, portable tool in the toolbox of the strength and conditioning practitioner provided the biomechanics of such application are understood.

# CHAPTER FIVE: SUMMARY

***SUMMARY***

The use of RBR has become increasingly popular amongst strength and conditioning practitioners to manipulate the kinematic and kinetic profiles of traditional isoinertial resistance and to provide resistance to sport-specific movements. A critical review of the literature reveals a lack of scientific understanding regarding the efficacy of RBR to alter muscular strength and power qualities and less is understood about the transference these alterations have on athletic performance. Uncertainty surrounds the prescription of RBR loading parameters because the T-D characteristics of RBR have not been thoroughly quantified. The research concerning RBR is limited and is typified by methodological inconsistencies and confounding interpretations, making it difficult to construct valid and concise conclusions as to the most appropriate manner to apply RBR.

Tension-Deformation characteristics were determined to provide with an accurate reference to base the prescription of loading parameters during RBR training. The tensile properties were curvilinear in nature and most appropriately represented by a second order polynomial function. Differences between loading and unloading and pre- and post-intervention were considered trivial.

The kinematic and kinetic profiles of FW and two RBR loading schemes during the bench press exercise were presented. It was observed that the

application of RBR resulted in alterations in force and power profiles at the repetition, set and total session level. The middle stages of the repetition were characterised by greater free weight force values, whereas the outer ranges of the repetition were characterised by greater RBR force values. These results corresponded to greater free weight mean force and power outputs and greater RBR peak power outputs when examined over the course of multiple sets. The results indicate that the application of RBR alters the force and power profiles of the bench press exercise but does not significantly alter displacement, velocity or acceleration profiles. The effect of different relative contributions of RBR to the total resistance remains unclear, warranting further investigation into the most appropriate loading parameters for RBR exercises.

### *RECOMMENDATIONS*

To fully comprehend the efficacy of RBR training further acute and longitudinal research investigating numerous variables is still required. Future research should attempt to standardise methodologies in order for results to be comparable and meaningful recommendations to be made. Researchers should quantify the T-D relationships of RBR products and report the methods used to determine the relationship. Where possible the determination of T-D relationship should replicate the deformation rates and direction of the exercise or movement in question. Further research investigating the influence of RBR on exercise kinematic and kinetic profiles should aim to equate resistance loads via the apex method which seems to more accurately represent current training practises. The use of force platforms is recommended to determine apex loads to ensure loads are equated accurately. Free weight exercises better reflect athletic movement and should be measured with a force platform in combination with two linear position transducers. Statistical analysis should include confidence limits and practical inferences rather than statistical significance through *p* values, which better illustrates the likely range of the effect across the population and is less likely to be misinterpreted.

The T-D reference charts developed allow strength and conditioning practitioners to determine the amount of resistance provided at a given displacement, which will enable more accurate monitoring of athlete training loads. Athletes, trainers and coaches should be aware of the discrepancies in resting length of bands and the potential for subsequent musculoskeletal imbalances. Applying RBR to free weight exercises will substitute force for greater power outputs, particularly peak power outputs. This application is suited more to the athlete who is required to produce power with high velocities such as the tennis player than an athlete who is required to produce power characterised by high forces such as a rugby prop. The application of RBR provides a useful tool when periodising athlete training programmes. Free weight resistance may be used during the off-season to promote improvements in strength and hypertrophy followed by substitution of a proportion of free weight resistance with RBR as athletes approach competition to augment peak power outputs. RBR used in isolation affords a greater ability to manipulate the direction of resistance, allows the execution of multi-planar movements at velocities representative of those experienced during performance and is a cost effective, portable tool for strength and conditioning practitioners.

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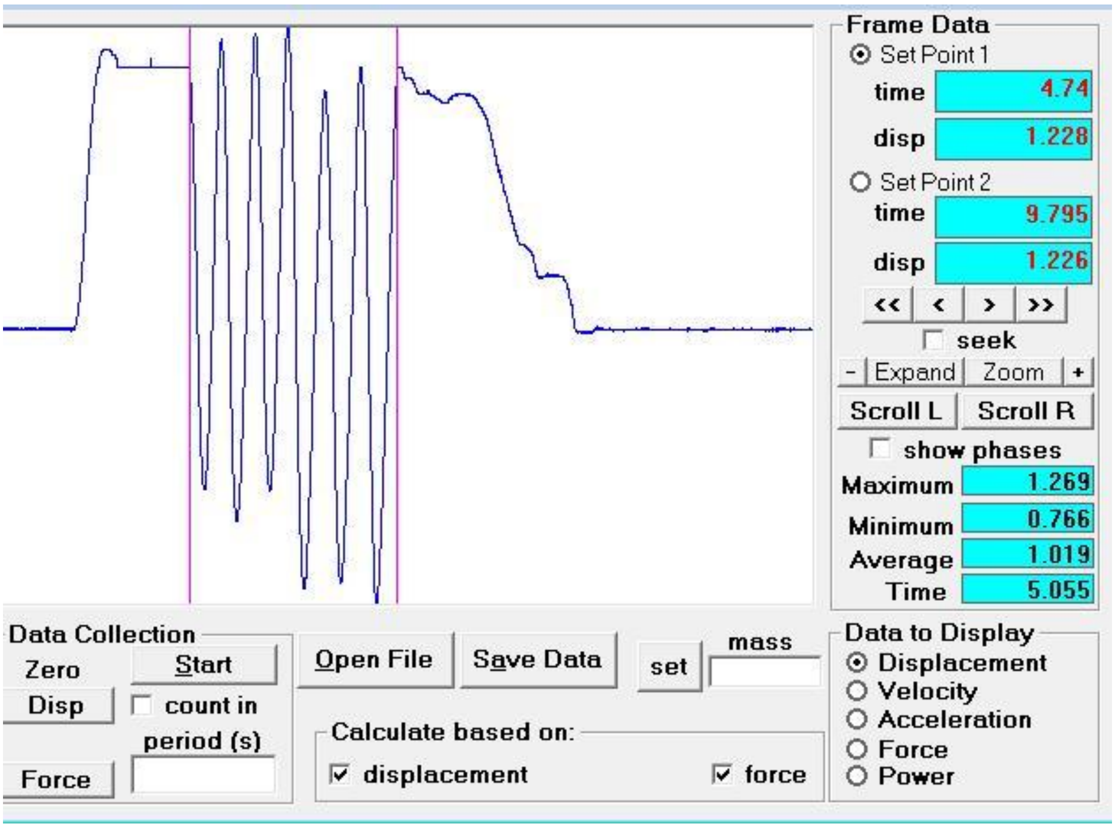
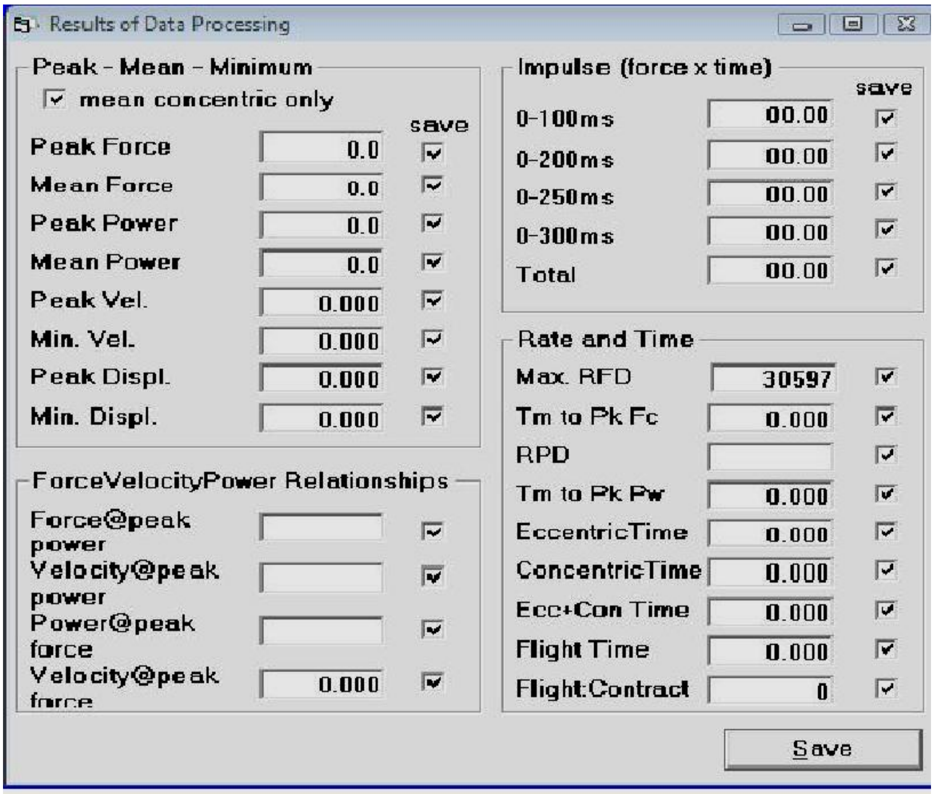
## APPENDICES

***Appendix 1:*** **Ballistic Measurement System data collection panel**



*Appendix 2:* **Ballistic Measurement System data processing panel**



## *Appendix 3:* Eccentric repetition kinematic and kinetic outputs

| Variable | | n | TIME | | | DISPLACEMENT | | | VELOCITY | | | ACCLERATION | | | FORCE | | | POWER | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean (s) | ± | SD | Mean (m) | ± | SD | Mean (m.s$^{-1}$) | ± | SD | Mean (m.s$^{-2}$) | ± | SD | Mean (N) | ± | SD | Mean (W) | ± | SD |
| FW | 10% | 14 | 0.039 | ± | 0.005 | 0.454 | ± | 0.040 | -0.443 | ± | 0.049 | -7.396 | ± | 1.316 | -524.789 | ± | 172.127 | 231.406 | ± | 77.585 |
| RBR20 | | 14 | 0.033 | ± | 0.004 | 0.514 | ± | 0.198 | -0.406 | ± | 0.091 | -7.746 | ± | 1.938 | -478.327 | ± | 148.074 | 190.777 | ± | 73.675 |
| RBR40 | | 14 | 0.028 | ± | 0.006 | 0.453 | ± | 0.059 | -0.421 | ± | 0.064 | -8.736 | ± | 2.158 | -313.449 | ± | 226.291 | 124.881 | ± | 95.839 |
| FW | 20% | 14 | 0.084 | ± | 0.010 | 0.419 | ± | 0.039 | -0.923 | ± | 0.078 | -6.055 | ± | 1.302 | -291.048 | ± | 332.675 | 276.990 | ± | 312.533 |
| RBR20 | | 14 | 0.072 | ± | 0.008 | 0.486 | ± | 0.197 | -0.896 | ± | 0.204 | -6.685 | ± | 1.764 | -381.056 | ± | 242.460 | 332.673 | ± | 232.387 |
| RBR40 | | 14 | 0.063 | ± | 0.011 | 0.423 | ± | 0.055 | -0.983 | ± | 0.170 | -7.616 | ± | 2.005 | -255.836 | ± | 262.344 | 227.686 | ± | 247.096 |
| FW | 30% | 14 | 0.130 | ± | 0.015 | 0.364 | ± | 0.038 | -1.256 | ± | 0.132 | -4.003 | ± | 1.186 | 150.469 | ± | 480.203 | -158.602 | ± | 596.536 |
| RBR20 | | 14 | 0.112 | ± | 0.013 | 0.439 | ± | 0.198 | -1.095 | ± | 0.741 | -4.820 | ± | 1.285 | -83.017 | ± | 330.594 | 62.904 | ± | 387.787 |
| RBR40 | | 14 | 0.098 | ± | 0.017 | 0.375 | ± | 0.051 | -1.409 | ± | 0.255 | -5.626 | ± | 1.642 | -68.798 | ± | 329.619 | 72.510 | ± | 472.147 |
| FW | 40% | 14 | 0.175 | ± | 0.019 | 0.297 | ± | 0.037 | -1.400 | ± | 0.206 | -1.702 | ± | 0.875 | 593.379 | ± | 277.363 | -815.077 | ± | 385.384 |
| RBR20 | | 14 | 0.152 | ± | 0.017 | 0.378 | ± | 0.199 | -1.498 | ± | 0.340 | -2.398 | ± | 0.743 | 314.210 | ± | 336.468 | -530.793 | ± | 359.071 |
| RBR40 | | 14 | 0.134 | ± | 0.023 | 0.310 | ± | 0.046 | -1.679 | ± | 0.331 | -2.959 | ± | 1.101 | 294.490 | ± | 349.029 | -516.934 | ± | 633.069 |
| FW | 50% | 14 | 0.221 | ± | 0.024 | 0.228 | ± | 0.035 | -1.379 | ± | 0.252 | 0.495 | ± | 0.364 | 1084.448 | ± | 678.647 | -1568.312 | ± | 1145.331 |
| RBR20 | | 14 | 0.192 | ± | 0.022 | 0.312 | ± | 0.198 | -1.528 | ± | 0.344 | 0.159 | ± | 0.599 | 898.062 | ± | 556.045 | -1506.382 | ± | 883.282 |
| RBR40 | | 14 | 0.168 | ± | 0.028 | 0.241 | ± | 0.040 | -1.756 | ± | 0.363 | -0.059 | ± | 0.483 | 849.740 | ± | 599.390 | -1422.497 | ± | 892.469 |
| FW | 60% | 14 | 0.267 | ± | 0.029 | 0.164 | ± | 0.033 | -1.253 | ± | 0.247 | 2.335 | ± | 0.638 | 789.850 | ± | 194.166 | -996.262 | ± | 266.969 |
| RBR20 | | 14 | 0.231 | ± | 0.026 | 0.251 | ± | 0.199 | -1.409 | ± | 0.301 | 2.321 | ± | 1.184 | 768.776 | ± | 384.927 | -1168.479 | ± | 562.001 |
| RBR40 | | 14 | 0.204 | ± | 0.033 | 0.173 | ± | 0.035 | -1.627 | ± | 0.392 | 2.721 | ± | 0.626 | 939.939 | ± | 357.294 | -1585.515 | ± | 843.423 |
| FW | 70% | 14 | 0.311 | ± | 0.033 | 0.110 | ± | 0.034 | -1.051 | ± | 0.201 | 3.865 | ± | 1.153 | 906.206 | ± | 98.407 | -971.843 | ± | 212.328 |
| RBR20 | | 14 | 0.271 | ± | 0.031 | 0.197 | ± | 0.201 | -1.192 | ± | 0.231 | 4.124 | ± | 1.703 | 793.397 | ± | 291.722 | -991.622 | ± | 417.703 |
| RBR40 | | 14 | 0.238 | ± | 0.040 | 0.117 | ± | 0.030 | -1.383 | ± | 0.369 | 4.885 | ± | 1.193 | 940.180 | ± | 296.844 | -1308.041 | ± | 601.463 |
| FW | 80% | 14 | 0.358 | ± | 0.038 | 0.065 | ± | 0.036 | -0.766 | ± | 0.137 | 5.086 | ± | 1.340 | 1132.660 | ± | 238.814 | -887.893 | ± | 253.748 |
| RBR20 | | 14 | 0.311 | ± | 0.035 | 0.153 | ± | 0.202 | -0.896 | ± | 0.150 | 5.516 | ± | 2.072 | 986.001 | ± | 245.341 | -899.538 | ± | 309.076 |
| RBR40 | | 14 | 0.274 | ± | 0.045 | 0.070 | ± | 0.024 | -1.009 | ± | 0.291 | 6.733 | ± | 1.812 | 1009.564 | ± | 254.231 | -1010.759 | ± | 409.931 |
| FW | 90% | 14 | 0.403 | ± | 0.043 | 0.036 | ± | 0.039 | -0.420 | ± | 0.073 | 5.842 | ± | 1.259 | 1225.122 | ± | 281.228 | -518.022 | ± | 144.921 |
| RBR20 | | 14 | 0.350 | ± | 0.040 | 0.123 | ± | 0.203 | -0.538 | ± | 0.113 | 6.436 | ± | 2.250 | 1181.584 | ± | 253.507 | -641.365 | ± | 203.988 |
| RBR40 | | 14 | 0.308 | ± | 0.051 | 0.038 | ± | 0.022 | -0.565 | ± | 0.192 | 7.873 | ± | 2.399 | 1025.726 | ± | 274.727 | -605.432 | ± | 263.695 |
| FW | 100% | 14 | 0.449 | ± | 0.049 | 0.025 | ± | 0.041 | -0.023 | ± | 0.014 | 6.021 | ± | 1.026 | 1327.183 | ± | 195.079 | -29.225 | ± | 17.475 |
| RBR20 | | 14 | 0.391 | ± | 0.043 | 0.109 | ± | 0.201 | -0.094 | ± | 0.199 | 6.721 | ± | 2.177 | 1391.638 | ± | 382.148 | -123.132 | ± | 242.546 |
| *RBR40* | | *14* | *0.340* | *±* | *0.046* | *0.027* | *±* | *0.022* | *-0.044* | *±* | *0.044* | *8.271* | *±* | *2.487* | *1302.907* | *±* | *337.920* | *-59.456* | *±* | *63.857* |

## *Appendix 4:* Eccentric repetition kinematic and kinetic outputs

| | | TIME | | DISPLACEMENT | | VELOCITY | |
|---|---|---|---|---|---|---|---|
| | | Effect ± 90% CL | *P* | Effect ± 90% CL | *P* | Effect ± 90% CL | *P* |
| FW - RBR20 | 10% | 0.0061 ± 0.0028 | 0.002 | -0.06 ± 0.091 | 0.266 | -0.037 ± 0.053 | 0.235 |
| FW - RBR40 | | 0.011 ± 0.0046 | 0.001 | 0.0015 ± 0.032 | 0.936 | -0.022 ± 0.038 | 0.312 |
| RBR20 - RBR40 | | 0.005 ± 0.0033 | 0.020 | 0.062 ± 0.1 | 0.311 | 0.015 ± 0.05 | 0.598 |
| FW - RBR20 | 20% | 0.012 ± 0.0051 | 0.001 | -0.067 ± 0.091 | 0.214 | -0.027 ± 0.095 | 0.624 |
| FW - RBR40 | | 0.021 ± 0.0087 | 0.001 | -0.0046 ± 0.028 | 0.779 | 0.06 ± 0.095 | 0.288 |
| RBR20 - RBR40 | | 0.0086 ± 0.0062 | 0.029 | 0.063 ± 0.1 | 0.172 | 0.086 ± 0.11 | 0.191 |
| FW - RBR20 | 30% | 0.018 ± 0.0071 | 0.001 | -0.075 ± 0.092 | 0.455 | -0.16 ± 0.35 | 0.428 |
| FW - RBR40 | | 0.031 ± 0.013 | 0.001 | -0.011 ± 0.025 | 0.288 | 0.15 ± 0.15 | 0.085 |
| RBR20 - RBR40 | | 0.014 ± 0.0093 | 0.022 | 0.064 ± 0.1 | 0.152 | 0.31 ± 0.36 | 0.145 |
| FW - RBR20 | 40% | 0.024 ± 0.0099 | 0.001 | -0.081 ± 0.094 | 0.276 | 0.098 ± 0.15 | 0.262 |
| FW - RBR40 | | 0.042 ± 0.018 | 0.001 | -0.014 ± 0.021 | 0.270 | 0.28 ± 0.19 | 0.025 |
| RBR20 - RBR40 | | 0.018 ± 0.013 | 0.023 | 0.067 ± 0.1 | 0.148 | 0.18 ± 0.18 | 0.098 |
| FW - RBR20 | 50% | 0.029 ± 0.012 | 0.001 | -0.084 ± 0.096 | 0.182 | 0.15 ± 0.15 | 0.103 |
| FW - RBR40 | | 0.053 ± 0.022 | 0.001 | -0.013 ± 0.016 | 0.242 | 0.38 ± 0.21 | 0.007 |
| RBR20 - RBR40 | | 0.024 ± 0.015 | 0.017 | 0.071 ± 0.1 | 0.138 | 0.23 ± 0.18 | 0.038 |
| FW - RBR20 | 60% | 0.036 ± 0.015 | 0.001 | -0.086 ± 0.097 | 0.294 | 0.16 ± 0.13 | 0.060 |
| FW - RBR40 | | 0.063 ± 0.027 | 0.001 | -0.0081 ± 0.013 | 0.192 | 0.37 ± 0.21 | 0.008 |
| RBR20 - RBR40 | | 0.028 ± 0.018 | 0.020 | 0.078 ± 0.1 | 0.140 | 0.22 ± 0.17 | 0.044 |
| FW - RBR20 | 70% | 0.04 ± 0.017 | 0.001 | -0.087 ± 0.098 | 0.243 | 0.14 ± 0.1 | 0.028 |
| FW - RBR40 | | 0.074 ± 0.031 | 0.001 | -0.0071 ± 0.01 | 0.183 | 0.33 ± 0.18 | 0.007 |
| RBR20 - RBR40 | | 0.033 ± 0.022 | 0.019 | 0.08 ± 0.1 | 0.137 | 0.19 ± 0.15 | 0.045 |
| FW - RBR20 | 80% | 0.047 ± 0.02 | 0.001 | -0.088 ± 0.099 | 0.449 | 0.13 ± 0.07 | 0.006 |
| FW - RBR40 | | 0.084 ± 0.035 | 0.001 | -0.005 ± 0.011 | 0.161 | 0.24 ± 0.14 | 0.008 |
| RBR20 - RBR40 | | 0.037 ± 0.025 | 0.020 | 0.083 ± 0.098 | 0.141 | 0.11 ± 0.11 | 0.103 |
| FW - RBR20 | 90% | 0.053 ± 0.022 | 0.001 | -0.087 ± 0.098 | 0.797 | 0.12 ± 0.063 | 0.006 |
| FW - RBR40 | | 0.094 ± 0.04 | 0.001 | -0.0018 ± 0.012 | 0.149 | 0.14 ± 0.086 | 0.011 |
| RBR20 - RBR40 | | 0.041 ± 0.028 | 0.021 | 0.085 ± 0.098 | 0.157 | 0.026 ± 0.092 | 0.618 |
| FW - RBR20 | 100% | 0.058 ± 0.024 | 0.001 | -0.084 ± 0.099 | 0.862 | 0.071 ± 0.097 | 0.220 |
| FW - RBR40 | | 0.11 ± 0.046 | 0.001 | -0.0014 ± 0.014 | 0.157 | 0.021 ± 0.018 | 0.062 |
| RBR20 - RBR40 | | 0.051 ± 0.026 | 0.004 | 0.082 ± 0.097 | 0.297 | -0.05 ± 0.1 | 0.409 |

| | | ACCLERATION | | FORCE | | POWER | |
|---|---|---|---|---|---|---|---|
| | | Effect ± 90% CL | *P* | Effect ± 90% CL | *P* | Effect ± 90% CL | *P* |
| FW - RBR20 | 10% | 0.35 ± 0.82 | 0.461 | -46 ± 71 | 0.267 | 41 ± 43 | 0.121 |
| FW - RBR40 | | 1.3 ± 1.2 | 0.066 | -210 ± 100 | 0.003 | 110 ± 48 | 0.002 |
| RBR20 - RBR40 | | 0.99 ± 1.2 | 0.176 | -160 ± 120 | 0.034 | 66 ± 64 | 0.093 |
| FW - RBR20 | 20% | 0.63 ± 0.73 | 0.149 | 90 ± 160 | 0.346 | -56 ± 160 | 0.546 |
| FW - RBR40 | | 1.6 ± 1.1 | 0.022 | -35 ± 90 | 0.503 | 49 ± 98 | 0.390 |
| RBR20 - RBR40 | | 0.93 ± 1.1 | 0.160 | -130 ± 140 | 0.132 | 100 ± 150 | 0.230 |
| FW - RBR20 | 30% | 0.82 ± 0.53 | 0.018 | 230 ± 230 | 0.094 | -220 ± 240 | 0.127 |
| FW - RBR40 | | 1.6 ± 0.88 | 0.006 | 220 ± 160 | 0.033 | -230 ± 230 | 0.105 |
| RBR20 - RBR40 | | 0.81 ± 0.81 | 0.102 | -14 ± 160 | 0.877 | -9.6 ± 27 | 0.928 |
| FW - RBR20 | 40% | 0.7 ± 0.35 | 0.004 | 280 ± 230 | 0.050 | -280 ± 570 | 0.094 |
| FW - RBR40 | | 1.3 ± 0.54 | 0.001 | 300 ± 160 | 0.005 | -300 ± 420 | 0.107 |
| RBR20 - RBR40 | | 0.56 ± 0.5 | 0.068 | 20 ± 270 | 0.898 | -14 ± 15 | 0.945 |
| FW - RBR20 | 50% | 0.34 ± 0.35 | 0.116 | 190 ± 320 | 0.323 | -62 ± 63 | 0.834 |
| FW - RBR40 | | 0.55 ± 0.19 | 0.001 | 230 ± 190 | 0.045 | -150 ± 2800 | 0.645 |
| RBR20 - RBR40 | | 0.22 ± 0.36 | 0.302 | 48 ± 290 | 0.771 | -84 ± 82 | 0.727 |
| FW - RBR20 | 60% | 0.014 ± 0.54 | 0.964 | 21 ± 180 | 0.841 | 170 ± 180 | 0.176 |
| FW - RBR40 | | -0.39 ± 0.4 | 0.111 | -150 ± 160 | 0.114 | 590 ± 15000 | 0.010 |
| RBR20 - RBR40 | | -0.4 ± 0.6 | 0.256 | -170 ± 210 | 0.171 | 420 ± 3400 | 0.058 |
| FW - RBR20 | 70% | -0.26 ± 0.74 | 0.547 | 110 ± 160 | 0.227 | 20 ± 74 | 0.856 |
| FW - RBR40 | | -1 ± 0.76 | 0.033 | -34 ± 130 | 0.662 | 340 ± 1700 | 0.040 |
| RBR20 - RBR40 | | -0.76 ± 0.88 | 0.150 | -150 ± 160 | 0.120 | 320 ± 390 | 0.045 |
| FW - RBR20 | 80% | -0.43 ± 0.84 | 0.379 | 150 ± 120 | 0.058 | 12 ± 6.8 | 0.867 |
| FW - RBR40 | | -1.6 ± 0.98 | 0.011 | 120 ± 140 | 0.143 | 120 ± 100 | 0.274 |
| RBR20 - RBR40 | | -1.2 ± 1.1 | 0.078 | -24 ± 120 | 0.726 | 110 ± 1100 | 0.295 |
| FW - RBR20 | 90% | -0.59 ± 0.86 | 0.245 | 44 ± 57 | 0.196 | 120 ± 96 | 0.016 |
| FW - RBR40 | | -2 ± 1.2 | 0.009 | 200 ± 150 | 0.031 | 87 ± 70 | 0.198 |
| RBR20 - RBR40 | | -1.4 ± 1.3 | 0.080 | 160 ± 140 | 0.066 | -36 ± 370 | 0.594 |
| FW - RBR20 | 100% | -0.7 ± 0.84 | 0.164 | -64 ± 110 | 0.330 | 94 ± 150 | 0.183 |
| FW - RBR40 | | -2.3 ± 1.2 | 0.005 | 24 ± 120 | 0.721 | 30 ± 49 | 0.078 |
| RBR20 - RBR40 | | -1.6 ± 1.3 | 0.059 | 89 ± 150 | 0.303 | -64 ± 41 | 0.391 |

## *Appendix 5:* Eccentric total session kinematic and kinetic outputs

| | | Mean | ± | SD | | Effect ± 90% CL | *P* |
|---|---|---|---|---|---|---|---|
| PD (m) | FW | 0.450 | ± | 0.039 | FW - RBR20 | 0.0029 ± 0.011 | 0.656 |
| | RBR20 | 0.447 | ± | 0.040 | FW - RBR40 | 0.45 ± 2.2 | 0.719 |
| | RBR40 | 0.446 | ± | 0.043 | RBR20 - RBR40 | 0.0005 ± 0.015 | 0.955 |
| PV ($m.s^{-1}$) | FW | -1.512 | ± | 0.132 | FW - RBR20 | 0.2 ± 0.1 | 0.004 |
| | RBR20 | -1.711 | ± | 0.281 | FW - RBR40 | 0.36 ± 0.17 | 0.003 |
| | RBR40 | -1.869 | ± | 0.354 | RBR20 - RBR40 | 0.16 ± 0.19 | 0.163 |
| PF (N) | FW | 585.479 | ± | 85.413 | FW - RBR20 | 48 ± 32 | 0.021 |
| | RBR20 | 537.474 | ± | 68.803 | FW - RBR40 | 51 ± 21 | 0.001 |
| | RBR40 | 486.412 | ± | 85.867 | RBR20 - RBR40 | 51 ± 38 | 0.034 |
| PP (W) | FW | -596.886 | ± | 84.799 | FW - RBR20 | 7.3 ± 63 | 0.839 |
| | RBR20 | -604.231 | ± | 139.856 | FW - RBR40 | 4.6 ± 24 | 0.745 |
| | RBR40 | -608.814 | ± | 186.994 | RBR20 - RBR40 | 4.6 ± 100 | 0.938 |

*Appendix 6:* **Ethics approval sheet**

# M E M O R A N D U M

*Auckland University of Technology Ethics Committee (AUTEC)*

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| | |
|---|---|
| To: | Nigel Harris |
| From: | **Madeline Banda** Executive Secretary, AUTEC |
| Date: | 11 November 2009 |
| Subject: | Ethics Application Number 09/246 **The acute effects of rubber based resistance on repetition and total set kinetics and kinematics during the bench press exercise.** |

---

Dear Nigel

Thank you for providing written evidence as requested. I am pleased to advise that it satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC) at their meeting on 12 October 2009 and that I have approved your ethics application. This delegated approval is made in accordance with section 5.3.2.3 of AUTEC's *Applying for Ethics Approval: Guidelines and Procedures* and is subject to endorsement at AUTEC's meeting on 14 December 2009.

Your ethics application is approved for a period of three years until 11 November 2012.

I advise that as part of the ethics approval process, you are required to submit the following to AUTEC:

- A brief annual progress report using form EA2, which is available online through *http://www.aut.ac.nz/research/research-ethics*. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 11 November 2012;
- A brief report on the status of the project using form EA3, which is available online through *http://www.aut.ac.nz/research/research-ethics*. This report is to be submitted either when the approval expires on 11 November 2012 or on completion of the project, whichever comes sooner;

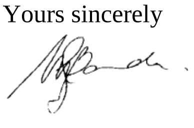
It is a condition of approval that AUTEC is notified of any adverse events or if the research does not commence. AUTEC approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are reminded that, as applicant, you are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

Please note that AUTEC grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this. Also, if your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply within that jurisdiction.

When communicating with us about this application, we ask that you use the application number and study title to enable us to provide you with prompt service. Should you have any further enquiries regarding this matter, you are welcome to contact Charles Grinter, Ethics Coordinator, by email at ethics@aut.ac.nz or by telephone on 921 9999 at extension 8860.

On behalf of the AUTEC and myself, I wish you success with your research and look forward to reading about it in your reports.

Yours sincerely



Madeline Banda
**Executive Secretary**
**Auckland University of Technology Ethics Committee**

***Appendix 7*: Participant information sheet**

# Participant Information Sheet

**Date Information Sheet Produced:**
November 2009

**Project Title**
The acute effects of rubber based resistance on repetition and total session kinetics and kinematics during the bench press exercise.

**An Invitation**
You are invited to take part in this study, which is being carried out by Adam Godfrey as partial fulfilment of a Master in Health Science qualification. Your participation in this study is voluntary. You are free to withdraw consent and discontinue participation at anytime without any consequences. Signing and dating the consent form indicates that you have freely given your consent to participate, and that there has been no coercion or inducement to participate.

**What is the purpose of this research?**
The aim of this study is to examine the influence of rubber based resistance on kinematic (the description of motion) and kinetic (the forces acting on the system which create the motion) variables during the bench press exercise. The benefit of this research will be to provide valuable information as to the most appropriate use of rubber based resistance to improve strength and power. It is anticipated that this research will be submitted to be published in reputable sports science journals and presented at the New Zealand Sports Medicine and Science Conference.

**How was I chosen for this invitation?**

- Volunteers that meet the criteria will be included in this study.
- These criteria include:
- You are between the ages of 18 and 35 years.
- You have at least one year of recent regular weight training experience.
- You have previous weight training experience using rubber based resistance.
- You do not currently have any injury or health problems that would impair your ability to complete three testing sessions consisting of three sets of six repetitions of a bench press with and without rubber based resistance.

**What will happen in this research?**
Each participant will be required to participate in a total of four sessions. During the first session you will have your one repetition maximum (the maximum weight you can lift once) bench press determined on a customised bench and a chance to familiarise yourself with the equipment setup. During the next three sessions, in a random order, you will have your bench press power tested at a lighter load, with and without the use of bands. Each session will involve a standard warm-up and three sets of six repetitions. Each session will be separated by at least 48 hours. Please ensure that the 24 hours prior to each test is a standard as possible. That is, avoid any weight training or strenuous exercise. This will greatly aid the accuracy of the tests.

**What are the discomforts and risks?**
There is possible risk of injury, particularly involving the shoulder joint. The potential for injury during this study will not be outside of those risks performed during your regular training sessions.

**How will these discomforts and risks be alleviated?**
The Millennium Institute of Sport and Health as well as Harbour Rugby have specific protocols in place to deal with potential injury during testing or training sessions. In house medical staff will be on-site during the testing procedures. Additionally, all participants are covered under the Injury Prevention, Rehabilitation and Compensation Act 2001. The Accident Compensation Corporation (ACC) is a crown organisation which provides comprehensive, no-fault personal injury cover for all New Zealanders.

**What are the benefits?**
You will gain detailed information on your strength and power capacity. This information may better aid you in planning future training programmes.

**What compensation is available for injury or negligence?**
In the unlikely event of a physical injury as a result of your participation in this study, rehabilitation and compensation for injury by accident may be available from the Accident Compensation Corporation, providing the incident details satisfy the requirements of the law and the Corporation's regulations.

**How will my privacy be protected?**
The identity of individuals will not be made available to any other source, and any information published elsewhere will have subject identities concealed.
What are the costs of participating in this research?
The only cost to you the participant is approximately three hours of your time.

**What opportunity do I have to consider this invitation?**
You will have one week to consider the invitation, in which time you will have the opportunity to ask any questions and to have them answered.

**How do I agree to participate in this research?**
Signing the consent form indicates that you have freely given your consent to participate, and that there has been no coercion or inducement to participate.

**Will I receive feedback on the results of this research?**
Signing the consent form indicates that you have freely given your consent to allow your individual results to be released to Harbour Rugby's Head Strength and Conditioning Trainer, and that there has been no coercion or inducement to participate.

**What do I do if I have concerns about this research?**
Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Nigel Harris, nigel.harris@aut.ac.nz, 921 9999

Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEC, Madeline Banda, *madeline.banda@aut.ac.nz*, 921 9999 ext 8044.

Whom do I contact for further information about this research?

***Researcher Contact Details:***
Adam Godfrey
Division of Sport & Recreation
Faculty of Health
Auckland University of Technology
E-mail adamgodfrey7@hotmail.com

***Supervisor Contact Details:***
Nigel Harris
Project Supervisor
Division of Sport & Recreation
Faculty of Health
Auckland University of Technology
E-mail: nigel.harris@aut.ac.nz
Ph: 921 9999

**Approved by the Auckland University of Technology Ethics Committee on 11 November 2009. AUTEC Reference number** 09/246.

***Appendix 8*: Informed consent sheet**

# Consent to Participation in Research

| | |
|---|---|
| Title of Project: | **The acute effects of rubber based resistance on repetition and total session kinetics and kinematics during the bench press exercise**. |
| Project Supervisor: | **Dr. Nigel Harris**<br>**Dr. John Cronin** |
| Researcher: | **Adam Godfrey** |

- I have read and understood the information provided about this research project in the Information Sheet dated 11 November 2009.
- I have had an opportunity to ask questions and to have them answered.
- I understand that the data recorded from the testing sessions will be stored on a computer for analysis.
- I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way. If I withdraw, I understand that all relevant data, or parts thereof, will be destroyed
- I agree to take part in this research.
- I have no injuries or medical conditions that may affect my ability to perform upper body weight training.
- I agree to allow my individual results to be disseminated to Harbour Rugby's Head Strength and Conditioning Trainer (please tick one).

  Yes○ No○
- I wish to receive a copy of the report from the research (please tick one).

  Yes○ No○

Participant signature: .......................................................

Participant Name: ……………………………………..

Date: ……………………………………..

Contact Details:
Adam Godfrey
Division of Sport & Recreation
Faculty of Health

Auckland University of Technology
E-mail adamgodfrey7@hotmail.com

**Approved by the Auckland University of Technology Ethics Committee on 11 November 2009. AUTEC Reference number** 09/246