

**THE ACUTE EFFECTS OF WEIGHT TRAINING ON SOFTBALL  
THROWING VELOCITY**

by

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## ABSTRACT

The short-term enhancement of physical performance known as post-activation potentiation could be exploited in the design of sport-specific training sessions. The purpose of this study was to compare the potentiation of softball throwing velocity following two kinds of resistance-training session: a control session consisting of traditional heavy-load sets, and an experimental “Pmax” session consisting of sets of loads selected to maximise the mean power output during explosive bench presses. Both sessions included plyometric medicine ball chest passes. Eight male softball players of premier grade, with at least 2 yr experience of resistance training, performed the two sessions in a crossover fashion, with 30 min recovery between sessions. Softball throwing velocity was measured with a radar gun immediately before and at 2-min intervals 4-10 min after each session. Percent effects on throwing speed were analyzed via log transformation, and *t* statistics were used to make magnitude-based inferences with respect to the smallest important change of 2%. The average throwing velocity increased between pre and post tests for both treatments; the average increase was a substantial 2.3% (0.5 to 4.1%). Throwing velocity after Pmax training was a trivial 0.4% slower relative to that after heavy-load training (90% confidence limits -1.2 to 1.9%). There was a greater change in throwing velocity by 10 min post treatment than by 4 min post treatment; the change by 10 min was 5.0% (3.2 to 6.7%) for the Pmax training session and 5.3% (2.1 to 8.6%) for the heavy-load session. These effects were almost certainly beneficial for throwing speed, but the difference between them was unclear (-0.3%; -3.7 to 3.1%). The mean change between 4 and 10 min for both treatments combined was 5.1% (90% confidence limits 3.6 to 6.7%). The short-term enhancement of throwing performance following heavy-load and Pmax training sets has implications for the design of softball warm-up routines. There is also the potential for softball players to use such training to improve their throwing velocity during games.

## GLOSSARY OF TERMS

Ballistic weight training	A training method that combines elements of plyometric training and weight training, and involves the lifting of relatively light loads at high speeds.
Combined weight training	Lifts in a complex of structured ground-based movement patterns that combine basic strength and explosiveness to maximise power.
Complex training	Alternates bio-mechanically comparable heavy resistance weight training and plyometric exercises in the same workout.
Contrast training	Involves the use of alternation of sets of heavy and light loads to train a muscle group in a single workout.
Excitatory Impulse	To rise to a higher energy level than the ground state.
Explosive strength	The maximum rate of force development achieved in an explosive contraction.

Inhibitory Impulse	To restrain or hold back an impulse or natural reaction.
Maximum voluntary contraction	The maximum force that can be developed in a muscle during a voluntary active muscle-action.
Neuromuscular activation	Enhanced activation results in excitatory and inhibitory impulses continually bombarding synaptic junctions between neurons, altering their threshold by increasing or decreasing its tendency to fire. In all-out, high power exercise, a large degree of disinhibition benefits performance because it maximally activates a muscle's motor units.
Pmax	Maximum mechanical power output.
Plyometrics	Exercises that are used to improve power output and increase explosiveness by training the muscles to do more work in a shorter amount of time. This is accomplished by optimizing the stretch-shortening cycle.

Post-activation potentiation

The term given to the increased contractile capability of the muscle after subjecting the muscle to maximal or near maximal forces.

Post-tetanic potentiation

During MVC's the activated motor units are stimulated with very high tetanic stimulus frequencies of more than 100Hz. After tetanic stimulations, the effectiveness of stimulus transmittance in excitatory synaptic junctions between nervous cells can remain increased for several minutes. A PTP expresses itself in the form of a better input-output relationship: After tetanization, an ideal pre-synaptic stimulation leads to a higher excitatory post-synaptic potential.

Reactive strength

The ability to utilize the muscle pre-stretch in a stretch-shortening cycle movement and quickly switch from an eccentric (stretching) contraction to a concentric (shortening) contraction.

Stretch-shortening cycle

A movement type, in which the concentric muscle action is immediately preceded by an eccentric muscle action.

The following abbreviations are used throughout this thesis:

BT	Bench press throws
CMJ	Countermovement jump
GRF	Ground reaction force
HS	Heavy set
JS	Jump squat
LCMJ	Loaded countermovement jump
mRFD	Maximum rate of force development
MVC	Maximum voluntary contraction
PAP	Post-activation potentiation
PTP	Post-tetanic potentiation
RBPT	Rebound bench press throw
RFD	Rate of force development
SSC	Stretch-shortening cycle
VJ	Vertical jump
1RM	One repetition maximum

## CHAPTER 1: INTRODUCTION

One of the issues to be considered when developing strength and power is sport specific training, specially, in the off-season. In New Zealand, sport specific training is often de-emphasised in softball and instead, basic generic strength and speed exercises are used to establish a training base. Recently Lachowetz, Evon and Pastiglione (1998) have suggested that throwing velocity is an important determinant of success in baseball. Athletes and coaches alike have explored ways to improve this parameter. Nevertheless, few studies have investigated the development of softball throwing velocity.

Sale, (1991) defined strength as the peak force developed during a maximum voluntary contraction (MVC) under a given set of circumstances. Harman (1993) has further added to this definition by defining body position, body movement and by which force is applied as well as the movement type (concentric, eccentric isometric, plyometric) and movement speed. The product of strength and speed is power and is known as speed-strength by some practitioners (Lundin & Berg, 1991; Schmidtbleicher, 1985). In mechanical terms, power is the rate of doing work and is defined as  $\text{power} = \text{force} \times \text{velocity}$  (Young, 1993). The relative importance of strength and power can be established by correlating the results of specific strength and power tests with sports performance. Therefore one of the challenges in training is to ensure that the strength or power that the athlete exerts in executing the necessary sporting action resembles the posture, speed, pattern and direction of movement that is performed in competition.

Strength development should be a one of the prime concerns for anyone attempting to improve an athlete's physical performance. Several traditional training methods employed since the ancient times involved a multitude of techniques designed to enable athletes to run faster, jump higher and throw an object as far as possible (Bompa, 1994). Maximal strength is the basic quality which underpins speed strength



especially when an external object such as a small ball is to be moved. Two factors requiring consideration when looking at developing maximal strength. They include increasing the cross-sectional area (CSA) of muscle, (which is achieved by bodybuilding/hypertrophy), and extensive strength training using heavier loads with longer rest periods. The heavier loads are thought to induce neural adaptations and are often determined using a one repetition maximum (1-RM) test. Thus strength training interventions are often referred to as a percentage of the maximum weight that the athlete can lift once as assessed by the 1-RM strength test (Newton & Kraemer, 1994).

Vossen, Kramer, Burke and Vossen (2000) have described plyometrics as a non-traditional form of resistance training emphasising the loading of muscles during an eccentric muscle action followed immediately by a rebound concentric action. Plyometrics training is most frequently performed using athlete's bodyweight rather than a mechanical load, although weights can be added for training to increase the resistance (Blattner & Noble, 1979; Ford, Puckett, Drummond, Sawyer, Gantt & Fussell, 1983; Polhemus, Osina, Burkhardt, & Patterson, 1980). This has been previously demonstrated by Newton and McEvoy (1994) who have used medicine balls and conventional weight training methods to examine the effects of upper body plyometric training. Current practice and research often involves traditional medicine ball throws for the upper body, and depth jumps, bounding and hopping exercises for the lower body.

A comparatively new method of training termed ballistic training combines the resistance lifting training and elements of plyometric training. Ballistic training overcomes one of the problems with traditional resistance training and power development that is the deceleration of the bar in the later part of the concentric phase of a traditional weight training movement. This can be overcome if the athlete actually throws or jumps with the weight. Ballistic resistance infers accelerative high velocity of the load or ones-self into free space (Newton & Kraemer, 1994). For martial arts skilled athletes, where speed rather than force is important, attempted ballistic training may be a helpful subsidiary to resistance training (Olsen & Hopkins, 2003). McEvoy and

Newton (1998) report the lifting of relatively light loads (30% 1-RM) at high speeds to be effective for maximizing power output and that heavy loads (80- 90% 1-RM) have been recommended for improving maximum dynamic performance. Atha (1981) describes dynamic performance as strength efforts repeated several times until halted by either fatigue or the clock.

Another training modality, which is attracting considerable interest, is termed complex training. This type of training is a combination of the aforementioned traditional and ballistic techniques. The training usually combines a heavy resistance exercise with a power movement and has been shown to acutely enhance performance (Adams, O'Shea, O'Shea & Climstein, 1992; Blakey, & Southard, 1987; Chu, 1992; Clutch, Wilton, McGown, & Bryce, 1983; Fleck, & Kontor, 1986; Ford et al., 1983; Hedrick, 1994; Hedrick 1996; Hedrick & Anderson, 1996). It may be that this type of training modality is suitable for improving throwing velocity. While this may appear so Hrysomallis and Kidgell (2001) reported that there is limited research, particularly for upper body plyometric movements, to support this practice. However Ebben and Watts (1998) listed a number of training studies which have examined combined weight and plyometric training programmes. Chu (1996) stated the power increases achieved through complex training were up to three times more effective than conventional training programmes. More recently new research has focused on the acute effects of complex training using lower limb exercises and the effects of heavy dynamic resistance exercise on upper body power.

The foundation on which this complex training is based assumes that the explosive capability of muscle is heightened after it has been exposed to maximal or near maximal contractions. This phenomenon has been referred to as postactivation potentiation (PAP). According to Docherty, Robbins and Hodgson (2004) two theories have been proposed to explain the PAP. One theory proposes that the pre-stimulation results in neural adaptations such as increased descending activity from the higher motor centers, direct myoelectrical potentiation, increased synchronization of motor unit firing, reduced peripheral inhibition from Golgi tendon organ, reduced reciprocal inhibition from the Renshaw Cell, post tetanic

potentiation and/or enhanced reciprocal inhibition of the antagonist musculature may account for the improvements in power output (Baker 2003; Baker, 2001; Ebben, Jensen & Blackard, 2000; Ebben & Watts, 1998; Lyttle, et al., 1996; Fleck & Kontor, 1986; Gullich & Schmidtbleicher, 1996).

The alternative theory that has been considered is phosphorylation of the myosin light chain (MLC). An increase in sarcoplasmic  $\text{Ca}^{+2}$  from muscle stimulation activates MLC kinase, which is responsible for making more ATP available at the actin-myosin complex. This in turn increases the rate of actin-myosin crossbridging (Sale, 2002). It is thought by researchers that phosphorylation and post-tetanic potentiation is not the only mechanisms contributing to PAP. It is possible that PAP is the result of exchanges between neural and mechanical adaptations and that a number could function together simultaneously. These exchanges are not well understood (Docherty et al. 2004).

## **STATEMENT OF THE PROBLEM**

This study was designed to determine if there were any post-tetanic potentiation effects following an acute intervention, utilising complex/contrast resistance training exercises, on the speed of a softball in overhand throwing. The complex/contrast resistance training was characterised by the use of both heavy and light loads and plyometric activity on biomechanically similar exercises in the same set and session.

## **PURPOSE STATEMENT**

The purpose of the study was to introduce evidence that "complex/contrast training" in the development of a discrete skill, such as throwing a softball, would in effects acutely improve the speed of a thrown ball.

## **BASIC ASSUMPTIONS**

Basic assumptions were:

1. That overhand throwing can be evaluated by measuring the speed of a thrown ball utilising appropriate measuring devices.
2. That non-specific power variables can be evaluated by measuring the vertical displacement of the bar in a bench-press throw exercise.
3. That progressive resistance training and plyometric exercises, using either a complex training heavy-load or a maximal mechanical output ( $P_{max}$ ) treatment are related to the neuromuscular skill being tested.

## **STUDY LIMITATIONS**

The limitations of the study were:

1. Generalised in the first instance only to Premier Men Softball Players.
2. The experimental period was limited to acute effects over two intervention periods.
3. All strength training data was collected in a laboratory setting. All attempts were made to maintain a constant laboratory environment utilising an internal air conditioning unit.
4. All throwing velocity data was collected in an indoor stadium where it was felt that the environment was stable and not affected by wind or weather variations.
5. Subjects may not have been equally motivated to during each data collection session. Verbal instruction and feedback was standardised and all efforts were made to ensure all subjects produced maximal effort in each of the trials.
6. Could not exclude the possibility, but small, chance of injury resulting from continual maximal throwing.

## **STUDY DELIMITATIONS**

1. This study was de-limited to an evaluation of two different training approaches in the development of speed in throwing a softball.

2. The methods used were progressive resistance training exercises, utilising maximum strength and explosive power and also incorporating functional sport specific throwing patterns.
3. All participants were male, aged between 23 and 34 years old and without any injury or illness that could have affected their performance.
4. It was further delimited to 8 softball players from the Auckland area.
5. All participants were of an athletic background and were required to have weight training experience of at least two years.

## CHAPTER 2: EFFECTS OF RESISTANCE TRAINING ON THROWING VELOCITY—A BRIEF REVIEW

### INTRODUCTION

Currently the throwing norms (mean  $\pm$  SD) for the New Zealand national players are: outfielders  $33.6 \pm 1.9 \text{ m}\cdot\text{s}^{-1}$ , for infielders  $28.6 \pm 2.8 \text{ m}\cdot\text{s}^{-1}$ , and for the catchers  $29.4 \pm 3.6 \text{ m}\cdot\text{s}^{-1}$ , and collectively for the team  $31.9 \pm 2.5 \text{ m}\cdot\text{s}^{-1}$  (data collected by NZ Softball Sport Science Staff during an early season training camp 2002). The average time to run to first base from home plate was 2.8 seconds. A comparison of these figures shows that the fielders throw the ball an average of  $28.6 \text{ m}\cdot\text{s}^{-1}$  compared to runners who cover only  $6.58 \text{ m}\cdot\text{s}^{-1}$ . By improving throwing velocity by as little as 2% this distance changes to  $29.2 \text{ m}\cdot\text{s}^{-1}$ . This may enable fielders to have more time to make decisions, throw the ball further (Watkinson, 1998) or to add further pressure to the runners by giving them less time to reach first base resulting in the fielding side getting more outs. While there is a lot more than sheer muscular strength and velocity involved in softball it is obvious that this quality is important to success and also injury prevention. Thus, the velocity of a softball throw is dependent on the athlete's ability to develop maximal force rapidly; this type of force is called power (Watkinson, 1997). Because time is limited during the throwing action the muscles involved must exert as much force as possible, therefore the rate of force development (RFD) is a contributing factor (Newton & Kraemer, 1994). Thus, to increase power with a stable technique, it is necessary to increase either the force applied to the ball or the speed of muscle contraction or doing both simultaneously (Gronbech, 1997, Yessis, 1994).

Strength training is one technique available to assist coaches and players in enhancing throwing velocity and hence is the focus of this study. This thesis will elaborate on the research in this area with particular emphasis to traditional, ballistic and combination training. Consideration of the effects of training, with particular attention to methods to

increase throwing speed, will assist the sport of softball. This is of particular importance to coaches and trainers alike who are preparing their national teams for the forthcoming World Championships. An increase in throwing velocity is a distinct advantage to the fielding side by putting added pressure on individuals when batting. They will have less time to hit the ball and run safely to first base.

Researchers DeRenne, Buxton, Hetzler & Ho, 1995; Hoff & Almasbakk, 1995; Lyttle, Wilson & Ostrowski, 1996; Vossen, Kramer, Burke & Vossen, 2000; have prescribed conditioning techniques for sports which involve throwing using light loads in the form of medicine ball training, weight implemented balls and bats, weighted pulley systems, depth jumps and bounding, and heavy resistance training such as traditional weight lifting. Newton and McEvoy, (1994) reported studies that have produced increases in throwing velocity using ball throws with over and underweight balls, as well as conventional weight training modalities. A possible negative aspect however is that the research on strength and throwing velocity has focused solely on increasing the strength of the muscles responsible for arm acceleration; with minimal attention given to the decelerators of the arm (Newton & McEvoy, 1994). Kaufman (1999) states that athletes involved in throwing are impervious to the harmful effects of repetitive deceleration of the arm and that the key to longevity is to maintain muscular balance within the shoulder complex. A moderate degree of static stability is provided by the ligamentous restraints surrounding the joint. However, this static joint stabilization is insufficient because the throwers take their arm through an arc at extreme speeds. Pretz (2004) reported that shoulder velocities reach as high as 10,000 degrees per second and that distraction forces greater than 947 N occurred during the deceleration phase of the overhead throw and that the softball players rely on the muscular components of their shoulders to resist distraction forces and provide dynamic stability. Dynamic stability is produced by a group of muscles comprising off the subscapularis, infraspinatus, teres minor and the supraspinatus (commonly referred to as the rotator cuff). To assist in obtaining peak performance and injury prevention, year round periodised programmes should include a variety of exercises for the upper body,

specifically the rotator cuff. As the season approaches, the exercises completed should become more specific to the movements involved in the sport.

The velocity of a softball throw is dependent on the athlete's ability to produce explosive muscular power. As a softball player attempts to maximise this explosive performance, the time over which they can apply force and accelerate the body segments decreases. Therefore Newton and Kraemer (1994) advocate harnessing the ability to develop RFD and as the muscle's velocity of shortening increases, continue to produce high force outputs. Velocity can be increased with an improvement of throwing biomechanics (Jacobs, 1987; Vaughn, 1996) and by resistance training (Baheti & Harter, 2001; Brose & Ilanson, 1967; De Renne, Ho, & Murphy, 2001; Glasser, Caterisano & Brown, 1999; Hoft & Almasbakk, 1995; Newton & McEvoy, 1994). The overhead softball throw is biomechanically a complex action involving the whole body in a synchronised manner and dependent on the most distal body segments, specifically the forearm and the hand. (De Renne, Ho, & Murphy, 2001; Jacobs, 1987). That is, the accuracy of the throw is a result of the fine motor coordination of the internal shoulder rotation, elbow extension, as well as wrist flexion, pronation and supination. The speed of a softball throw is therefore determined by the muscular forces exerted prior to the release of the ball. De Renne, Ho, and Murphy (2001), reported that in the overhead throw, 46.9% of the velocity could be attributed to the stride and body rotation. The remaining 53.1% was due to the arm action. De Renne et al. (2001) advise that when designing resistance training programmes for softball players, the exercises should include lower body, trunk and arm exercise.

## **GENERAL STRENGTH TRAINING**

In theory, general resistance training aims to improve the contractile capabilities of the muscle and involves the muscles involved in throwing. Baker (1996) advocated that depending on their biomechanical characteristics and the effects on the neuromuscular system, weight-training exercises are classified as general, specific and special. Overall maximal strength for throwing is increased by performing general exercises which include: bench-press, latissimus dorsi pull-downs, shoulder press, straight or bent-arm pullover, bicep curls, triceps extensions, shoulder dumbbell exercises, (lateral



raise, supraspinatus raise, internal rotation, external rotation, flexion, and abduction), ulnar and radial deviations, wrist rolls, trunk flexion, extension, rotation, squats, leg curls and leg extensions (De Renne et al., 2001; Glasser, Caterisano & Brown, 1999; Hedrick, 2000; Parker, 1988; Santana, 2000; Watkinson, 1997; Yessis, 1984).

Kaufman (1999) reported that certain exercises, used to strength the upper back and shoulder area, are contraindicated and that if performed there was a tendency for athletes to injure themselves in training. The potentially dangerous exercises include: behind the head military press, wide-grip bench press and dips because they place unwanted stress on the glenohumeral ligaments in the shoulder. Suggested alternative exercises comprise modifications of hand placement and/or position to prevent the humerus from exceeding 60 degrees of horizontal abduction has been achieved by using a close-grip bench press, the pectorals deck being substituted for dumbbell flies and the military press be performed in front of the head.

Hoff and Almasbakk (1995) interpreted the effects maximum strength training had on team-handball players. They believed that training with maximal heavy weights could enhance the speed of the unloaded movement (throw) when combined with specific training for that movement. Sixteen participants (matched on throwing velocity) were randomly placed in the training group (TG) while their partner went to the control group (CG). TG participants participated in a nine-week programme using training loads of 85% 1-RM for five – six repetitions. The bench press was chosen because it utilised two of the major muscles involved in the throwing action, specifically the pectoralis major and the triceps brachialis. The participants were requested to focus on execution speed during their concentric movement of the bar, the key being high-intended velocity even if the bar moved slowly. Rest periods were between two – five minutes allowing full recovery. The authors reported that the training period was carried out during their late preparation/early competition phase and such there was a high volume of high-velocity running-throw during training. Testing in this area focused on a three-step run-in throw and a standing throw. The TG bench press results showed an increase in strength of 32% with little or no improvement for the CG. Both groups showed an increase in their three-step throwing velocity of 17% for the TG and 9% for

the CG. The significant difference in running throw (8%) was thought to be because of the maximum strength training and team handball training. During the standing throw, the TG increased 18% and the CG 15%. The authors concluded that because the participants had insufficient standing-throw situations in either training or competition there was little training effect or carry over from the strength training on throwing velocity. It can be further surmised that Hoff and Almasbakk (1995) support the theory that maximal heavy strength training improves the speed of throwing but only when combined with specific training associated with the required movements. They also advocate that during the concentric phase of the weight training exercises, execution speed or high intended velocity should be the main focus.

Initially Hoff and Almasbakk (1995) found no significant correlation between 1-RM bench press and throwing velocity ( $r = 0.597$ ), however after the training period a significant correlation was found between 1-RM bench press and 3-step run-in throwing velocity ( $r = 0.883$ ). From these results it appears that the use of general strength training (in particular, maximum strength training) along with training specific to the desired movement will enhance velocity of throwing so therefore may be beneficial to softball.

In throwing athletes, pain occurring in the posterior aspect of the shoulder has been recognised as a cause for deteriorating performance. This may be due to the late-cocking phase of the throwing action which is characterised by extreme rotation of the abducted arm resulting in repeated stress in that position. The outcome may be laxity in the glenohumeral joint (Kuhn, Bey, Huston, Blasier & Soslowsky, 2000). To prevent possible injury during training and playing this possible condition needs to be considered. While the emphasis is now on developing power, each time a softball player throws a ball, the front of the shoulder accelerates the arm forward. For this to occur, the back of the shoulder must remain relaxed. The role of the back of the shoulder changes to then decelerate the arm once the ball has been released. Therefore to prepare for the stresses of throwing, these muscles must be trained eccentrically, at as high a speed as possible. Traditional methods of strength training involved negative repetitions, lowering a specific weight against gravity. While there is

an increase in eccentric strength, the movement is far too slow compared to the speed of the throwing arm (Behm, & Sale, 1993; Panariello, 1992). To simulate the action, arm deceleration exercises involve catching different weighted medicine balls at various speeds over the shoulder (Panariello, 1992). In addition shoulder stabilisation exercises utilising light weights ranging from 1-kg to 2-kg are recommended. Athletes should perform five to eight exercises for 15 – 30 reps in order to develop strength-endurance of the rotator-cuff muscles (Watkinson, 1997). Jackson (1994) attempted to show that by using light weights ranging from three to eight pound strength could be increased in the rotator cuff muscles and as such improve throwing velocity. The participants completed three sets of ten reps 3 d<sup>-1</sup>wk<sup>-1</sup>. Tests between groups and within groups showed that there was no significant increase in the velocity of a thrown baseball after participating in a weight-training programme. A probable answer for the lack of significant results lies in methodology used by the researcher. Strength exercises orientated towards the accumulation of relative strength should encourage nervous and muscle coordination of effort in what Spassov (1988) has termed the forming of conditioned reflex ties. Thus training would be better conducted with only a few repetitions focusing on achieving maximal tension as a greater number of repetitions have proved to be ineffective.

Lachowetz, Evon and Pastiglione (1998) studied the effects of an upper-body strength programme on baseball throwing velocity. Twenty-two baseball players participated in an eight-week study involving the treatment group completing 4 d<sup>-1</sup>wk<sup>-1</sup> while the control group did no weight training. Both groups did however adhere to throwing programmes three times per week over two distances for 35 – 40 minutes. Both groups were pre and post-tested for throwing velocity as well as 10-RM strength variables for the eleven prescribed strength exercises. A 2 x 2-mixed factorial ANOVA with repeated measures on test time was used to determine any mean differences in throwing velocity. Training group recorded pre-test 30.7 m·s<sup>-1</sup>, post-test 31.5 m·s<sup>-1</sup>; control group pre-test 31.3 m·s<sup>-1</sup> and post-test 30.8 m·s<sup>-1</sup>. These results revealed that the training group had a significantly higher mean throwing velocity over their pre-test score. At post-test they also had a significantly higher mean throwing velocity score than the control. Implications of this study were that throwing velocity could be enhanced by using a

progressive strength-training programme, which included some eccentric work, coupled with a scheduled and supervised throwing programme.

While Lachowetz et al. (1998) study focused on 10-RM resistance training as the intervention, and specific functional exercises Mayhew, Ware, Johns and Bembien (1997) looked at changes in upper body power following heavy modified periodised resistance training with loads ranging from 74% to 88% of 1-RM. The purpose of their research was to determine what effects this training had on measures of bench press power (BBP) and seated shot-put (SSP). BPP was measured with free weights randomly assigned loads equivalent to 30%, 40%, 50%, 60%, 70% and 80% of 1-RM load. The same absolute loads were used for pre and post-testing. Following the 12-weeks of training, the BPP increased significantly at each load with the resultant power curve moving upward by an average of 13.6%. While an increase of 9.1% was seen for the 1-RM bench press, there wasn't a significant increase in for the SSP (1.8%).

The greatest increases in upper body power occurred at the highest resistance and that these resistances corresponded with the loads used during the final 5-weeks of the training programme. Loads between 40% and 50% 1-RM produced peak power before and after training. Despite the greatest increase in BBP at the heaviest resistance, the major finding of the study was the small change in SSP performance comparative to the significant increase in both strength and BPP in a matching movement. A possible explanation for this is that the increase in bench press strength and power from the programme may have presented little transference to SSP power performance. The heavier loads may have produced a slower movement thus effecting the neuromuscular facilitation at the lower end of the power spectrum. In addition it is thought that the athletes programme should have contained some functional SSP movements in order to combine the gains in strength with the neural controlling motor performance.

In summary, general resistance training with loads of 5 - 6RM (74% to 88% of 1-RM) appear to have a positive influence on throwing velocity. Schmidtbleicher (1985) gives a possible explanation of two mechanisms that could be responsible for this

improvement. An increase in maximal muscle contraction is the product of: recruitment of all motor units accompanied by the involvement of all muscle fibers; and optimal firing rate determined by the innervation frequency. In contrast, training with lighter loads of between 40% and 50% 1-RM at higher velocities can also achieve peak power production which supports the contention that this form of training may be more beneficial than heavy-load, low-velocity resistance training. No clear prescription can be specified as to which type of resistance training optimally increases throwing velocity.

## **SPECIFIC TRAINING**

Specific training exercises provide a training stimulus that is very similar to the actual movement. Examples of resistance exercises (designed to follow the concept of specificity) that are very similar to the actual motion of throwing include weighted softballs, surgical tube exercises, wall pulleys and Dura Bands™ / Flexi cords (Brose, & Hanson, 1967; De Renne, Ho, & Blitzblau, 1990; De Renne, Ho, & Murphy, 2001). What researchers are looking to establish is whether or not the specific training can improve performance principally by the recruitment of the high-threshold motor-units. The goal is to achieve this by imitating the actual throwing motion and velocity. Using modified standard equipment; weighted implement training involves exercising while attempting to duplicate the force-velocity output and full range of movement (ROM) specific to the throwing pattern (De Renne, Ho, & Blitzblau, 1990; De Renne, Ho, & Murphy, 2001). Throwing studies have indicated that the throwing velocity of a softball can be increased significantly by either throwing a heavier ball or by overload training (Bagonzi, 1978; Brose, & Ilanson, 1967; Elias, 1964). In contrast, by using weighted implements that are slightly lighter than the standard competitive weights, throwing velocity can be increased (De Renne, 1987).

### **Overweight and Underweight Training**

De Renne et al. (1990) had conducted three throwing and pitching velocity studies using under-and-over weighted baseballs. It was stated by De Renne et al. (2001) that during the De Renne (1985) study, a significant gain in throwing velocity using either

lighter or heavier balls was reported and that the under-weighted group (UTG) showed a significant increase in velocity that was twice as great as the over-weighted group (OTG). Increasing or decreasing their standard weight by 20% modified the balls. De Renne et al. (1990) used 30 high school pitchers to replicate the previous De Renne (1985) study. Their results were similar in that the UTG had a significant increase in throwing velocity of  $2.1 \text{ m}\cdot\text{s}^{-1}$  and the OTG also had a significant increase of  $1.7 \text{ m}\cdot\text{s}^{-1}$ . The control group improves slightly by  $0.4 \text{ m}\cdot\text{s}^{-1}$ . During the 10-week training period all participants threw an identical number of throws (1,500). However the OTG and UTG performed 600 throws with modified balls.

The third study by De Renne et al. (1994) used various combinations of standard, light and heavy baseballs. A total of 180 college and 45 high school pitchers were randomly assigned to two experimental groups and a control group. The training prescription consisted of the control group pitching only standard baseballs; group one pitching with a weighted sequence of a standard-heavy-light-standard baseball  $3 \text{ d}\cdot\text{wk}^{-1}$  for 10-weeks. The second group pitched with a system utilising two “5-week periods of block training.” The first block sequence of training comprised off standard-heavy-standard followed with the second block of standard-light-standard. Their findings revealed a significant increase of throwing velocity in both training groups with either high school or college pitches. The authors further concluded that the results of the three-weighted implement studies indicate that a greater exertion of muscle force at high speeds was possibly due to the transformation of the recruitment pattern of motor units in the central nervous system as evident by the increased throwing velocities.

De Renne, Buxton, Hetzler and Kwok (1995) also looked at the effects of weighted bat implementation on bat swing velocity. Sixty men were randomly assigned to either batting practice (BP), dry swings (DS) or a control group. The BP alternated with over-weighted, under-weighted and standard bats hitting live pitched baseballs  $4 \text{ d}\cdot\text{wk}^{-1}$  for 12-weeks. The DS group performed the same actions with over-weight, under-weight and standard bats while the control group swung a standard bat only. During the study, significant increases in bat-swing velocity were shown by the three groups. Significant improvements for the BP and DS groups as compared to the control group were

revealed with Scheffe post hoc  $F$  testing. The BP group also showed significantly more improvements than the DS group. The researches concluded that either the BP or the DS training programme can significantly increase bat swing velocity and that a combination of weighted bats can serve as a supplement training method to significantly increase bat swing velocity.

In contrast to De Renne et al. (2001) finding, Brylinsky, Moore and Frosch (1992) investigated the use of weighted softballs in training to improve wrist strength, handgrip and throwing velocity. The participants (37 novice women pitchers) were randomly assigned to either the weighted ball or regulation group. During the 6-week training programme, each group threw an identical number of pitches per session (58). At the completion of the prescribed number of reps at the maximum distance of 65-ft, the women completed a further ten minutes of lob pitching at 70-ft. They were encouraged to work at their own pace but to try and maintain a continuous rate throughout the session. No mention is made of how many sessions per week were conducted. The results revealed no statistically significant differences between the two groups on any of the three variables. The results showed no difference between the two groups and that training with the weighted ball achieved the same results as training with a regulation ball. Sergo and Boatwright (1993) also found that regular swinging of a bat of any weight (at least 3 d $wk^{-1}$ ) 100 times daily, as an adjunct to normal training would improve bat velocity.

In summary while De Renne et al. (1985) had significant improvements in throwing velocity using overweight balls ( $0.7m\cdot s^{-1}$ ) and underweight ( $1.3 m\cdot s^{-1}$ ) the number of subjects was limited to five per group and that there was no control group participating in the study. This was rectified with the De Renne et al (1990) study where two experimental groups and a control group were utilised. Both groups showed a significant increase with the underweight group improving throwing velocity by  $0.4 m\cdot s^{-1}$  over the overweight group. Further studies by De Renne et al. (1994, 1995) produced similar results. Using overweighted or underweighted implements resulted in improvements in either throwing or swing velocity. Brylinsky, Moore and Frosch (1992) results showed no significant differences however when their subjects used a weighted

or regulation ball. The differences between the studies methodology appears to be the volume of training and the intensity with which the training was carried out by Brylinsky et al. (1992) was considerably less. This indicates that while the amount of throws is important the total exercise intensity should be compatible. The time of the season and the age of the subjects could also influence the results. Any type of throwing programme could produce initial increases in throwing velocity especially if the arm is in an untrained state (such as at the beginning of the pre-conditioning phase). All the subjects appeared to be of a similar age 16 – 19 (high school and varsity), and De Renne et al. tended to use experienced male subjects while Brylinsky et al. used novice females. It is possible that due to the increased upper body muscle mass of the males their performances would be expected to produce superior results. Therefore, to maximise the full effects of resistance training on improving throwing velocity experience and age must be considered.

## **SPECIAL TRAINING**

Special strength exercises are those aimed at training for power once increased strength levels have been obtained. Examples of special strength exercises would be push presses, power cleans / snatches / pulls and power shrugs (Newton & Kraemer, 1994). These have the effect of training to transform all the gains in strength into a competitive and sport-specific power as relevant to throwing. The advantage of explosive power and high velocity training is that it trains the nervous system and that the increases of performance can be based on neural changes to help the individual muscle to achieve greater performance capability. These specific strength exercises may be distinguished by rapid execution, high power output and at times, loss of contact of the limbs with training implements.

### **Olympic Style Lifts Weight Training**

De Renne, Ho, and Murphy (2001) propose that once the general strength has been developed then the emphasis should shift to developing power through special explosive isotonic exercises. Accordingly Baker (1996) emphasised that the training effect or goal of the athlete is to convert general muscular strength to power. To achieve this goal, athletes would be advised to perform Olympic style lifts such as



power cleans, snatches, pulls and push presses. To get the best gains and to assist in the conversion of muscular strength to power, athletes are advised to perform these power exercises first in their daily workout session. This is because the empirical evidence shows that the nervous system is fresh and able to move the working muscles quickly in the beginning of the workout as compared to the end (Marandino, 2003).

### Maximal Strength and Power using Ballistic Techniques

Cronin, McNair and Marshall (2001) investigated the change in chest pass throw velocity of semi-elite female netball players after 10-weeks of training. The twenty-one participants were divided up into three homogeneous groups consisting of: a heavy group (HG), a power group (PG) and a control group (CG). The HG trained with 80% 1RM with an average training velocity of  $0.308 \text{ m}\cdot\text{s}^{-1}$ , the PG used 60% 1RM – average training velocity of  $0.398 \text{ m}\cdot\text{s}^{-1}$ . Training for the two groups consisted of equal volume of load (total lifted per set) for the bench press performed as explosively as possible. At the conclusion of each set of presses, the participants performed twenty netball chest passes as rapidly as possible. Their results show that the HG produced significantly greater velocity, force and power output in the bench press compared to the PG and CG. They report that both training groups produced significant improvements in chest pass velocity (9 – 12%) compared to CG but were not significantly different to each other. These studies reveal that even though there is a resemblance in the velocity profiles of the strength training to the throw, heavy load training was still the preferred method to improve throw velocity and therefore the focus should be on the ability to rapidly develop force for these types of athletes,

Baker (1996) examined the effect of general, special and specific strength training exercises on vertical jump ability. General strength exercises are those targeted at increasing maximal strength and included squats, front squats, split squats and power shrugs; special exercises are those aimed at training for power and included jump squats, power shrug jumps, power cleans/snatches/pulls and push presses. As previously mentioned these special exercises are recognised by a more rapid implementation, high power out-puts and leaving the ground with the feet. In

comparison, the specific exercises are very similar to competition and vertical jumps with the overload being applied by the addition of small weights, volume of repetitive jumps and height of depth jumps.

With regard to baseball, De Renne, Ho, and Murphy (2001) concur with Baker that the concept of specificity is followed because the specific resistance training exercises provide a training stimulus similar to the actual motion in performance. The exercises attempt to mimic the high-velocity throwing motion by using weighted baseballs, surgical tubing and flex-band cords (Baheti & Harter, 2001; Brose & Ilanson, 1967; De Renne, Ho, & Murphy, 2001; DeRenne, Ho & Blitzblau, 1990; Rudolph, 1999; Shenk, 1990; Sullivan, 1970; Yessis, 1981). Young (1993) also reported that by adding light weights to equipment is another method of achieving specificity of training. Examples included weighted golf clubs, bats, throwing implements and weighted sleds and tires for resisted running.

### Plyometric Training

An enormous amount of literature has been published about the use of the SSC and its implications to sport. In order to maximise efficiency, athletes should allow the counter-movement or back-swing and forward-swing actions to flow naturally from one phase to another without delay. One of the reasons is that the SSC enhances the quality and efficiency of movement through the utilization of the elastic energy (Blanpied, Levins & Murphy, 1995; Farley, 1997; Huber, 1987; King, 1993; Komi, 1983; Komi & Bosco, 1978; Wilson, Elliot & Wood, 1990) thus allowing the muscles to build up a high level of active state at the beginning of the positive work (Bosco, 1997). The coupling time is important to the effectiveness of the SSC (Goubel, 1997) and the effectiveness of the SSC movements is reduced if there is a delay between the eccentric and concentric phases of the movement. Wilson (1993) points out that the cross-bridge linkages in the myofibrils detach during delays between the eccentric and concentric phases and that the elastic energy stored is dissipated as heat. The ability of a muscle to store and utilise elastic energy depends on the speed of the stretch, length of the stretch, force at the end of the stretch, and the length of time the stretch is held (Chu, 1983; Gehri, Ricard, Kleiner & Kirkendall, 1998; Lord & Campagna, 1997; Lundin & Berg, 1991;

Schenau, Bobbert & de Hann, 1997; Wathen, 1993). The storage of the elastic energy is thought to have a life of approximately 4 s and every second that there is a delay between the eccentric and concentric action the energy is reduced by as much as a half-life of 50% (Wilson, 1993; Wilson et al., 1990).

Research has determined that once the cross-bridges have detached, the musculo-tendinous system fails to remain taut, and subsequently any remaining elastic energy stored in the tendon is also dissipated (Wilson, 1993). Wilson (1993) has also reported the time period over which the dissipation occurs when a SSC movement is performed with a delay. A one-second delay has been found to dissipate 50% of the stored energy and a two-second delay will result in a loss of 75%. A four-second delay results in all stored elastic energy being dissipated. Conversely, a SSC movement with no delay assists performance by approximately 18%.

The use of plyometrics exercises such as depth jumps, bounding, hopping drills as well as throwing and pushing were originally developed for track and field athletes (Polhemus, Osina, Burkhardt & Patterson, 1980; Wathen, 1993). They are now being used for sports requiring power (Blattner & Noble, 1979; Bompa, 1993; Chu, 1983; Renfro, 1999; Robertson, 1998; Waller & Piper, 1999). However, strength and conditioning coaches need to reflect the SSC demands of the specific sport and sporting actions. This information can be gleaned by gathering data about the duration of the movement and in particular information about contact times, coupling times, and duration of contractions (King, 1993).

The effectiveness of plyometric training in improving explosive performance has been supported by most training studies during the last three decades (Blattner & Noble, 1979; Clutch, Wilton, McGown, & Bryce, 1983; Ford, Puckett, Drummond, Sawyer, Gantt & Fussell, 1983, Pate, 2000). Blattner and Noble (1979) compared a depth jumping group, an isokinetic training group and a control group. They found both depth jumping and isokinetic better than the control group, but there were no differences between the two training routines. However, a limitation in this study was the lack of dependent variables including isoinertial or isokinetic dynamometry. The jump and

reach test using a board marked in feet and inches was the only test conducted and there were no descriptive data for the forty-eight men volunteers. The inclusion of peak power, mean power between the two training routines may have provided a clearer picture of the more effective training regime.

### Medicine Ball Training

Vossen et al. (2000) chose to see if there was any advantage to be gained by comparing dynamic push-up (DPU) training and plyometric push-up (PPU) training on upper-body power and strength. The DPU were completed from the knees with the body remaining straight from the head to the knees and the knees and toes remaining in contact with the floor. The press up action was completed from the knees in the normal manner. The PPU were completed from a kneeling position with the trunk held vertical. From this start position subjects allowed themselves to fall forward. At contact, the subjects absorbed the force and immediately reversed the downward action and propelled themselves back to the starting position. Forty-one females were pre and post-tested using a seated medicine ball put and a seated 1-RM chest press. Each of the participants was required to complete a total of eighteen sessions ( $3 \text{ d} \cdot \text{wk}^{-1}$ ) comprising either DPU or PPU starting with three sets of ten progressing to four sets of eleven. Each programme resulted in significant improvements in the medicine ball put and the chest press ( $p < 0.01$ ) with the PPU demonstrating greater improvements. The PPU group improved significantly for the ball put and approached significance with the chest press. The authors concluded that plyometric training might be beneficial for developing upper-body power and strength.

Newton and McEvoy (1994) examined the effects of upper body plyometric training and conventional weight training on baseball throwing velocity and strength levels. Twenty-four baseball players combined medicine ball training and weight training with their baseball training. The first group performed explosive medicine balls throws, the weight training group concentrated on conventional weight training while the third focused on normal baseball training. Throwing velocity and 6- RM bench press measurements were recorded pre and post training. The results showed that the group that trained using conventional weight methods improved throwing velocity and strength to a

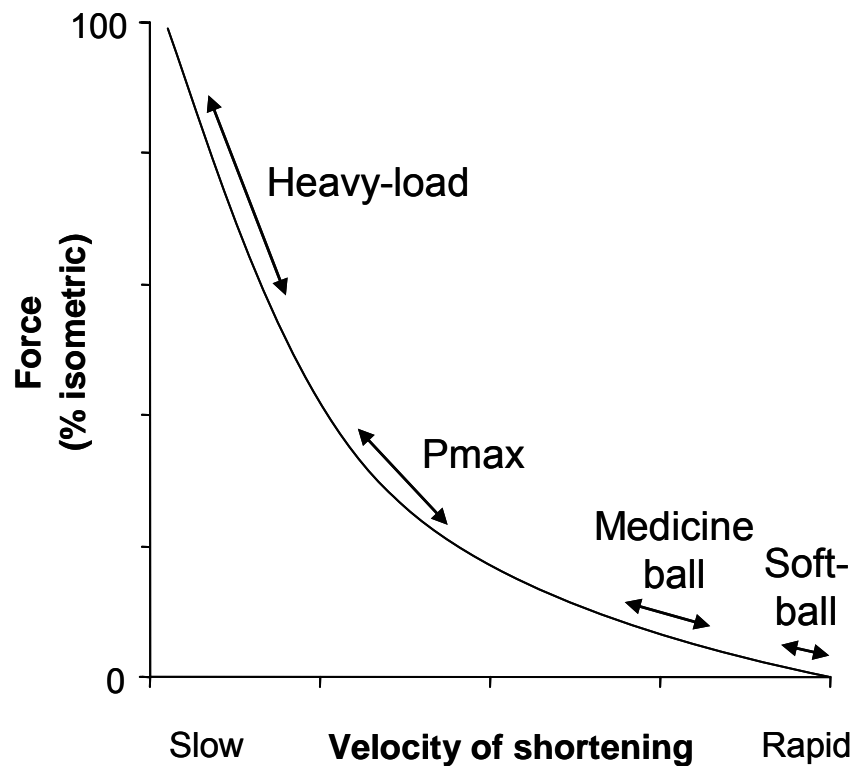
greater degree than the other two groups. Percentage changes for the weight training group included a 4.1% change in throwing velocity and a 22.8% change in 6 – RM strength. Both results were significantly different. Throwing velocity for the medicine ball group did not increase.

## **COMBINATION AND COMPLEX TRAINING**

Explosive muscular power is an essential element of most athletic events and softball is no exception. A large volume of time is spent during the pre-competitive and competitive phases of the season attempting to enhance the power production of players. Modern, sophisticated training programmes mix resistance training, plyometric exercise and playing simulations in an attempt to maximise a player's ability to generate power. According to Verkhoshansky (1986) the best results are attained when a combination of heavy and light loads are executed within one workout. One method of integrating strength and power into this one workout has been labeled as complex or contrast training.

Throwing in softball requires a high power output of the involved muscles and this can be expressed as the force applied multiplied by the velocity of movement (Newton & Kraemer, 1994). This is demonstrated in Figure 1 where the shape and nature of the force-velocity curve will alter in response to the type of training undertaken. Light resistance power, with an accent on speed rather than pure force (as demonstrated by the softball throw) will tend to improve power first and foremost at the right end of the curve where resistances are low. Maximal strength training may only improve power at the extreme left side of the curve where resistances to movement are high. A combined approach, such as complex training, may induce improvements throughout the entire force-velocity curve. With this in mind several researchers have attempted to modify their training programmes to reflect the current research that heavy resistance training with slow contraction velocities will not on its own effectively increase power. Hrysomallis and Kidgell (2001) conducted research to support the notion that heavy resistance training immediately before a power movement may acutely enhance the performance. The researchers investigated whether a set of five repetitions of 5-RM-bench presses preceding explosive push-ups would significantly influence power. The

indicators measured were impulse (impulse, N·s) and rate of force development (mRFD, N·s<sup>-1</sup>). The data derived from the force platform during the condition of the explosive push-ups and the condition of 5-RM preceding explosive push-up indicated that there were no significant differences for the average and peak force when preceded by strength training.



**Figure 1:** Force velocity curve indicating training velocities for differing methods of resistance within a complex.

When one set of bench press (5-RM) were performed three minutes before the press-ups the results obtained by Hrysmallis and Kidgell (2001) indicate that the impulse and mRFD were not enhanced compared to the explosive push-up only condition. While this is in contrast to previous findings (Young, 1997), a possible reason is the preferred option of one set of five repetitions of 5-RM which was chosen due to the considered lower injury risk than completing a 1-RM load. The neural response, specifically; increased motor unit activation, synchronization, increased motor unit firing

rates increased activation of prime movers, increased coactivation of agonist and antagonist (Ebben, 1997) and lack of increase in twitch tension (Duthie, Young & Aitken, 2002) may therefore have been limited. In addition Ebben, (2002) has indicated that 2 minutes is the optimal rest time between performances.

Jones, Hunter, Fleisig, Escamilla and Lemak (1999) compared the effects of maximum concentric acceleration training versus traditional upper-body training on the development of strength and power. Power was tested with a seated medicine ball throw and a force platform plyometric push-up. While all participants ( $n = 30$ ), completed the identical training programme, the control group were required to perform their exercises with routine concentric velocity. The experimental group accomplished the concentric phase of each repetition as fast as possible. Previous studies had shown that as long as the participants attempted to accelerate the bar during contraction, training would increase strength over a wide range of testing velocities.

While no significant group effects were found for any of the tests in the study of Jones et al. (1999) substantial training by group contact indicated that the experimental group increased significantly more than the control group. Their percentage increases were over two times more in both the 1-RM bench press (+ 9.4 versus + 2.8) and the seated medicine ball throw (+ 8.6 versus + 3.8), than the control. These results confirm previous research for improving strength and power was correct and that the intent to maximally accelerate concentrically with heavy weights may be better than slower heavy weight training.

While Jones et al. (1999) research is a very important concept for the conditioning of softball players, Newton, Kraemer, Hakkinen, Humphries and Murphy (1996) study was more attuned to actual softball throwing because the barbell was projected from the hands. They set out to compare the kinematics, kinetics and neural activation of the conventional bench press movement performed explosively and the explosive bench press throw. What was important to these researchers was the notion that, while strength coaches advise their athletes to move the resistance as rapidly as possible, a significant segment of the lift involves an interval when the bar is decelerated prior to

the end of the concentric phase. It was hypothesized that compared to the bench press, the bench throw would be superior in terms of velocity, force, power output and muscle activation due to the athlete actually releasing the load at the end of the motion in a ballistic manner.

The results show that there were significant differences between the press and the throw in velocity and force profiles throughout the concentric movement. Given the inherent limitations of traditional weight training and particular the bench press, attempting to perform the exercise in a explosive manner even with a light load results in reduced velocity, force output and muscle activation due to the load stopping at the end of the concentric phase. Thus, the throw away type of movement would appear to be more specific to the explosive movements required in sporting performances and therefore would be a consideration when prescribing training for softball.

Toji, Suei and Kaneko (1997) also looked at the force-velocity relationship and maximum power output in the upper-body. In particular they investigated the effects of training using multiple loads or so-called combination training. The study involved two groups of six participants, 3 d $\cdot$ wk<sup>-1</sup> for eleven-weeks. Group G30 + 100, performed combined training in which the participants exerted maximum power output five times at 30%  $F_{max}$  and five times at 100%  $F_{max}$  for three seconds each, while the G30 + 0 completed combined training with the participants exerting maximum power five times at 30%  $F_{max}$  and five times at 0%  $F_{max}$  (no external load). The combined training term corresponds to the isometric-dynamic nature of the training employed. Maximum power increased significantly in both groups with the G30 + 100 groups achieving the greater increase. Maximum strength was significantly higher in the G30 + 100 groups while maximum velocity increased in both groups. A combined programme of training, isometric strength and maximum power were concluded to be a more potent form for augmenting power production than a combination of maximum velocity and power training.

Lyttle, Wilson and Ostrowski (1996) examined the relative effectiveness of traditional heavy weight training and plyometric training. Thirty nine men were assigned to either



a combined weights and plyometrics group (CG), maximal power training group (MPG) and a non-training control group (NCG). The CG programme involved squats and bench presses with training loads designated as six -ten repetitions moving the weight as fast as possible. The lower body plyometric routine consisted of rebound depth jumps starting from a height of 20cm and increasing to 60cm by the completion of the study. Drop medicine ball throws were used for the upper body with both the weight and drop height increasing as the study progressed. The MPG undertook training on a Plyometric Power System using squat jumps and bench press throws. Training loads were set at eight repetitions x 30% 1RM. Each experimental group was overloaded by increasing the number of sets from two – six.

Their results show that the two training groups produced significant improvements in the tests of athletic performance. The training groups do not differ significantly on any of the measures. The explosive push-up test, showed larger changes in the SSC activities from the CG than the MPG. Lyttle, et al. (1996) suggested that this was attributed to the dynamic SSC nature of plyometric training enhancing the use of elastic strain energy to a greater extent than maximal power training. They concluded that the MPG programme and the CG programme were equally effective in improving sports performance and that the CG programme tended to produce superior performance in SSC movements. This has an important effect in terms of this proposal for softball throwing because when the SSC is practiced and perfected, the athletes will be better able to accelerate their bodies and generate greater force at high velocities.

A number of studies demonstrate the effectiveness of plyometrics compared to non-exercising control groups. Hedrick and Anderson (1996) described three studies where plyometric and speed/strength training were combined. They stated with confidence that in all three studies the participants had all improved on their vertical jump scores while the control groups showed no significant change. That combining weight training and plyometrics resulted in significant increase in vertical jump ability is not surprising as this form of training improves performance in strength and speed and thus optimizes the power flow of linear and rotational energy transfer during eccentric to concentric contraction.

Young, Jenner and Griffiths (1998) conducted research to determine whether a loaded counter-movement jump (LCMJ) could be enhanced if it was preceded by a set of 5-RM half-squats. Ten men with weight training experience performed two sets of five LCMJ, one set of squat reps using a 5-RM load, and one set of five LCMJ with four-min rest between all sets. They found between the first two sets of LCMJ the results were non-significant and that the repeatability between these sets was high. An intraclass correlation (ICC) and technical error of measurement (TEM) established the reliability of the measuring instruments. The results were 0.95 and 2.0% respectively. The jump height for the LCMJ after the 5-RM squat set increase by 2.8% than for the LCMJ set immediately preceding the squats. They concluded that the stronger the individual, the greater the gain in power potentiation from the squats and that high intensity warm-up may be of benefit to researches and coach.

Cronin, McNair and Marshall (1999) looked at plyometric exercises and in particular whether velocity-specific strength training was important to functional performance. They comprehensively reviewed a series of isokinetic and isoinertial studies and found that there was great disparity between training velocity and actual movement velocity as assessed in testing and as such much of the research failed to record details of the relationship of the movement task and the training velocity. Training techniques that simulate the velocity and the necessary acceleration profiles will assist with functional adaptation. Cronin et al. (1999) suggested that activities using the SSC such as throw or jump training, as well as combination training using either a heavy or mixed load incorporating sport specific training, would be the optimal approach to take. With regard to velocity-specific resistance training, Doherty and Campagna (1993) suggested also that for athletes requiring speed and power, to enable adaptation to occur within the nervous system and muscle their training should include both fast and slow movements.

Recent studies involving the SSC and in particular depth jump training have resulted in contradictory findings. Considering the inter-study differences relating to sample size, athlete experience, training lengths, volume of work performed (reps, sets and heights)

and supervision, this is not unexpected. For example, with regard to athlete experience, the magnitude of change or adaptation for athletes with two years experience compared to novices, researchers would expect to see a difference.

The longer an athlete participates in a given sport, the greater the need to alter the training programme to meet the ever-changing requirements of the body and to enable the athlete to train smarter without spending inordinate periods of time in the weight room. To assist in this regard the training programmes of professional baseball players are, according to Charniga et al. (1987), a good example of basic periodised programmes. A typical programme begins with a preparatory phase punctuated with a large volume of general development followed by specific activities. Once the competitive season commences the volume and intensity of the exercise decreases.

Therefore, periodised conditioning is a system of organising training to achieve optimum results in strength, mass, definition, speed, power, endurance and flexibility without encountering the pitfalls of overtraining, injury and stagnation. With regard to resistance training, different phases such as anatomical adaptation, hypertrophy, maximum strength, strength endurance, conversion to power and power training are manipulated according to individual training and competition goals. This is to ensure peaking at appropriate times and reduce the potential for over-training (Ebben, 2001; Fleck, & Kraemer, 1997; Hedrick, 1996; Pearson et al. 2000; Robertson, 1998; Rudolph & Smith, 1999; Szymanski, 2001; Szymanski & Fredrick, 1999; Watkinson, 1997). In line with this thinking Harris, Stone, O'Bryant, Proulx and Johnson (2000) after researching studies and observations of weight lifting methods and the training of strength/power athletes, they advocated that in order to maximise high power / velocity movements, a specific order of periodised training should be followed.

Traditionally in planning for sports that require high power / velocity outputs the emphasis in the early part of the year is generalised concentrating on maximum strength development, with the emphasis shifting to more specific exercises that focus on developing power and speed later in the yearly cycle. Researchers (Ebben & Blackard, 1997; Fees, 1997; Fleck, 1999; Fleck & Kontor, 1986; Roque, 1999;

Summers, 1999) believe that these phases may be compressed and that there is sufficient evidence to show that a combined training programme can contribute to improving power production. This may be of benefit to athletes who are able to include power training into their programmes at a greatly reduced volume (Fleck, 1999) as well as duplicate what the athlete is required to do in the competitive situation (Hedrick, 1996). Hedrick (1994) demonstrated this to good effect with the USA National Speed Skating Team, where the power component of speed skating was addressed by integrating plyometric training into the resistance training portion of the conditioning programme during the September – November cycle. Poliquin (1992) had also demonstrated the effectiveness of short-term periodisation when after eighteen-weeks of individualised strength training; a hammer thrower set an indoor world record. He previously had not improved in four years following surgery.

Ebben and Watt's (1998) review of complex training discussed possible mechanisms of adaptation. They provide a table in which proposed complex-training mechanisms of adaptation are cited in the literature. Researchers such as Bompa (1983); Chu (1983); Fees (1997); Fleck and Kontor (1986); and Verkhoshansky (1986) provided the reader with their views on these adaptations. For example, Verkhoshansky (1986) commented that, "...complex training is directed mainly to the development of reactive ability of the nerve-muscle apparatus during significant dynamic effort and speed of switching the muscles from yielding work to overcoming work ...". He continued "... basic exercise for the development of reactive ability is fulfilled in a background of heightened excitability of the central nervous system, bought about by preliminary fulfillment of exercises requiring great power ..." p. 21.

Ebben and Watts (1998) reviewed studies by Adams, O'Shea, O'Shea and Climstein (1992); Blakey and Southard (1987); Clutch, Wilton, McGown and Bryce (1983); Ford, Puckett, Drummond, Sawyer, Gantt and Fussell (1983); Lyttle, Wilson and Ostrowski (1996); Polhemus, Burkherdy, Osina and Patterson (1980); and Verkhoshansky and Tatyana (1973) that examined combined weight and plyometric training during the same workout session. Most failed to describe how these training modalities were combined and little explanatory value for the mechanisms of complex training were offered. All

the training studies showed an increase in vertical jump, standing long jump, depth jump and bench press. From the review it seemed that the following factors need to be addressed if complex/contrast training is to be used: complex training to be part of a periodised plan, athletes need to work at high intensity levels for both plyometric and weight training and that the volume of training to be focused on quality not quantity.

Ebben and Watts (1998) stated that ten training studies have examined combined weight and plyometric training programmes but cited only Verkhoshansky and Tatyana (1973) as having specifically examined complex training. In their view, Bompa (1983); Chu (1992, 1996); Fees (1997); Fleck and Kontor (1986); and Verkhoshansky (1966, 1986) studies provide evidence of the benefits of combined weight and plyometric training. One training study by Bompa (1983) is reported by Ebben and Watts (1998) to have stated that "... a strength training programme should utilize free weights in concert with other means of training (medicine balls, apparatus, bounding, etc.). Since the training effect is more complex, they complement each other and therefore are more beneficial to the athlete ..." (p.275).

Adams et al. (1992) critiqued the relationship between neuromuscular efficiency and dynamic strength performance. They concluded that parallel squats were conducive to the development of hip and thigh strength and that plyometrics applied simultaneously permitted the effective use of this strength to produce explosiveness especially in speed related sports. Blakey and Southard (1987) also reported that a combined 8-week programme utilizing both weight training and plyometrics increased dynamic leg strength and power. Duthie, Young and Aitken (2002) examined power performance in jump squats using complex/contrast training. Fleck and Kontor (1986) described complex training as a series of several exercises performed in succession, designed to increase the ability to produce power quickly or explosiveness. Young (1997) in support described complex/contrast training as high resistance exercises that stimulate the nervous system and therefore enhance power output of subsequent explosive exercises while MacKenzie (2002) prescribed resistance training followed by matched plyometric exercise.

To add confusion, the terms, “complex training” and “contrast training” have been used interchangeably in the literature to define the use of heavy and light resistance loads within the same workout. For the purposes of this literature review the definition of complex training, as discussed by Duthie et al. (2002), defines various sets of groups/complexes of exercises performed in a manner in which several sets of a heavy resistance exercise are followed by sets of a lighter resistance exercise while contrast training refers to a workout that involves the use of contrasting loads, that is alternating heavy and light exercises set for set.

A study by Duthie et al. (2002), eleven women participated in three randomly ordered testing sessions. One session involved jump squats before traditional half squats, the complex method involved half squats before jump squats and a third session involved alternating sets of half squats and jump squats (contrast method). No significant difference in jump squat performance between each of the training methods was found. In the first set of each session, there was a significant difference with the complex method having a significantly lower peak power. There was a significant difference in performance changes between the higher and lower strength groups, with the higher strength group having a greater improvement in performance using the contrast training method compared with the traditional method. The authors concluded that for athletes with high strength levels the contrast training is advantageous for increasing power output.

Fatouros, Jamurtas, Loentsini, Taxildaris, Aggelousis, Kostopoulos and Buckmeyer (2000) also conducted a study which compared the effects of 3 different protocols on selected parameters of vertical jump performance and leg strength. Forty-one men were randomly assigned to one of 4 groups: plyometric training, weight training, plyometric plus weight training and a control group. The 12-week programme involved training 3 days per week with pre and post-testing measuring vertical jump, mechanical power, flight time, and maximal leg strength

Their results showed that in all tested variables there was significant improvement. Of note however were the significant improvements in vertical jump performance (vertical

jump 8.6-cm, power 16.9-W/kg, flight time 89 m s<sup>-1</sup> and ground time 83 m s<sup>-1</sup>) for the combination training group over the plyometric and weight training groups. In the leg-press and squat-measured leg strength, the combination group presented significantly higher improvement compared with plyometric group (leg-press 83.5-kg, squat 36.1-kg) but not compared with the weight-training group. The authors concluded that to improve jumping ability and explosiveness, the results of their study supported the use of combination of traditional and Olympic-style weightlifting exercises and plyometric drills. Unaccounted variables may have confounded the results however because the total workload performed in each training session was not equated between groups (time under tension and the rate of contraction were not considered).

Harris, Stone, O'Bryant, Proulx and Johnson (2000) also concluded from their research that when considering the improvement of a wide variety of athletic performance variables requiring strength, power and speed, superior results were obtained by combination training. They based their conclusion on a study involving forty-two men who performed the same high-volume weight training programme for 4-weeks prior to the initiation of the study. On completion of the 4-week training period the participants were randomly assigned to one of three groups which then trained 4 d wk<sup>-1</sup> for 9-weeks. The high force (HF) group trained using 80-85% 1RM, the high power (HP) group trained at relative intensities approximately 30% of peak isometric force and the combination (COM) used a combination training protocol.

Of nine variables measured, the HF group improved significantly in four variables ( $p = 0.05$  for squat,  $\frac{1}{4}$  squat, mid-thigh pull, Margaria-Kalamen [MK] power test); the HP group in five variables ( $p = 0.05$  for  $\frac{1}{4}$  squat, mid-thigh pull, vertical jump [VJ], MK, standing long jump [SLJ]); and the COM group in 7 variables ( $p = 0.05$  for squat,  $\frac{1}{4}$  squat, mid-thigh pull, MK, VJ, VJP, 10-yd). The study results indicate that increases in the performance variables tested, concerned with maximal strength and power, are best accomplished using a combined training programme utilising heavy strength and high power exercises.

Ford, Puckett, Drummond, Sawyer, Gantt and Fussell, (1983) researched the effects of prescribed training programmes on 5 physical fitness test items. Fifty boys participated for 10-weeks. Three groups consisting of wrestling, softball and plyometrics; weight training and plyometrics; and weight training were pre and post-tested on sit-ups, 40 yd dash, vertical jump, shuttle run and pull-ups. With the exception of the shuttle run, the results were significant. Ford et al. (1983) concluded that programmes utilising weight-training and plyometrics in combination with other activities show promise as a training programme to increase physical fitness. This study lends further weight to the theory of previous researchers and in particular Chu (1983) who believes that the link between speed and strength is plyometric training. A weakness however in Ford et al. (1983) research is that they didn't use a control group or a training group utilising plyometrics only.

In contrast, Ebben, Jensen and Blackard (2000) examined motor-unit recruitment, using EMG, in the upper body of male basketball players during the medicine ball power drop after one set of heavy bench press (three – 5 five RM). During the medicine ball power drop there was neither change in EMG activity or in the peak ground reaction forces after heavy bench press. However, no direct measurement of the medicine ball power drop performance was measured. Further, it was not stated whether the maximal force delivered was a result of catching the ball or the force generated in the pushing movement of the exercise. Because of no significant differences in the results, the authors concluded that complex training does not result in a decrease in performance and therefore may only provide an organisational advantage to the performance of heavy resistance training and plyometric exercises.

In support of Ebben et al. (2000), Burger, (1999) compared the effectiveness of two different resistance-training programmes combined with plyometric training on power and strength development in Division 1A football players. Seventy-eight men football athletes were divided into complex and combined training groups and, with one exception, each group performing the same seven-week training programme. Both training cycles consisted of the same intensity, volume, and exercise selection. The difference between the two groups was that the experimental group used a complex



training protocol where the plyometric exercises were performed in a super-set with biomechanically similar core exercises while the control group followed a more traditional approach. They combined weight training and plyometrics where the plyometrics were performed following the core exercises of the weight training workout.

Pre and post-testing involved strength and field tests with significant improvement on eight of the tests. Those tests showing significant improvements were: body fat, bench press, squat, power clean, medicine ball throw, broad jump, vertical jump and pro-agility. For the combined versus the complex group the bench press improved significantly, 23.33-1b and in the vertical jump the complex training group approached significance, 1.11-in. Burger (1999) concluded that statistically the results do not indicate that complex training programme utilised for the study was superior to the combined training programme for increasing strength, power and agility. What Burger failed to demonstrate was; what were the expected improvements in the tests to make worthwhile enhancements for the Division 1A football players

## **ISSUES IN PROGRAMME DESIGN**

### **Specificity**

One of the global training principles stipulates that the best gains in performance are achieved when the training is completed in a manner very specific to the competitive performance. Wilson (1994) believes that the more specific the training, the better will be the transference of the training gains to the competitive performance. Studies of resistance training have shown specific adaptations of muscular force depending on the training programme applied (Sale & MacDougall, 1981). In relation to sport performance there would appear to be two divergent philosophies of strength training. The first postulates that strength training should simulate the sport movements as closely as possible. This would take into account the contraction type, contraction force, velocity and anatomical movement pattern. The second theory suggests that training the appropriate muscle groups in the fitness room is all that is required and that there is no requirement to have movement-specific exercises providing the resistance training occurs in conjunction with specific skills training for the sport. This is in

agreement with the findings of Sullivan (1970) who found that training with weights was more effective for increasing baseball-throwing velocity than training with a wall pulley in simulating the baseball throwing action. Sale and MacDougall (1981) believe that while both approaches will produce results the evidence to date strongly supports specificity in training. Harris, Stone, O'Bryant, Proulx and Johnson (2000) have found that specificity is also concerned with performance-and training-associated kinetic and kinematic factors. Specificity concerns not only the movement pattern, but also the speed of movement. Ebben, (2001) provides examples of bio-mechanically specific exercises for cross-country running including bounding, multiple cone, box and hurdle hops.

## Velocity

Another variable to consider when designing programmes is training velocity. Bompa and Cornacchia (1998) stated " ... the speed with which one intends to lift, however is not necessarily reflected in the appearance of the lift. When lifting a heavy load that is 90% 1-RM, the performed motion may look slow, however, the force against the resistance must be applied as quickly as possible ..." p. 29. Although Bompa and Cornacchia (1998) statements are clear Cronin, McNair and Marshall (1999), has pointed out, that, although there is no doubt that strength training can improve functional performance, the implication to perform velocity-specific strength training would appear questionable due to the disparity between the actual velocities of most athletic tasks and the training velocities achieved during weight training.

Short study periods, unrepresentative subject groups, absent or inadequate comparison groups, inadequate dependent variables, inadequate independent variables, interference via strength measurement, (Wilks, 1996)

Almasbakk and Hoff (1996) agree that while velocity specificity is the method to establish optimal strength and power improvement, the further the velocity of movement in actual performance from the trained velocity, the less effective the training will be. To complicate matters further, Behm and Sale (1993), while acknowledging that "... strength training increases strength most at the specific velocity

at which the training exercises are performed ...” (p. 359), the mechanisms responsible are unknown. This is because the studies with tests of voluntary contractions involving specificity, have been completed with different movement velocities (as previously portrayed in Figure 1) and that the relative roles of neural and muscle adaptations is not known.

Research by Cronin, McNair and Marshall (1999) suggest that training techniques that simulate the velocity and acceleration profiles that replicate the desired functional performance may optimise adaptation to that task. They state that combination training incorporating heavy load with sport specific training in the same session might provide an optimal strategy for promoting intramuscular and intermuscular co-ordination and thereby improve functional performance. For example; they found that velocities attained during both concentric bench press and bench press throws simulate the velocity and acceleration profiles associated with throwing. Cronin, McNair and Marshall (1999) identified the issue relating to velocity-specificity; in whether optimal functional performance is gained by training with one exercise speed during complex training. The results indicated that combining both slow and fast movements are suggested methodology to optimise neuromuscular adaptation. One flaw appears however in this thinking as the researchers only investigated velocity-adaptations and changes to kinematic and kinetic variables as demonstrated during the bench press and bench press throw. Changes in actual throwing performance during sport specific functional tasks were not examined.

## Equi-Volume

Much of the research has also failed to equate training volume between subject groups. Volume is most commonly measured as the total product of repetitions, sets and loads (expressed as %1RM) but can be measured as total time under tension (TUT), electromyography (EMG) activity, or total mechanical work performed (force x distance). Bompa (1993) adds the time or the duration of training in hours, as an integral part of this assessment of the volume. Comparison between studies using no volume equation and / or different methods of volume equation is dubious. This point was recognised by Atha (1981) who, on examining

load intensity for strength gains, stated that five – six repetition maximum (approximately 84%1-RM) appeared to provide the greatest gains in strength compared to heavier (2-RM) or lighter (10-RM) loads. He noted that a true load-gain relationship was unresolved due to the different number of repetitions required in each loading scheme.

It appears that the literature is widespread with research that has failed to equate loading between training protocols. Berger (1962) sought to determine the optimum number of repetitions per set to produce the greatest gains in maximal strength. Six subject groups were defined according to the number of repetitions to failure they would perform (either: 2, 4, 6, 8, 10 or 12 repetitions) and loads selected to elicit “maximum effort” for the given number of repetitions. Each group performed only one set so that the two-rep group performed a total of six repetitions per week whereas the twelve repetition group performed 36 per week. Thus the training groups were not equivalent. After a twelve – week training programme results showed that four, six and eight repetitions produced significantly higher mean changes in 1-RM strength compared to two, ten and twelve repetitions. Berger (1962) stated that the results indicated between three to nine repetitions for one set are the optimum number for improving strength. In practice however, where maximal strength gains are desired, Pearson, Faigenbaum, Conley & Kraemer (2000) and Rhea, Alvar, Ball and Burkett (2002) believe that three sets of weight training is superior to one set of weight training.

In contrast to Berger’s findings, Dons, Bollerup, Bonde-Petersen and Hancke (1979) monitored 1-RM, CSA and muscle fiber composition on different training groups equated for volume using reps x load. One group trained with a load of 50% 1RM for 20 reps, the other with 80% 1RM for 12 reps. Load was adjusted regularly as strength increased. Over the course of the seven-week intervention the 80% 1RM group significantly increased 1RM (42.3% from starting values) whereas the 50% 1RM group did not increase strength significantly. No increase in isometric strength was recorded in either training group. CSA showed overall tendencies to increase, and strength per unit muscle CSA (specific tension) increased significantly in the 80% group, but insignificantly in the 50% 1RM group. Dons et al. (1979) commented that this

supported research that concluded “heavier” training was most effective in increasing strength. This was in contrast to the aforementioned studies that used novice participants and did not equate for equi-volume training, which found no significant difference between groups.

Cronin and Crewther (2002) conducted a study to determine if three training loads equated by volume, differed in terms of the kinematics and kinetic characteristics of each set. Twelve participants performed three sets of ballistic squats on an instrumented supine squat machine. Each subject completed a set at three different load conditions, 30% 60% and 90% of their 1RM. To ensure the mass lifted between the three conditions was identical, the volume of each set was equated (% 1-RM x reps). Compared to the other conditions, significantly greater TUT ( $P \leq 0.05$ ) during the eccentrics and concentric phases was observed for the 30% 1RM as well as greater total force output. Cronin and Crewther (2001) also found greater total power output was associated with the 30% 1RM condition. Compared to the 90% 1RM condition, the 60% 1RM produced significantly greater total work, force and power. Greater concentric impulse was associated with the 90% 1RM condition.

The optimal training load during complex training needs to be established so that the optimum benefit of complex training can be attained. According to the National Strength and Conditioning Association’s basic guidelines, multiple set periodised resistance programmes are superior to single set (Pearson et al., 2000) so it make sense to have at least three sets comprising of a complex to obtain optimal results. With regard to intensity and volume the athletes need to work at a high intensity level for both weight and plyometric training (Chu, 1992; Ebben & Blackard, 1997, Hedrick, 1994; Newton & Kraemer, 1994; Verkhoshansky, 1986; Yessis, 1995).

A concern with complex training studies is, due to the absence of published numerical data, there appears to be no uniform design considering variables such as exercise selection, load and rest between sets. While recent research offers considerations and possible guidelines regarding these variables, they also raise the questions about age and gender specific effects as well (Ebben, 2002).

## CHAPTER 3: ACUTE ENHANCEMENT OF STRENGTH RELATED PRE-CONDITIONING ACTIVITIES—A BRIEF REVIEW

### INTRODUCTION

The principle objective of throwing in softball is for the ball to beat a runner to a base. This usually necessitates some compromise between accuracy and speed. According to van den Tillaar and Ettema (2002), if an athlete wishes to throw more accurately, velocity decreases. An advantage in softball however, is that the fielder receiving the throw can make major body adjustments, both proximal and distal, to assist in making the throw successful and therefore the velocity of the throw can be emphasised. Given this information, knowledge of those factors determining throwing velocity is desirable. No doubt many biomechanical factors are important, however it has been stated that because throwing requires specific muscle actions, increasing muscle power in the upper limb (specifically elbow extensor and shoulder internal rotation), will increase throwing velocity (Clements, Ginn & Henly, 2001; Toyoshima, Hoshikawa, Miyashita & Oguri, 1974). It is thought that a combination of weight training and plyometric training (thus termed complex training) may be useful for developing power as both the force and velocity characteristics of muscular performance are addressed in such training (Newton & Kraemer, 1994). Complex training is also an efficient way to train as weight training and plyometric training can be performed in the same session thus reducing training time. Researchers using a longitudinal approach have shown such training to improve functional performance such as vertical jump height by 3 - 10 cm, speed by 0.18 – 1.5 s over 40 yd and Margaria power scores by ~ 3.35 – 5.69 W (Ebben & Watts, 1998). Whether such training effects can be observed within a single session, the magnitude of change, if any, and the ideal loading parameters have yet to be clearly identified.

Portraying inference about effects sizes and their worthwhile enhancements from existing research is difficult; largely due to the way researchers appear to calculate the value of a statistic that summarises the outcome. According to Batterham and

Hopkins (2005), the results from any study would generate a different value for the outcome statistic if another sample was used and in addition, when reporting their findings, researchers are expected to make a deduction about the population value of the statistic. In line with this practice the universal approach requires researchers to use a statistical package to produce and report the statistical probability (the  $p$  value) of their results. This statistic represents the reproducibility of the study, i.e. at the 0.05 level the results of a study can be expected to occur 95 out of 100 times. It is felt by recent researchers, Batterham and Hopkins (2005) and Rhea (2004) that this form of reporting of the statistic may be misleading. Large differences in groups or interventions may fail to be identified due to small sample sizes or large variance and those trivial differences may reach the 0.05 level if the study had sufficient sample size. It would appear then, the most relevant issue is not whether there is an effect but how big it is and whether it is a worthwhile enhancement for an athlete. Various methods have been described for estimating the magnitude of a treatment effect or an effect size (ES). The most frequent and by and large the most appropriate are eta squared, omega squared and Cohen's  $d$ . The most favoured method of ES in the area of strength and conditioning research is Cohen's  $d$  and the standardised mean difference. While reporting the magnitude of change may be more important than, or at least just as important as, the reproducibility of a study there is an apparent lack of understanding about the interpretation of changes in test scores (Hopkins, 2004). To understand the issue of magnitude, the researcher requires some concept of change that matters to the athlete in their sport. Examples of this include solo athletes where about half a coefficient of variation (CV) is the smallest worthwhile enhancement (Hopkins, Hawley, & Burke; 1999) and for team athletes the smallest worthwhile difference is  $\sim 0.20$  which is equivalent to moving from the 50<sup>th</sup> to the 58<sup>th</sup> percentile. To address this issue and to compare the effectiveness of previous research, ES have been calculated where possible in Tables 1 and 2 and throughout this paper.

**Table 1:** Acute enhancement (percent and effect size) of strength related pre-conditioning activities on the upper body kinetics and muscle activity.

Author Date	& Subjects Study Design	Pre-Conditioning Activity	Time Course	Outcome Variable/s	Results (% change and P value)	Effect Size
Baker Experiment 3 (2001)	N = 8 Professional Rugby League Players with training experience 1 -2 years. Repeated measures design	Bench press throws of 40, 50 & 60 kg for 6, 5 & 4 reps.	240s	Ascending order (Asc P40, Asc P50, Asc P 60) or descending (Dsc P60, Dsc P50, Dsc P40)	Mean P40 (10.7% $p \leq 0.05$ ) Mean P60 (10% $p \leq 0.05$ )	2.1 Large 1.9 Large
Baker (2003)	N = 16 (C =8, Exp = 8) Rugby League 1 years experience in contrast / complex training. Pretest-posttest design	Bench press throws 6 reps @ 65% 1RM between tests	240s	Bench Press Throws 50 kg (BT P50) Power (W)	Power (W) (4.5% $p \leq 0.05$ )	0.77 Large
Baker (2003)	N = 27 (C =12, E = 15) College Rugby League Players, experienced power training. Pretest-posttest design	Explosive bench press throw (BT P40)	90s 420s	Power Output (W)	Mean P40 (-18% $p \leq 0.05$ ) Mean P40 (-6.6% $p \leq 0.05$ )	- 1.9 Large -1.1 Large
Ebben et al. (2000)	N = 10 Div. 1 Basketball Players with plyometric experience. Repeated measures design	3 – 5 RM bench press	300s	Medicine ball power drops EMG <sub>int</sub> pectoralis major & triceps	EMG Pectoralis (1.3% $p \geq 0.05$ ) EMG Triceps (8.5% $p \geq 0.05$ )	0.02 Trivial 0.28 Small
				Mean GRF (N)	Mean GRF (4.8% $p \geq 0.05$ )	0.27 Small
				Max GRF (N)	Max GRF (-16.2% $p \geq 0.05$ )	-0.63 Large
Gulich & Schmidt-bleicher (1996)	N = 36 Competitive speed-strength athletes of regional, national & international level. Time series design	Bench press 3 sets 90% 1RM (sub-MVCs)	180s 300s	Bench Press Movement Velocity F (N) t (ms)	F (N) (1.0% $p \leq 0.05$ )	0 Nil
Hrysomallis & Kidgell (2001)	N = 12 Active males engaged in recreational weight training, mean 3.1, SD $\pm$ 2.6 years. Repeated measures design	5 RM bench press	180s	3 Explosive Push ups over a force platform - impulse mRFD Average Force (N) Peak Force (N)	Impulse (0% $p \geq 0.01$ ) mRFD (-15.2% $p \geq 0.01$ ) AF (0.04% $p \geq 0.01$ ) PF (3.6% $p \geq 0.01$ )	0 Nil -0.72 Large -0.01 Trivial 0.13 Trivial

N = number; C = control; E = experimental; BT = Bench press throws; EMG<sub>int</sub> = electromyography; GRF = ground reaction force; MVC = maximal voluntary contractions; mRFD = maximum rate of force development.



## UPPER BODY

### Subjects and enhancement

Enhancement in strength among “untrained” subjects are easily accomplished and increases of 10% or more can be obtained after only two weeks of intense training and it is one of the reasons why it is difficult to evaluate accurately the effects of different treatments (Hakkinen, 1989). This could have an effect of the treatment as a growing body of research has found that an individual’s training level may affect such responses as post-activation potentiation (Gullich & Schmidtbleicher, 1996; Young, Jenner & Griffiths, 1998). Recently, Chiu, Fry, Weiss, Schilling, Brown and Smith (2003) were in agreement and commented that the effect of participant’s training status and the time-course of adaptations were not well studied.

With regards to the research reviewed in this paper, the characteristics of the subject’s can be observed in Table 1. The subjects for the most part were sportsman and varied in ability and strength training experience (recreational to professional rugby league with 1 – 2 years weight training experience). The subject descriptions for most studies give little indication of true training status. Nonetheless, the percent changes in performance and effects sizes ranged from -18% to 10.7% and large negative (-1.9) and positive (2.1) effects, respectively. The effects of the pre-conditioning activity on the outcome of these subjects were mostly negative or trivial. The largest negative effects were found with relatively untrained (college and recreational) athletes, whilst the largest positive effects were with relatively well trained (> 12 months strength training) rugby league players (Baker, 2003; 2001). A study performed by Duthie, Young and Aitken (2002) established that following a set of 5-RM back squats, stronger participants improved VJ performance more than weaker participants. They also went on to say that while peak power and peak force increased in stronger participants during JS exercises (following 3-RM squats), the same variables were decreased for weaker participants. It would seem that the training status might affect the

magnitude of the acute enhancement, with better trained athletes more likely to respond positively to a complex training approach to strength training.

### Pre-Conditioning activity and enhancement

The bench press or derivatives such as bench press throw were used as the pre-conditioning activity for all studies observed in Table 1. Absolute loads used ranged from 40 – 60kg, whereas the relative loads ranged from 40% 1-RM to approximately 90% 1-RM. The largest percent changes (-18% to 10.7%) and effect sizes (-1.9 to 2.1) were associated with explosive power (lighter load) orientated loading schemes (40 – 60kg). However, it does seem that the heavier loading schemes do have mostly negative or trivial effects on acute enhancement.

### Time Course and enhancement

The recovery time allocated between the conditioning activity and the outcome measure may affect the magnitude of the enhancement. That is, if the duration between events is too short fatigue may inhibit performance whereas if too long between events, the neural and/or hormonal responses that produce the enhancement may have decayed. Figure 7, page 89 demonstrates this concept. Ebben, Jensen, and Blackard (2000) and, Young, Jenner, and Griffiths (1998) have suggested that there may be an optimal time of recovery between activities when complex training. However for the most part the magnitude of the optimal duration is not well researched or the results are varied. For example, Jensen and Ebben (2003) reported anecdotal recommendations reported ranged from no rest up to 600 s in duration while Docherty et al. (2004) reported time periods between activities of 15 – to 1110 s. In comparison, the translated interpretation from Gullich and Schmidtbleicher (1996) paper, the rest used between treatment stimulus and post-test measures were 180 – 300 s, resulting in a 1.5% increase in single leg jumps. Jensen and Ebben (2003), protocol required a rest period of 240 s while Baker (2003) attempted 240 and 180 s rests. Young et al 1998) also used 240 s rests between heavy preload of 5RM and LCMJ. Radcliffe and Radcliffe (1996) tested athletes 180 s after a variety of explosive type warm-up protocols. Smilios et al (2005) rested 180 s between interventions and then measured

performances; before treatment, 60 s after each set, at the completion of the 5<sup>th</sup> set and after 600 s of recovery.

In terms of the time course of enhancement of the upper body (Table 1), most researchers have recorded effects between 90 – 420 s after the pre-conditioning activity. One such study using relatively short (90s) and long time (420s) durations between the pre-conditioning activity and the outcome measure reported a large negative effect (-1.1 to -1.9). However, whether intermediate times had a similar negative effect is unclear from this methodology, so concluding that very short or very long durations post the conditioning activity, have negative effects is problematic. Trivial to moderate effects appear to occur when the time course is between 180- 300 s. Drawing conclusions for the time course for optimal enhancement of the upper body is somewhat problematic given the paucity of literature in this area, but it would seem that the greatest acute enhancement occurs (ES 0.77 moderate to 2.1 large) at 240 s.

### Instrumentation and sensitivity

The instruments used to measure acute enhancement have ranged from: a custom-built strain gauge force platform (Victoria University Technologies, Australia), a force plate (OR6-7-2000, AMTI, Watertown, MA), a contact free photoelectric measuring system (Fichte, Gullich & Schmidtbleicher, 1994) and the Plyometric Power System (PPS, Nor-search, Lismore, Australia). The smallest percent changes (0.04%) and effect sizes (-0.01 trivial) were associated with the strain gauge platform. Whereas the largest percent changes (-18%) and effect sizes (2.1 large) were associated with the PPS system.

### Variables and sensitivity

It can be observed in Table 1 that a number of outcome variables (impulse, mGRF and power output) were used to determine the magnitude of change after the pre-conditioning activities. The largest percent changes (-18 to 10%) and effect size (-1.9 to 2.1) were associated with power. Because the power signal reflects both the force and velocity characteristics of muscle, it may be that this measure is more

sensitive to the effects of the pre-conditioning activity than those measures that use solely force.

### Other findings

Baker (2001) while not specifically comparing the enhancement to performance does suggest that power output developed using a descending order is higher when lifting lighter resistances (when a strength exercise precedes the power exercise). This matters in sports where movement speed and power output against lighter external resistances is important as in the throwing of a softball. He also suggested that by following a contrast loading scheme and using slightly heavier than normal implements in the later stages of a warm-up, could possibly provide acute augmentation. Gullich and Schmidtbleicher (1996) also support the use of MVCs into the warm-up and that it has been shown to be effective in top-level international sport. They reported 2.7% CMJ increase in bobsledders after 3 x 3 MVCs, 1.8% longer distance in the one legged jump test for decathlon and sprint athletes and 4.2% improvement in a 2kg medicine ball throw from kneeling position for 5 decathletes.

## LOWER BODY

### Subjects and enhancement

The subject characteristics used in the lower body research can be observed in Table 2, page 63. Similar to the upper body, the subjects for the most part were sportsman and varied in ability and strength training experience (recreational to professional rugby league with 1 – 3 years experience). The percent changes in performance and effects sizes ranged from – 3.1% to 5.4% and nil to moderate (0.47) effects, respectively. The effects of the pre-conditioning activity on the outcome of these subjects were mostly trivial or small. In comparison to the upper body where better trained athletes were more likely to respond positively to a complex training approach to strength training, the same acute responses cannot be said for the lower body.

**Table 2:** Acute enhancement (percent and effect size) of strength related pre-conditioning activities on the lower body kinetics and kinematics

Author Date	& Subjects Design	Study	Pre-Conditioning Activity	Time Course	Outcome Variables	Results (% change and P value)	Effect Size
Baker Experiment (2001)	N = 6 Weight trained 2 sportsmen Professional League 2 – 3 years weight training experience Pretest-posttest design	trained	2 sets of 6 reps with JS P40, 1set of 3 reps with 60 kg between the 2 JS P40 sets.	12 –180s	JS 40 kg barbell (JS P40)	Mean P40 (5.4% $p \leq 0.05$ )	0.18 Small 0.47 Moderate
Duthie et al. (2002)	N = 11 F experience with resistance training and plyometrics Repeated measures design	Previous with resistance training and plyometrics Repeated measures design	Using a 3RM load S1 sets of half squats 60 & 80% before sets of jump squats (traditional method). S2 sets of half squats before JS (complex method).	300s	JH cm JH cm Peak Power (W) Peak Power (W) Maximal Force (N) Maximal Force (N)	JH cm Complex (0% $p \leq 0.05$ ) JH cm Contrast (1.6% $p \leq 0.05$ ) PP (W) Complex (1.5% $p \leq 0.05$ ) PP (W) Contrast (1.4% $p \leq 0.05$ ) MF (N) Complex (0.16% $p \leq 0.05$ ) MF (N) Contrast (0.81% $p \leq 0.05$ )	0 Nil 0.11 Small 0.13 Small 0.12 Small 0.02 Trivial 0.12 Small
Gourgoulis al. (2003)	N = 20 Physically active men Repeated Measures	Physically active men Repeated Measures	5 sets of half squats with 2 reps @ 20, 40, 60, 80 & 90% 1RM.	30s	2 CMJ Power (W) VH cm	VH cm (2.39% $p \leq 0.05$ )	0.04 Trivial 0.16 Small
Gulich Schmidt-bleicher (1996)	& N = 36 speed-athletes of regional, national & international level. Pretest-posttest design	Competitive strength jumped (1.4 cm)	3 MVC for the CMJ	18 - 300s	VJ height in cm MVCs EMG <sub>int</sub>	CMJ cm (3.3% $p \leq 0.05$ ) EMG <sub>int</sub>	0.36 Moderate
Jones & Lees (2003)	N = 8 strength trained Experienced and plyometric training Pretest-posttest design	strength trained in 2 <sup>nd</sup> 3 <sup>rd</sup> & 4 <sup>th</sup> at 3, 10 & 20 mins and plyometric training Pretest-posttest design	5 squats @ 85% 1RM with 3 <sup>rd</sup> & 4 <sup>th</sup> at 3, 10 & 20 mins	CMJ 180s 600s 1200s  DJ 360s 780s	Height cm Velocity m/s Peak GRF Peak power (W) Height cm Velocity m/s	CMJ Height cm (-0.26% $p \geq 0.05$ ) Velocity (ms) (-2.29% $p \geq 0.05$ ) Peak GRF (-1.9% $p \geq 0.05$ ) Peak Power (W) (-3.1% $p \geq 0.05$ ) DJ Height (0.83% $p \geq 0.05$ ) Velocity (m/s) (0.39% $p \geq 0.05$ )	0.20 Small 0.11 Small 0.18 Small 0.06 Trivial 0.06 Trivial 0.04 Trivial

					Peak GRF	Peak GRF (3.0% $p \geq 0.05$ )	0.06 Trivial
					Peak power (W)	Peak power (W) (0.69% $p \geq 0.05$ )	0.16 Small
						Contact Time (ms) (3.5% $p \geq 0.05$ )	0.34 Moderate
Masamoto .al. (2003)	N = 12 M Male athletes 1 year experience plyometric exercises Repeated measures design	5 sub-max sets 1 – 8 30s before attempting 1RM.			1RM back squat 1RM kg	1RM (3.5% $p \leq 0.05$ )	0.17 Small
Mc Bride et al. (2005)	N = 15 NCAA Division 111 football players Pretest-posttest design	HS 1 set 3 x 90% 1RM Squats LCMJ 1 set 3 x 30% 1RM	240s		Running velocity 10, 30 & 40 meters.	HS 40 meters (0.87% $p \leq 0.05$ ) HS 10, 30 meters LCMJ 10, 30, 40 meters	0.16 Small
Scott Docherty (2004)	& N = 19 Resistance trained men 1 year experience back squat Repeated measures design	5RM squat.	300s		VJ & HJ Power enhancement cm	VJ (0% $p \leq 0.05$ ) HJ (0% $p \leq 0.05$ )	0 Nil 0 Nil
Radcliffe Radcliffe (1996)	& N = 35 inter college athletes 24 M, 11 F	4 sets of 4 snatches @ 75 – 85% 1RM	180s		HCMJ Peak Power (W)	Peak power (W) (1.5%, $p \leq 0.05$ )	0.5 Large
Smilios et al. (2005)	N = 10 M Regional team sports, training -3 times per week with loads of 40 – 70% 1RM.	HS & JS twice with 2 loads of 30% 1RM & 60% 1RM. On each occasion 3 sets x 5 reps	60s 300s 600s		CMJ JS 60 CMJ JS 30 Squats HS 60 Squats HS 30	CMJ JS 60 (3.41% $p \leq 0.05$ ) CMJ JS 30 (3.96% $p \leq 0.05$ )	Doesn't list pretest heights or SDs
Young et .al. (1998)	N = 10 M1 year experience in half of 18 – 31. Repeated measures design	2 sets of 5 LCMJ, 1 set of 5 squat reps with a 5RM load, & 1 set of 5 LCMJ	240s		LCMJ cm	cm (2.8% $p \leq 0.05$ )	0.29 Small

N = number; M = males; F = females; JS = jump squat; JH = jump height; CMJ = counter movement jump; DJ = drop jump; VJ = vertical jump; LCMJ = loaded counter movement jump; HCMJ = heavy counter movement jump; HS = heavy set; GRF = ground reaction force; MVC = maximum voluntary contraction; 1RM = one repetition maximum

## Pre-Conditioning activity and enhancement

The choice of either MVCs, LCMJ, squat, and snatches were used as the pre-conditioning activity for all researchers observed in Table 2. Relative loads ranged from 3-RM to 5-RM and absolute loads from 20 – 90% 1-RM appear to be the loads most widely used for the squats and snatches, while LCMJ used absolute loads 30 – 60% 1-RM and a relative load of 60kg. The largest percent changes (-3.1% to 5.4%) and effect sizes (0.04 to 0.47) were associated with explosive power (lighter load) orientated loading schemes. It appears that the heavier loading schemes do have mostly negative or trivial to small effects on acute enhancement; however, the results are somewhat equivocal (Gullich & Schmidtbleicher, 1996; Jones & Lees, 2003; Young et al, 1998).

## Time Course and enhancement

As with the upper body the recovery time allocated between the conditioning activity and the outcome measure may affect the extent of the enhancement. As stated previously fatigue may inhibit performance when the duration between the conditioning activity and the outcome variable of interest is too short whereas if too long between events, the neural and/or hormonal responses that produce the enhancement may have decayed. In terms of the time course of enhancement of the lower body, most researchers have used durations between 30 – 1200 s after the pre-conditioning activity. Two such studies using relatively short (30s) duration between the pre-conditioning activity and the outcome measure reported trivial and small effects for power (w) and VH (cm) of 0.04 and 0.16 respectively (Gourgoulis et al., 2003) while Masamoto et al., (2003) obtained a small effect (0.17) for 1-RM squat. In comparison the extended time for recovery of 1200 s (20 minutes) showed a negative effect on peak power (W) of -3.1% but this was deemed to be trivial (Jones & Lees, 2003) and that suggests that it is unclear whether there is an effect on plyometric performance following heavy resistance exercise. Trivial to small positive effects appear to occur when the time course is between 120 – 600 s and the optimal time appears to be is between 120 and 240 s.

## Instrumentation and sensitivity

Advances in technology have enabled a more sensitive direct measure of power output during certain training exercises. The collection and analysis of this type of data can be used successfully to gauge the effects of various training variable manipulations on muscle power. Of the eleven studies reviewed three researchers used force platforms. The KISTLER model was chosen on two occasions and the Onspot 2000-1 was used in conjunction with a modified Smith Machine. One researcher chose to monitor EMG in conjunction with the force platform. Jones and Lees (2003) collected kinetic, 3-dimensional motion and muscle EMG. Scott and Docherty (2004) measured VJ height using a jump timing mat that calculated the VJ from the time in the air of the participant (Just Jump System, Probotics Inc., Huntsville, AL). Smilios et al. (2005) used a resistive platform connected to a digital timer (Ergojump, Psion CM, MAGICA, Rome, Italy) to measure CMJ while Young et al. (1998) utilised a sliding pointer and a steel tape measuring to the nearest 0.5 cm while Baker used the PPS (as described previously). Masamoto et al. (2003) increases in 1-RM back squat were assessed by the amount of weight lifted while Radcliffe and Radcliffe (1996) and McBride et al. (2005) used increases performance measures relating to distance jumped and decreased sprinting time. Their instruments detected small changes in performance (1.5% and 0.87%) respectively and when these were calculated the ES were 0.16 small to 0.5 large.

## Other findings

While most effects sizes were trivial to small it would seem that any practical benefit requires careful implementation and individual experimentation. A load of 30% of 1-RM appears to be equally effective as a load of 60% of 1-RM to increase CMJ performance (average of 3.5% in both cases) and that to use the complex method effectively the athletes require significant lower limb strength levels. While some researchers advise that when completing heavy strength exercises during a warm-up, a sub-maximal to moderate load (5-RM) can be used for short-term enhancement of vertical jump performance. They are contrast to a study by Scott and Docherty (2004) which failed to support the use of heavy preload to enhance



subsequent performance. They did point out however that some discrepancies in results may be due to lack of internal validity and differences in methodology.

## **CONCLUSION**

Researchers using a longitudinal approach appear to have shown complex training to improve functional performance in most cases. However, whether such augmentation can be observed conclusively within a single session, the magnitude of change, if any, and the ideal loading parameters have yet to be identified. The aim of this chapter was to identify if acute enhancement could be identified within a session and if so what factors seemed to be most important in producing this enhancement. As expected the beneficial effects observed from a single session were trivial to small. It is through progression and repetition that these effects become substantial and of clinical and practical importance. Nonetheless the benefits of single conditioning session are of interest to some athletes and coaches and by identifying the critical acute factors it is proposed that the benefit from longitudinal should be magnified. Given this some conclusions can be made from this review but the reader needs to be cognizant of the limitations given this approach and the paucity of research in this area.

It would seem that well trained subjects would benefit more so than novice trainers from complex training, with greater enhancement effects observed in this population particularly in the upper body. This may mean that the novice trainers may need a solid base of strength training before progressing to complex type of training.

The optimal duration for this enhancement appears to be between 180 – 240 s for both the upper and lower body. Complex combinations need to be performed with this in mind. Furthermore, if a conditioning activity is being used to enhance actual performance, it would seem that if the actual performance cannot be performed within the optimal time period there is decay in the benefit of the pre-conditioning activity.

In terms of the preconditioning activity it appears as if the bench press or derivatives such as the bench press throw using absolute loads of 40 – 60kg should be used for the upper body. The lower body should include MVCs, LCMJ, squats and snatch exercises. When selecting dynamometry, the use of a PPS system for the upper body and a force-platform for the lower body seem to be the better options for measuring changes. This could be due to their sensitivity or the nature of the exercise e.g. multi-articular movement. Furthermore power output would seem the variable of choice particularly in the upper body.

Generally the amount of rest between sets of resistance training and subsequent prescribed training interventions, such as plyometrics, in a complex is limited. It is possible that muscles used may be fatigued from the heavy preload stimulus thus masking any potential potentiating effects. No doubt the benefits of such training relate to whether the complex has a fatiguing or potentiating effect. It is believed that fatigue and potentiation could coexist in muscle and can be developed as an acute expression of the fitness-fatigue theory (Zatsiorsky, 1995). This theory is based on the thought that preparedness, as shown by the athlete's sporting performance, is not constant and varies with time. Accordingly the instantaneous training effect after a workout is an amalgamation of two processes namely, gains in fitness encouraged by the workout and fatigue. The result to an athlete's preparedness after the workout improves due to fitness gain, but deteriorates because of fatigue. The final outcome is determined by the summation of the positive and negative changes. In this model, performance is the result of the interaction of fatigue and fitness after-effects following an exercise stimulus. The key would seem, is to find the optimal duration when and how to maximise fitness effects and minimize fatigue effects.

It is possible that acute augmentation to sport performance could be achieved by the use of complex training. It will most likely offer an enhanced training stimulus for athletes possessing well developed functional strength and ability. However, a great deal of research is needed in this area before definitive conclusions can be made. In addition, studies would be of greater value if the subjects were measured

on multiple lift RMs, one or more field measure for explosive power or some precise laboratory measures of neural or metabolic functions. The recording of these multi-variables allows a greater understanding of the different effects of different pre-conditioning activity regimes on the development of different strength qualities e.g. maximal strength, explosive power, impulse (N·s), mRFD (N·s<sup>-1</sup>), average force (N) and peak force (N), mean and peak GRF. Because the subjects are measured on a greater range of variables this may enable a broader and better understanding of a particular activity's beneficial/harmful effects.

## **CHAPTER 4:**

# **A COMPARISON OF DIFFERENT WEIGHT TRAINING TECHNIQUES AND THEIR ACUTE EFFECTS ON SOFTBALL THROWING VELOCITY**

## **INTRODUCTION**

The use of resistance training methods to augment muscular strength, speed and power for improving sports performance would seem prevalent. Since softball requires movements performed with both force and velocity, the produce of force and velocity, power, is of considerable interest to strength and conditioning coaches (Newton & Kraemer, 1994). Traditionally strength and conditioning coaches have focused on developing strength with the expectation that it will transfer into power. The coaches believe that if the athlete's slow velocity strength increases, then power output and hence dynamic performance will also improve. As all explosive movements start from zero or from slow velocities this belief to a certain extent is true since maximum strength, even at slow velocities, is a contributing factor to explosive power. Nevertheless, when the sport specific task requires these muscles to achieve high velocities of shortening, slow velocity strength has a reduced amount of influence on the muscle's ability to produce high force at rapid shortening velocities.

Softball throwing is a high velocity ballistic movement in which velocity is linked to performance. It is reported that the musculature involved in the throw disciplines is pre-stretched before the acceleration phase which is related to the implementation of the principle of starting strength (Newton & Kraemer, 1994; Wilson, Elliot & Wood, 1990). To maximise this starting strength the biomechanical phases and major musculature of the throwing motion have been identified by Brumitt, Meira and Davidson (2005); Jacobs (1987) and Pretiz (2004) as: the wind-up, early cocking, late cocking, acceleration, deceleration and follow through phases. The extreme range of motion available at the shoulder is required for successful throwing, however when combined with intra-articular forces at the shoulder, lack of conditioning and poor mechanics, it can lead to severe injuries. The large external muscles used to create the motion and speed often create sub-luxating shear forces in addition to the desired actions. As throwing requires specific muscle actions, sound strength and conditioning

principles are considered necessary for optimal performance when throwing. The specific shoulder musculature and throwing actions involved are listed in Table 3:

<b>Muscle</b>	<b>Throwing Function</b>
Serratus anterior	Scapula protraction
Trapezius	Scapula elevation
Rhomboids (major and minor)	Scapula retraction
Deltoid	Shoulder abduction
Supraspinatus	Shoulder abduction & eccentric deceleration
Infraspinatus	Shoulder external rotation & eccentric deceleration
Teres minor	Shoulder external rotation & eccentric deceleration
Subscapularis	Shoulder internal rotation
Triceps	Shoulder extension & elbow extension
Latissimus dorsi	Shoulder internal rotation & shoulder extension
Pectoralis major.	Shoulder internal rotation & horizontal adduction

**Table 3:** Shoulder musculature and throwing action (adapted from Brumitt, Meira & Davidson, 2005).

If we are to maximise enhancement in power implementation then, we must focus our attention on involving both the force and velocity components. However extensive debate exists concerning not only methods to produce power adaptations but also the optimal resistances for power adaptations (Adams et al., 1992; Baker et al., 2001; Lyttle et al., 1996; Young, 1993). While some researchers advocate low resistance ( $\leq 30\%$  of 1-RM), high velocity (speed orientated) training others advise high resistance ( $\leq 80\%$  of 1-RM), low velocity (strength-orientated) training to produce the necessary power adaptations (Baker et al., 2001). More recently, research has indicated a combination of methods. By using both speed-orientated and strength-orientated training strategies (Adams et al., 1992; Lyttle et al., 1996) or through specific maximum mechanical power output (Pmax) training methods athletes may develop power and diverse performance variables more effectively (Wilson et al., 1993).

The premise on which complex training is based assumes that the explosive capabilities of muscle are enhanced after it has been exposed to maximal or near maximal contractions

(Baker, 2003; Gullich & Schmidtbleicher, 1996; McBride, Nimphius & Erickson, 2005) and that this phenomenon has been referred to as postactivation potentiation (PAP). According to Docherty, Robbins and Hodgson (2004) two theories have been proposed to explain the PAP. One theory proposes that the pre-stimulation results in neural adaptations such as increased descending activity from the higher motor centers, direct myoelectrical potentiation, increased synchronization of motor unit firing, reduced peripheral inhibition from Golgi tendon organ, reduced reciprocal inhibition from the Renshaw Cell, post tetanic potentiation and/or enhanced reciprocal inhibition of the antagonist musculature may account for the improvements in power output (Baker 2003; Baker, 2001; Ebben, Jensen & Blackard, 2000; Ebben & Watts, 1998; Lyttle, et al., 1996; Fleck & Kontor, 1986; Gullich & Schmidtbleicher, 1996).

The alternative theory that has been considered is phosphorylation of the myosin light chain (MLC). An increase in sarcoplasmic  $Ca^{+2}$  from muscle stimulation activates MLC kinase, which is responsible for making more ATP available at the actin-myosin complex. This in turn increases the rate of actin-myosin crossbridging (Sale, 2002). It is thought by Docherty et al. (2004) that phosphorylation and post-tetanic potentiation is not the only mechanisms contributing to PAP. It is possible that PAP is the result of exchanges between neural and mechanical adaptations and that a number could function together simultaneously. These exchanges are not well understood (Docherty et al. 2004).

## **METHODS**

### **Experimental Approach to the Problem**

This study used a repeated measures design where the players were randomly assigned to 1 of 2 groups and assigned to different ordering of the treatment which allowed the players to serve as their control. This ordering of the treatment, based on the counter-balance design, was to reduce order bias. Each subject was required to participate in one familiarisation day and two data collection sessions, with each one performed on a separate day. Each session was separated by at least two days. Participants were asked to refrain from participating in strenuous activity the day preceding testing. In addition

subjects were asked to consume their normal food intake but to refrain from drinking coffee 2 hours prior to testing.

## Participants

Eight male softball players from premier softball teams volunteered to participate in this research. All had extensive softball experience, being at least members of Auckland or North Shore provincial softball teams, and all had participated in some form of resistance training consisting of conventional weight training as part of their preseason general preparation. After procedures for the research were explained the participants completed the familiarization phase and were randomly assigned to one of two treatment groups. The subject's mean ( $\pm$  SD) age, mass, height and maximal bench press strength (1-RM) were  $28.5 \pm (3.7)$  yrs,  $88.7 (\pm 14.6)$  kg,  $178.4 (\pm 6.2)$  cm and  $103.8 (\pm 17.5)$  kg respectively (Appendix 6). The Auckland University of Technology Ethics Committee approved all the procedures undertaken and all participants signed an informed consent form prior to the commencement of the study.

While the subjects were athletes with at least two years' experience in weight training, they varied in ability and strength training experience as demonstrated by the range in their bench press 1-RM (Appendix 6). There was also a large range in their Pmax intervention weights (Appendix 6). In addition, as the subjects were in their pre-season conditioning phase and following their own individual team programmes and because there was no requirement for the athletes to produce their training diaries, there was little prior indication of their true training status. It may be that some of the athletes' weight trained less than the recommended three times per week and were focusing on muscle endurance or hypertrophy as opposed to maximum strength. This possibly would have had an effect on muscle response to either of the treatments.

## Instrumentation

Participants performed bench press throws on a modified Smith Press machine. A linear transducer (P – 80A, Unimeasure, Oregon, USA – average sensitivity 0.499m/V/Vmm, linearity 0.05% full scale) was attached to the bar and measured vertical displacement

relative to the ground with an accuracy of 0.01-cm. These data were sampled at 1000 Hz by a computer-based data acquisition and analysis programme (LabVIEW VI, National Instruments Corporation).

The displacement-time data were filtered using a low-pass filter with a cut-off frequency of 5 Hz. The filtered data were then differentiated using a finite differences algorithm to determine velocity and acceleration data. The variables of interest were: velocity max (m/s), velocity mean (m/s), force max (N), force mean (N), power max (w), power mean (w), work (N.m) and impulse (N.s). Instantaneous power output was calculated as the mean from the power-time data over every 20 ms until peak power was achieved in the respective bench press conditions. The changes within 20 ms were found to be representative of the signals collected using the 5-ms data-collection inter-sample interval. The bench press throw was chosen for analysis as this type of movement appears to be more specific to the explosive movements typically used in sports performance (Newton et. al. 1996; Wilson & Newton, 1992). The movement involves acceleration through the end of the concentric phase with the load being moved as rapidly as possible throughout the range of movement (McEvoy & Newton, 1998).

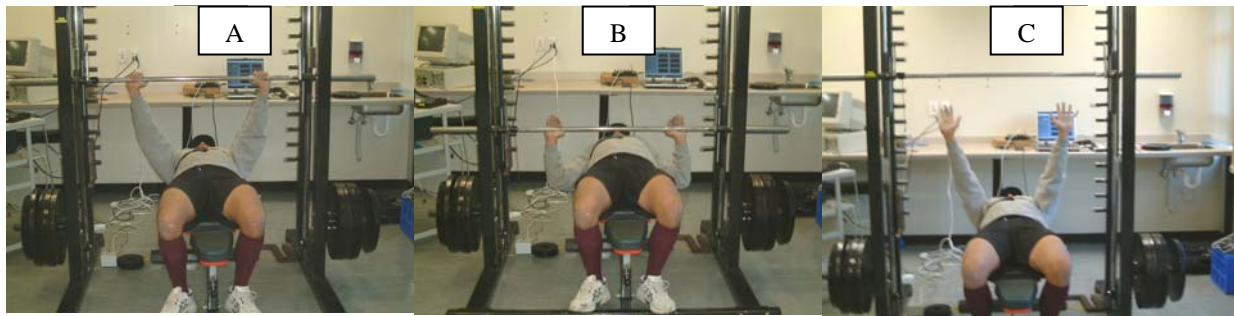
## Test Procedures

Testing and familiarization was performed over three sessions, the first of which determined base line throwing velocity and the maximum bench press (BP) load that each subject could lift for one repetition (1-RM). Maximum strength was assessed by a 1-RM BP performed with an Olympic-style barbell contained within the modified Smith Press machine. After warm-up with progressively heavier loads, the participants attempted a 1-RM load that had been predetermined by the tester after discussing the subject's training progress. If the subject was successful with this load, he was allowed to attempt another load(s) until both the subject and the tester were confident that a 1-RM had been attained. This usually entailed three attempts. For the 1-RM BP, the bar could not be bounced off the chest, the feet had to remain in contact with the floor, and the buttocks had to remain in contact with the bench.



At the completion of the 1-RM testing, participants rested for 12 minutes prior to testing for maximal Pmax. The Pmax was assessed during a rebound bench press throw (RBPT) performed within the Smith Machine. The participants performed 1 rebound stretch-shortening cycle repetition against loads of 20, 30, 40, 50, 60, 70 and 80 kg (BT P20, BT P30, BT P40, BT P50, BT P60, BT P 70, and BT P80), performed in order with approximately 2-minute rest between loads. These absolute loads, rather than loads individually predetermined using selected percentages of 1-RM were used following the precedent of Baker, Nance and Moore (2001).

For the RBPT, participants laid supine on a bench with arms extended straight over the shoulders. They were instructed to begin with the weighted barbell at arm's length and then lower the bar as quickly as possible, to just above the nipples and then immediately push the bar upwards as fast as possible. The participants released or threw the bar at the end of the concentric phase. The subject caught the bar on its decent. Each subject was strapped across the upper chest to the bench and was instructed to move the bar as "fast" as possible for all loads. Strapping of the upper body was necessary as it was noted by Cronin, McNair and Marshall (2001) that the kinematics of the lift differed markedly when the upper torso came away from the bench as opposed to remaining fixed. For the RBPT, participants were instructed to throw the barbell for maximum height. Participants self-selected hand placement on the barbell, however, participants were encouraged to place the hands at approximately slightly more than shoulder width apart. Feet were either placed flat on the ground or legs raised to the curl position. No definitive anatomical locations were given to the participants regarding hand and foot placements during the task. The reliability of such a procedure is reported elsewhere (Alemany, Pandorf, Montain, Castellasni, Tuckow & Nindl, 2005; Cronin, McNair & Marshall, 2000).



**Figure 2:** Subject performing rebound bench press throw: (a) starting position; (b) descent phase; (c) flight phase.

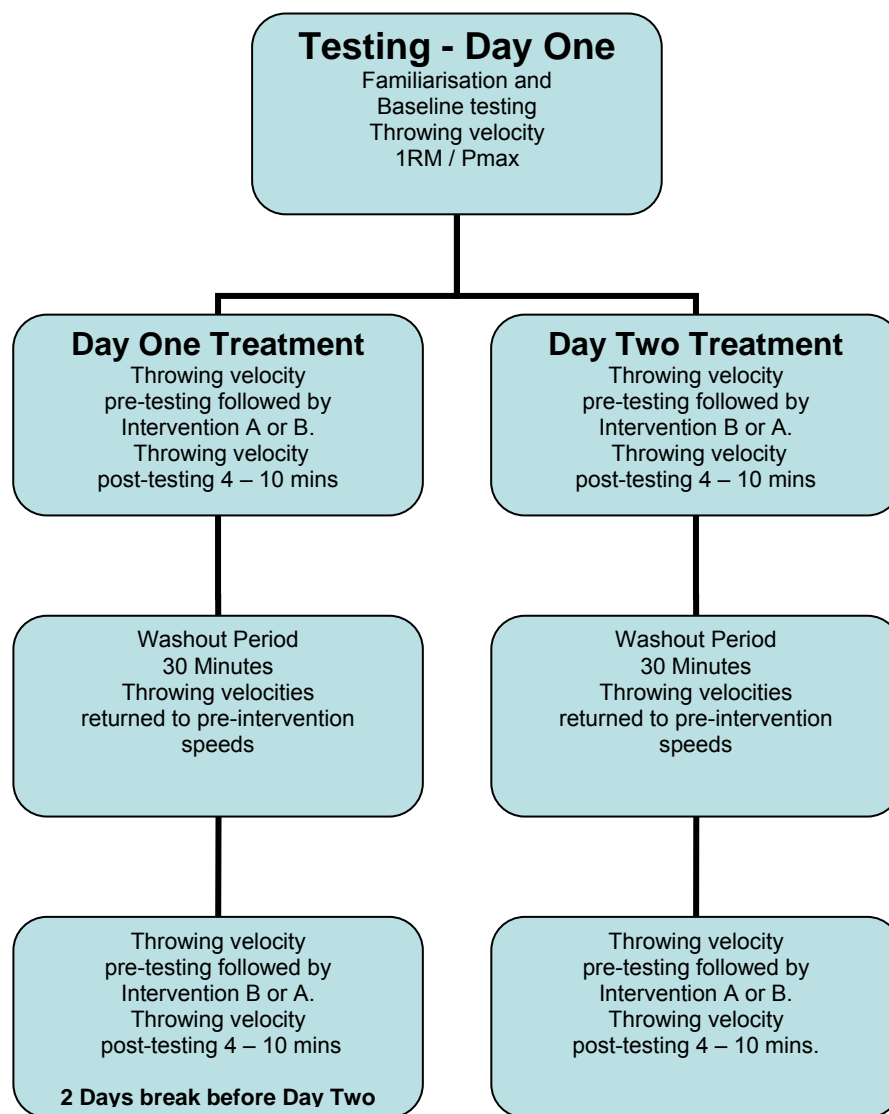
On the same day as the 1-RMs were determined and prior to collecting any ballistic power data, participants were allowed to perform 5 – 10 RBPT in an unloaded state to get the feel of the bar with the modified smith machine and to develop a kinesthetic sense of the preferred position for the body on the bench as well as arm and feet / leg positions. During this familiarization process, participants were instructed and coached on how to perform the lift in a safe and appropriate manner.

The Day One treatment session began with a standardized warm-up consisting of a five minute stationary bike ride at 60 RPM, followed by full body mobilization exercises, and a set of 10 repetition sub-maximal bench press throws. The participants then completed the prescribed interventions. Four athletes completed treatment A: B while the remaining four completed treatment B: A.

(a) Treatment A:

Consisting of traditional heavy loading 90% 1-RM x 3 reps x 3 sets followed by a rest of 4 minutes and then the power loading prescription of plyometric passing with medicine balls. It has previously been reported by Adams et al. (1992) that bigger gains can be achieved from combining heavy load training and plyometrics. The participants were instructed to perform 12 reps x 3 sets of 3kg medicine ball chest throws at maximum effort with a rest period of 2 minutes between sets. Bompa (1993b) advises 10 -30 reps for low impact implement throws and 2 – 3 minutes rest interval between sets for plyometric activities.

The work period was followed by a period of 4 minutes in which time the subject warmed up for softball throwing. Throwing velocity was then completed with 5 throws being recorded every two minutes from the four minute mark until the ten minute mark (4min., 6 min., 8 min. and 10 min).



**Figure 3:** Study design (see Appendix 5 for full study design)

(b) Treatment B:

Consisting of each individual's predetermined Pmax (group mean of 50 kg  $\pm$  8.7) loading of approximately 3 – 5 reps x 4 sets (determined by their Pmax and the loads necessary to equate for equi-volume). Baker, Nance and Moore (2001) advise that only 3 – 5 repetitions should be prescribed. They report a fatigue-related decrease of up to 10% in speed and power output should this guideline be exceeded. Following a further rest period of 4 minutes the participants repeated the power loading prescription of plyometric passing with medicine balls. The participants were instructed to perform 12 reps x 3 sets of 3kg medicine ball chest throws at maximum effort with a rest period of 2 minutes between sets.

The work was followed by a rest period of 4 minutes in which time the subject warmed up for softball throwing. Throwing velocity was then completed with 5 throws being recorded every two minutes from the four minute mark until the ten minute mark (4min. 6 min, 8 min and 10 min).

The Day Two treatment session began with a standardized warm-up consisting of a five minute stationary bike ride at 60 RPM, followed by full body mobilization exercises, and a set of 10 repetition sub-maximal bench press throws. The participants then completed the reverse order intervention. The four athletes who initially completed treatment A: B then completed treatment B: A., while the remaining four athletes who had previously completed treatment B: A turned their attention to treatments A: B.

Prior to testing the treatment groups were randomized between participants to reduce the possible confounding effects of order and fatigue. Pmax testing weights remained the same for all subjects and were completed in an ascending order (Baker et al., 2001). The absolute loads represented approximately 19.2%, 28.9%, 38.5%, 48.2%, 57.8%, 67.4% and 77% of the group mean 1-RM BP.

## Measurement of Throwing Speed

Throwing speed was assessed over the distance between first base and home plate (18.4m). The gun was positioned at chest height on a tripod and aimed at the first base markers. Speed was recorded on a Stalker Acceleration Testing System (Stalker ATS), version 4.50, and situated 2-m and directly to the right behind home plate (Appendix 12). The radar gun was calibrated immediately prior to all testing sessions according to the user's manual. A regulation size (30 cm) yellow Rawlings softball weighing 198 g was utilized for the throwing assessments.

The measurement of throwing speed by this technique has been shown to be reliable with an intraclass correlation of 0.95 between repeated measures on different days using the same participants (Newton & McEvoy, 1994). Unlike the baseball participants used by Newton & McEvoy (1994) softball do not throw the ball over arm through a strike zone and as such the throws from the softball participants did not have to pass through a strike zone.

Pre-test throwing speed was assessed using the following format. After a standard general warm-up consisting of five minutes jogging and muscle stretches specific to throwing, participants were allowed an unlimited number of warm-up throws. Participants were instructed to throw with their front foot positioned behind the tape placed on the ground (representative of first base) to home plate where the receiver stood to catch the ball. Five recorded throws were made with the mean of the best two throws recorded in meters per second ( $\text{m}\cdot\text{s}^{-1}$ ) as advocated by McEvoy and Newton (1998).



**Figure 4:** The positioning of the stalker radar gun, computer and marker cones indicating the throwing distance (18.4m).

Pre-treatment one and pre-treatment two throwing speed were assessed using the format previously described above. Five recorded throws were made with the mean of the best two throws recorded in  $\text{m}\cdot\text{s}^{-1}$ .

The four post-treatment throwing speed recording sessions consisted of a warm-up utilising light throwing for a period of 3 to 4 minutes after which time five recorded throws were made every two minutes from 4 mins to 10 mins (total of 20 throws). The mean of the best two throws for each of the time periods was recorded in  $\text{m}\cdot\text{s}^{-1}$ .

### Statistical Analysis

Data analysis was performed using spreadsheets downloaded from Sportscience web pages ([sportsci.org](http://sportsci.org)). These spreadsheets included analysis of straightforward controlled trials by Hopkins (2003) and fully controlled trials also developed by Hopkins (2005). Mean values and standard deviations were used throughout as means of centrality and spread of data. The percent change scores for throwing velocity between heavy-load and Pmax was the variable of interest. Additional analyses were performed on the change scores where observable differences were thought important in order to gain a greater understanding of the influence of the interventions. This analysis involved examining the magnitude of the effect and reporting confidence limits, thereby determining the probability that the true value of the effect statistic was practically beneficial, trivial or harmful (Batterham & Hopkins, 2005).

To determine the smallest worthwhile change in throwing velocity, it was assumed that: for the ball to arrive earlier than the batter-baserunner and thus improve the likelihood of the umpire making the correct decision in favor of the fielding team, the ball should arrive at the base while the runner is at least 25 cm away. To convert the 25 cm into a time it was further assumed that the batter-baserunner's speed was increasing linearly (that is, the acceleration was constant) between home-base and first-base. Given that the distance between the bases is 18.4 m and that it takes approximately 2.8 s to run that distance, it follows from the kinetic equation  $d = \frac{1}{2} a \times t^2$  (where  $d$  = distance between bases,  $a$  = acceleration and  $t$  = time) that the ball has to arrive at first base 0.019 s earlier than the batter-baserunner. For a throwing speed of a  $100 \text{ km}\cdot\text{h}^{-1}$  from a distance of 25 m this time corresponds to an increase of throwing speed of 1.9%.

Smallest important effects for differences or changes in the mean can also be defined as 0.2 of the between-subject standard deviation (Cohen, 1988). The throwing velocity in the second pretest (which is the most appropriate for this calculation) was  $101.8 \pm 8.8$  (mean  $\pm$  standard deviation; Table 4). The smallest important effect is therefore  $100 \times 0.2 \times 8.8 / 101.8 = 1.7\%$ . Since this value is close to the 2.0% change in the mean specific for softball, for simplicity I chose 2.0% as the smallest important effect for inferences about whether changes were substantial. However, the spreadsheets provide an analysis of effects standardized with the between-subject standard deviation, and the magnitudes of these standardized effects were classified using a modified Cohen scale: 0.2-0.6, small; 0.6-1.2, moderate; and  $>1.2$ , large (Hopkins, 2003).

Comparisons were made between the mean changes in performance of the heavy-load and Pmax interventions across the post intervention throwing velocities from 4 minutes to 10 minutes using a published spreadsheet for crossovers (Hopkins, 2003). Analyses were performed on the natural logarithm of mean velocity of the 4 time frames because variation in human performance is better modeled as a percentage of a subject's performance rather than as an absolute value. Precision of the estimates of all effects are shown as 90% likely limits (the interval within which the true value of the effect is 90% likely to fall) without adjustment for inflation of the study-wise chance of any true effect being outside its confidence level. The 90% confidence level was

chosen because the 95% level was considered too conservative and that the 90% was a better option because the chance that the true value lies below the upper or lower limit are 5%, which are interpreted as very unlikely (Hopkins, 2002).

## RESULTS

The group means ( $\pm$  SD) for each of the throwing pre-test and pre-treatments are presented in Table 4. The maximum throwing velocity recorded was  $113 \text{ km}\cdot\text{h}^{-1}$  ( $31.4 \text{ m}\cdot\text{s}^{-1}$ ) while the minimum was  $83.5 \text{ km}\cdot\text{h}^{-1}$  ( $23.2 \text{ m}\cdot\text{s}^{-1}$ ), (Appendix 9 for subject throwing data). No injuries occurred throughout the study period, and with the exception of one athlete the testing procedures were well tolerated by the participants.

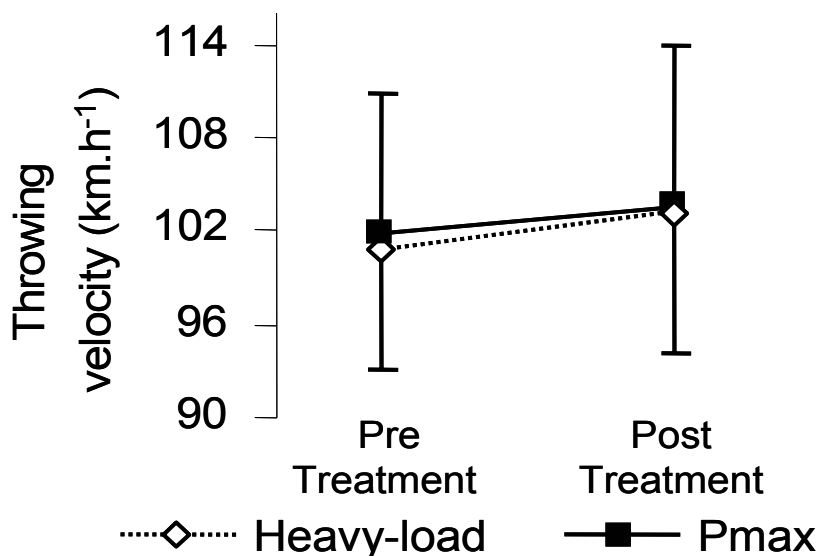
Between pre-test and pre-treatment 1 there was a small decrease in the throwing speed (0.5%, 90% confidence limits -1.6 to 0.8%); there was a further small decrease between pre-treatment 1 and pre-treatment 2, (0.6%, -1.8 to 0.6%). The typical errors of measurement (TEM) and the intraclass correlation coefficients (ICC) were the same for both consecutive pairs of tests (TEM = 1.3%, 0.9 to 2.3%; ICC = 0.98, 0.91 to 1.00).

**Table 4:** Mean throwing velocities ( $\text{km}\cdot\text{h}^{-1}$ ) for the pre-test and pre-treatment trials.

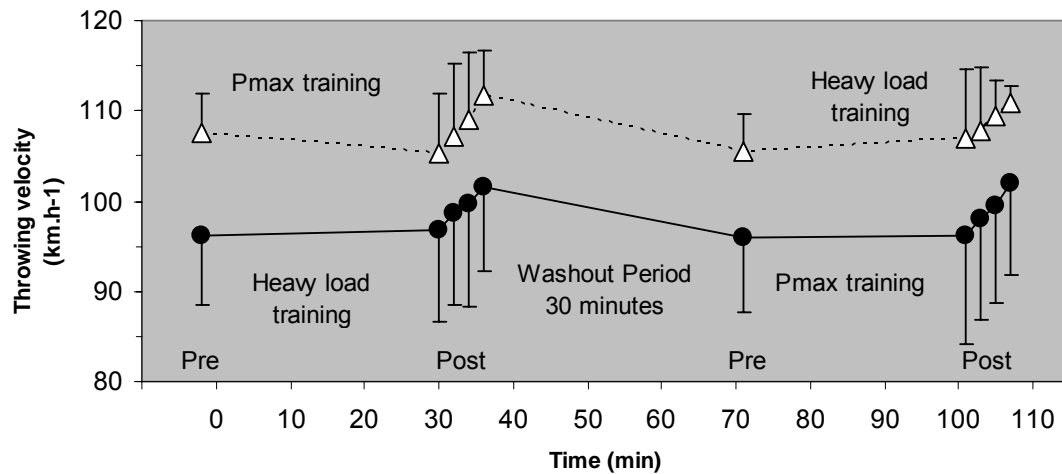
Participants	Pre-Test	Pre-treatment 1	Pre-treatment 2
1	86.5	84.0	83.5
2	100.5	98.0	96.5
3	101.0	103.0	104.0
4	101.5	99.5	100.0
5	103.0	103.0	104.0
6	112.5	113.0	109.0
7	109.5	110.0	111.0
8	103.0	104.0	101.5
Mean	102.2	101.8	101.2
SD	7.7	8.8	8.5



Figure 5 shows the overall mean throwing velocity pre and post the two treatments. Figure 6 shows the time course for the throwing velocity for the heavy-load and Pmax weight training treatments, and it is apparent from Figure 5 that there is little difference in the effect of the two treatments on mean throwing velocity. To obtain the best precision for a comparison of the effects, a simple crossover analysis was used. Throwing velocity after Pmax was 0.4% slower relative to that after heavy-load training (90% confidence limits -1.2 to 1.9%). Quantitatively the chances that this effect represents a beneficial/trivial/harmful change were 1/95/4%; qualitatively, the true effect was likely to be trivial. A fully controlled crossover analysis produced a similar trivial outcome; however, the estimate was less precise, owing to the contribution of error from the pre-test scores and as such was not used and therefore the data is not shown.



**Figure 5:** Mean changes in throwing velocity (km.h<sup>-1</sup>) and SDs for heavy-load and Pmax. Data were averaged out for 4 to 10 min for the post-treatment value.



**Figure 6:** Changes in throwing velocity for the heavy-load and Pmax weight training treatments data are expressed as means and between subject's SDs.

It is apparent from Figure 5 that throwing velocity increases somewhat between pre and post tests for both treatments. Taken together, the average increase in speed was 2.3% (0.5 to 4.1%). The chances of a beneficial/trivial/harmful change in velocity 62/38/0%; thus, the average true effect was possibly beneficial. The effects of both the treatments on each subject are summarized in Table 5. It is evident from the change scores for each subject and from the standard deviation of the change scores that there were considerable individual differences in the effects of the treatments. Subject 6 had a projected 11.2% increase in throwing velocity after completing the heavy-load treatment of the complex (refer to Appendix 10 and Appendix 11, Table 8).

**Table 5:** Individual throwing velocity percent (%) change scores for heavy-load and Pmax treatments using pre-treatments.

Subject	Heavy-load	Pmax
1	1.9	0.1
2	-3.0	-0.3
3	6.8	5.4
4	5.6	6.1
5	0.2	2.4
6	11.2	1.1
7	-0.3	3.7
8	0.7	-5.0
<b>Mean</b>	2.9	1.7
<b>SD</b>	4.6	3.6

It is apparent in Figure 6 that there is a large difference in the pre-treatment scores for the Pmax ( $107.6 \text{ km}\cdot\text{h}^{-1}$ ) versus heavy-load ( $96.3 \text{ km}\cdot\text{h}^{-1}$ ) and heavy-load ( $105.5 \text{ km}\cdot\text{h}^{-1}$ ) versus Pmax ( $96.0 \text{ km}\cdot\text{h}^{-1}$ ). While the subjects were randomly selected to each training intervention they were not ranked from fastest to slowest and as such the odd numbers placed in one group and even in another. The subjects were drawn from a hat as they completed their pre-testing and by chance, the four athletes with the fastest speed ended up in the Pmax – heavy-load intervention group. While this may have produced a large difference in pre-treatment starting levels what is noticeable however is that both groups throwing velocity returned to pre-intervention levels after the 30 minute washout period. It is also apparent in Figure 6 that there was a greater change by 10 min post treatment than by 4 min post treatment. The Pmax/heavy-load group increased throwing velocity from  $105.3 \text{ km}\cdot\text{h}^{-1}$  at 4 mins to  $111.8 \text{ km}\cdot\text{h}^{-1}$  at the 10 min mark following the first intervention and  $107 \text{ km}\cdot\text{h}^{-1}$  at 4 mins to  $110.9 \text{ km}\cdot\text{h}^{-1}$  at 10 mins following the second intervention. The heavy-load/Pmax group also increased throwing velocity from  $96.8 \text{ km}\cdot\text{h}^{-1}$  at 4 mins to  $101.6 \text{ km}\cdot\text{h}^{-1}$  at 10 mins after their first intervention and  $96.3 \text{ km}\cdot\text{h}^{-1}$  at 4 mins to  $102 \text{ km}\cdot\text{h}^{-1}$  at 10 mins following the second intervention. At 10 min the change was 5.0% (3.2 to 6.7%) for the Pmax and 5.3% (2.1 to 8.6%) for the heavy-load treatments, which were both around the threshold for small-moderate effects. Both these effects were almost certainly beneficial for throwing speed. However, the difference between Pmax and heavy-load and was -0.3% (-3.7 to

3.1%); quantitatively, the chances of a positive/trivial/negative change were 12/69/19%; qualitatively, the true effect difference between effect of the treatments was therefore unclear.

Figure 6 shows that the post-treatment changes in velocity appear to have developed gradually between 4 and 10 min post the treatments. This gradual change was analysed by fitting a straight line to each subject's post-test data and estimating the change in velocity from the slopes of the lines. There was an increase of  $4.3 \pm 2.7\%$  for heavy-load treatment and  $5.9 \pm 4.2\%$  for Pmax, with an overall difference of 1.6 (90% confidence limits -0.6 to 3.8%); and thus quantitatively the chances of a beneficial/trivial/harmful change were 37/63/1%. Qualitatively, the true effect of the treatments on individual subjects response was possibly trivial. The mean change for both treatments combined was 5.1% (90% confidence limits 3.6 to 6.7%); chances of a beneficial/trivial/harmful change were 99.8/0/0%, which represents an almost certain beneficial effect (Appendix 11).

## DISCUSSION

When all subjects' data were pooled, one of the major findings was that the execution of heavy-load and moderate load Pmax treatments, measured 4 min post treatments, has a negligible effect in increasing upper body power as measured by the over arm throw. The difference between the treatments was clearly trivial. A second major finding was that the velocity of the throws was steadily increasing further by 10 min post-treatment mark. There was a substantial increase of 5% for Pmax and 5.3% increase for heavy-load. These findings are in agreement with previous acute studies (Table 1) showing that a complex programme of strength training can increase upper body power and that these ES can be trivial to large.

The total volume of weight lifted for each treatment was equaled by controlling the number of repetitions performed for the bench press, the rebound bench press throw, and the medicine ball chest-pass. Although the total volume was accounted for, the intensity level was more difficult to control as was the speed of contractions. In an effort to control variability the subjects were asked to attempt a maximum effort with every repetition. Verbal support was used in an attempt to promote maximum effort from each subject.

Both treatments produced small-moderate positive effects on throwing velocity 10 min post treatment. It is not clear whether this improvement would continue or whether there would be decay in potentiation post 10 min. Indeed, when retested post treatment at the 30 minute mark, the enhancement was no longer apparent. To investigate this, further research is required to establish the time course between 10 and 30 min. However Chiu, Fry, Weiss, Schilling, Brown and Smith (2003) reported that following heavy-load squats (90% 1-RM) power was significantly greater at 18.5 min postactivation than at 5 min postactivation. This discussion will now focus on the mechanisms via which the augmentation to power output may occur as a result of the treatments.

Nonetheless, using the pre-tests as comparison, the individual percent changes in performance and individual effects sizes ranged from -0.3% to 6.8%  $\pm$  4.6 for heavy-load intervention and -5.0 to 6.1%  $\pm$  3.6 for Pmax intervention (Table 5). Although some of the individual effects of the pre-conditioning activity on the outcome of these subjects were negative the majority were positive. However it is unclear how much of this range in the effect is due to error of measurement vs true individual responses. The magnitudes of the standard deviations representing individual differences in the change in throwing speed between 4 and 10 min post-treatment were of similar magnitude, but again it is unclear how much of the variation is due to error of measurement. It would seem that the training status might affect the magnitude of the acute enhancement, with better trained athletes more likely to respond positively to a complex training approach to strength training (Gullich & Schmidtbleicher, 1996; Young, Jenner & Griffiths, 1998).

The reason that throwing velocity is increased acutely by the interventions of complex training using heavy-load and Pmax rebound bench press throw and medicine ball chest passes may be due to short-term neural or mechanical adaptations or both. In the studies listed in Tables 1 and 2 the various researchers have speculated on why the alternating of bio-mechanically comparable heavy resistance weight training and plyometric exercises in the same workout may increase power output. The principle on which complex training is based assumes that the explosive capability of muscle is enhanced after it has been subjected to maximal or near maximal contractions and that this phenomenon has been referred to as post-activation potentiation (PAP). The ballistic nature of the rebound bench

press throw using moderate loads has been shown to cause a short-term increase in performance and this has been demonstrated again in this study. One could assume that when following a training programme over a period of time, because the potentiated state of muscle is considered to have an acute effect on enhancing its heightened performance capabilities, it is expected to produce superior chronic adaptations compared with other training programmes (Chu, 1996; Gullich & Schmidtbleicher, 1996). However, as there is little or no documented proof that this is the actual case, researchers should be wary of making such assumptions.

It has been stated above that power training is commonly conducted using moderate resistances that are performed explosively because it has been shown by Wilson et al. (1996) that performance gains can be optimized by the use of individual Pmax loads. The best results however are attained when a combination of heavy loads and light loads are implemented within the same workout (Wilson et al, 1996). By performing heavy loads before power exercises there is greater activation and preparation for the maximal effort in the lighter load (Verkhoshansky, 1986). The heavy resistances are an effort to bring about adaptation in tension-dependent neural mechanisms that inhibit the excitation of motor neurons in voluntary maximal contractions (Fleck & Kontor, 1986).

In support of the thinking by Fleck and Kontor (1986), Gullich and Schmidtbleicher (1996) and Young et al. (1998) deduced that the treatment strategy must be a heavy resistance of maximal or near-maximal intensity to increase motor unit activation ( $\geq 85 - 90\%$  1-RM) hence why the heavy-load complex was set at 90% 1-RM for the bench press intervention in the current study. The fact that Young et al. (1998), after completing 5-RM half-squat treatment, found a positive correlation between power performance and performance enhancement as measured by loaded counter-movement jumps, supports the possibility that some tension-sensitive mechanisms were at least partly responsible (Table 2). The present study also entailed a much lower resistance when performing the Pmax sets (Appendix 6). As 5 repetitions performed at a resistance of below 62% of 1-RM does not produce sustained MVCs (Robbins, 2005; Zatsiorsky, 1992), the PAP as theorized by Gullich and Schmidtbleicher (1996), could not fully account for the augmentation to power output and thus the increase in throwing velocity in the current study. Previous upper-body studies (Table 1) using lighter contrast resistances have

also reported substantial effects. This supports the finding of Baker (2003) who reported a 4.5% increase in power output with a resistance of 50 kg (BT P50). While using resistance of 65% 1-RM or lower, Baker, Nance and Moore (2001) advise that only 3 – 5 repetitions should be prescribed. They report a fatigue-related decrease of up to 10% in speed and power output should this guideline be exceeded. This was taken into account when prescribing the number of reps per set to ensure an equi-volume between workloads for heavy-load and Pmax treatments. The heavy-load comprised of 3 sets of 3 reps. Previous studies have demonstrated acute power enhancement after only 1 set of resistance exercises (Gullich & Schmidtbleicher, 1996; Young et al., 1998) as well as multiple sets of resistance exercises (Radcliffe & Radcliffe, 1996).

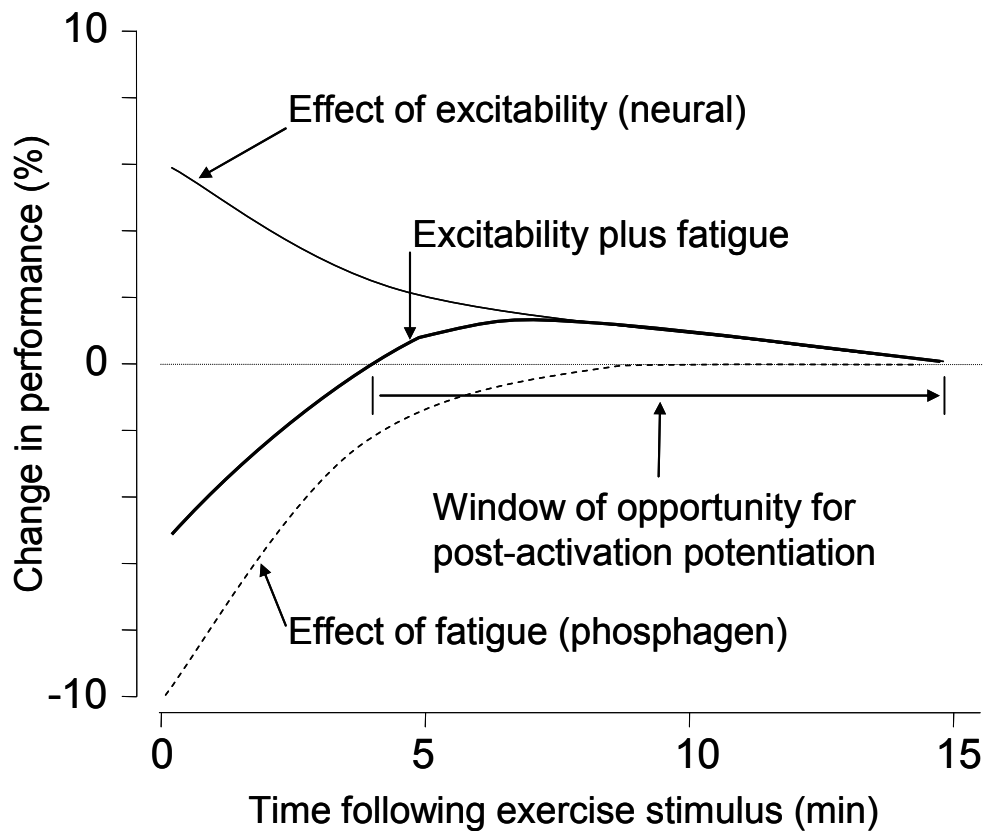
Two theories have previously been put forward as to the positive enhancements obtained from complex training and they may be part of the cause for the small-moderate increase in throwing velocity 4 – 10 min. Another possible reason for these increases may be attributed to the potentiated state of the muscle due to the actual softball throwing effect. The subjects were given 5 min to warm up in the same way subjects are advised to complete warm-up sets using lighter resistances prior to attempting maximal effort when weight training. In the study, the athletes started with light throws and slowly increased the intensity. There is a possibility that as the athletes warmed-up they felt the physiological effects associated with normal warm-up routines and were able to produce more power; however the weight of the ball was probably too low on its own to alter the neuromuscular function and improve subsequent performances. In sports where the motor task is similar, such as shot putting or javelin throwing, the goal is to impart maximal velocity to an implement. For high performance athletes the velocity of a shot release is nearly  $14 \text{ m}\cdot\text{s}^{-1}$ , while javelin release velocity is above  $30 \text{ m}\cdot\text{s}^{-1}$  (Zatsiorsky, 1995). According to Zatsiorsky (1995) these values correspond to different parts of the force-velocity curve. The shot-putters need a high force because of a high correlation between maximal strength and the velocity of movement at delivery phase. This correlation is low in javelin throwing and in turn would be even lower for softball since the velocity required is also around  $24 - 31 \text{ m}\cdot\text{s}^{-1}$ , (Appendix 9). Due to the weights of the implements and to obtain the necessary results, elite shot-putters spend about 50% of their training time on resistance training while in comparison javelin throwers spend up to 25% (Zatsiorsky, 1995). Using these

figures as a comparison, it is difficult to see how the softball players could expect to improve their throwing velocity by approx 5% without some percentage of their training time being spent on resistance training. This training could take the form of either heavy or power training.

The reliability analysis indicated that the standard error of measurement for throwing velocity (1.3%, 0.9 to 2.3) was considerably less than the smallest important change in throwing velocity (2%). The measurement procedures utilised and the sample size were deemed to be adequate for quantification of small changes in performance (Hopkins, 2004). Previous researchers (Newton & McEvoy, 1994) reported an ICC of 0.95 between repeated measures for throwing velocity on different days. The ICC for this study was the same for both consecutive pairs of trials (0.98, 0.91 to 1.00). As there was no substantial difference between trials in the reliability set, indicating that the individual subjects attended each session in a similar physical state and that the 30 min washout period was sufficient to bring players' throwing velocity back to pretest values.

Adequate rest between strength training, plyometric sets and specific functional exercises is an important complex training variable, as the recovery time allocated between the treatment and the outcome measure may affect the magnitude of the enhancement. Researchers using longitudinal studies have recommended 120 s to 600 s (Chu, 1996; Ebben & Blackard, 1997). The current study followed practices suggested by Jensen and Ebben (2003), Radcliff and Radcliff (1996); and Young et al. (1999) who suggested between 180s and 240 s rest between resistance training and plyometric-like exercises. Their results suggested an ergogenic advantage following this degree of recovery. Adequate rest between sets of strength or power training is necessary to allow the body to replenish the phosphagen system needed for performing high-velocity contractions at high power output (Figure 7).





**Figure 7:** Effect of fatigue and neural excitability combining to produce post-activation potentiation.

There is evidence in the literature that particular substances are exhausted as a result of strength and power training workouts and that after the recovery period the levels of the given substrates are believed to increase above the initial level and that this one factor theory is referred to as supercompensation (Zatsiorsky, 1995). A second two-factor theory more sophisticated than the supercompensation theory is based on the suggestion that the athlete's preparedness is not constant and that it varies with time. According to this two-factor model the acute training affect immediately after a workout is a combination of two processes: fatigue and a gain in fitness as a result of the treatment. Zatsiossky (1995) has termed this training effect the fitness – fatigue theory because the athlete's preparedness is more tolerable due to the fitness gain, but deteriorates because of fatigue. The final outcome, being the window of opportunity as depicted in Figure 7, is determined by the summation of the positive (neural) and negative (phosphagen) changes.

Zatsiorsky (1995) goes on to say that the duration of the fitness gains and the fatigue differs by a factor of three (the fatigue effects is three times shorter in duration). The implication here is that if the negative impact of the strength and power training lasts for instance 240.s, then the positive PAP effects from the workout will last 720. s. As reported elsewhere, the acute studies of the upper body have recorded enhancement effects between 90 – 420 s after the pre-conditioning activity. Previous studies reporting trivial to moderate effects appeared to occur when the time course is between 180 -300 s. The time course for the current study focused on collecting data from 240 – 600 s. The results in the current experiment show that for the heavy-load followed by Pmax treatment the throwing velocity times tended to improve as the recovery times were increased. Results in Figure 6 show the change in throwing velocities at 4, 6, 8 and 10 min for both interventions. During the Pmax followed by the heavy-load treatments there was a slight drop after the Pmax treatment. This was possibly due to the Zatsiorsky's (1995) fitness-fatigue theory. Throwing velocity changes during the time course for these intervention orders are also in Table 5.

At first glance there is a substantial difference between the effectiveness of the two treatments, with the Pmax followed by heavy-load appearing to be more effective. However, when the data was pooled and averaged out across the 6-mins the heavy-load training was found to increase throwing velocity at post  $2.9\% \pm 4.7$  (Figure 5). Pmax was found to increase throwing velocity at post  $1.7\% \pm 3.6$ . A load of 50% of 1-RM was as equally effective as a load of 90%1-RM to increase throwing velocity, therefore it can therefore be concluded that there was no significant difference between groups. It may be that a time between 10 and 30-mins may be optimal, as on the basis of the results, by 30-mins the throwing velocity had returned to baseline.

In comparison to using heavy-load treatments, Smilios et al. (2005), found that while counter movement jump performance (CMJ) with a load of 60% 1-RM was sufficient to stimulate neuromuscular function after the first and second sets, this increase was not stable. After the third set, and at the 5 and 10th minutes 60% 1-RM CMJ performance was lower than the pretest. It is possible that if the researchers had used less reps and longer rest periods, than their 180 s, the 60% 1-RM CMJ performance increase might have lasted longer. Gullich and Schmidtbleicher (1996) had mixed results after a rest interval of 180 s.

They found that in their first set they had an intra-serial positive staircase in CMJ from their 1st to 8th jump. After a further 180 s rest interval this staircase effect did not continue. The same subjects when tested 180 – 320 s, after 3 maximal voluntary contractions, jumped 3.3% higher and the performance intra-serial rise of the 8 jumps was steeper. This indicates that CMJ performance probably increases following an exercise of sufficient stimulus. The use of short-term maximum voluntary contractions (MVCs) can possibly be used to improve performance during competition by integrating MVCs into the warm-up routines.

Another finding of the study was that after determining each individual subject's Pmax (Appendices 6 and 8), the range of the loads prescribed for the power exercise (BPT) were greater than the 30% 1-RM traditionally prescribed for power training (Bompa, 1999; Newton & Kraemer, 1994). The results of this study suggest that athletes who specifically trained via both maximal strength and power training methods may generate their maximal power outputs at higher percentages of 1-RM than those previously reported for strength-trained athletes. The mean and SD for the subjects was  $51.1 \pm 6.3\%$  1-RM indicating that there may be an effective range of resistances for maximizing power output. In addition, athletes with limited training histories and hence low 1-RM results often produce power at a higher percentage of their 1-RM (Zatsiorsky, 1995). This is demonstrated in the results for subject 1 (Appendix 6) whose bench press 1-RM was 80kg and Pmax % 1-RM was 52.6%.

In terms of training status the subjects in the current study were international and national men softball players. At this time of year the goal of their training programmes were multi-directional and did not focus solely on the development of strength and power, but rather on training several components of fitness. A typical programme included cardiovascular endurance, speed, and flexibility and strength endurance rehabilitative exercises for the rotor-cuff region. This may have had an effect of the results because the initial pre-season training focus was not on improving maximal strength. During the course of the current study the only variable to be considered was power, as assessed by throwing velocity, because power normally reflects both the force and velocity characteristics of muscle. The use of additional variables associated with throwing may have broadened the conclusions that could be drawn from the results. Although Hrysomallis and Kidgell (2001) used impulse, mRFD and force variables as their measure of

sensitivity to the preconditioning activity, the results of the treatment were trivial. In comparison, the longitudinal effects of flexibility, strength and power on the stretch shortening cycle (SSC) movements were examined by Wilson, Elliot and Wood (1992). Their flexibility training programme resulted in 13.1% increase in flexibility and 7.2% increase of the elasticity of the musculo-tendinous systems. The alteration in elasticity resulted in a momentous increase in the use of the elastic energy allowing the athletes to boost their bench press by an average of 7.2 kg. Flexibility-induced performance can be attributed to an increase in the ROM and may also result from increased musculo-tendinous compliance facilitating the use of the elastic energy in SSC activities. This may explain why the softball players affirm that they sense they can throw harder and faster with increased flexibility (Wilson, 1993).

## **CONCLUSION**

The most important finding in this research is that by using a combined complex of heavy-load and Pmax resistance training methods an increase upper-body power output can occur during speed-strength activities as demonstrated by softball throwing. In addition using either heavy-load or Pmax complex training softball players also have the potential to improve their throwing velocity. The short-term enhancement of power performance following heavy-load and Pmax exercises has implications for the design of softball warm-up routines. The results of this study suggest that the inclusion of either a set of bench presses with a 5-RM load or five reps using three sets of a 50 - 55% 1-RM might result in an acute improvement in activities dominated by the power output of the arm extensors. In this regard, it can be hypothesized that a dynamic warm-up that includes an appropriate conditioning activity may increase throwing performance. It has been suggested by Duthie et al. (2002); Gullich and Schmidtbleicher (1996) and Young et al that PAP may be employed when training to produce chronic adaptations. Therefore these exercises could be embodied in a more time-efficient complex resistance training programme than the traditional periodised model that may tend to emphasis blocks to specific training goals such as maximum strength or conversion to power. Following this revised training programme format may also help solve the problem of performing exercises for the same muscle groups on consecutive days. It should be noted however that the results of this study demonstrating the benefits of the “complex training” are specific to the subject population and cannot be generalized for athletes from different populations.

## CHAPTER 5: SUMMARY AND RECOMMENDATIONS

### SUMMARY

This study concentrated on investigating and discussing general, special, specific and combination training effects to increase throwing speed and in particular a new method of strength training gaining popularity: Complex/contrast training. The results of papers studied were drawn together and were identified under three headings with subheadings. The research suggests a possible relationship between strength and plyometric performance in the complex/complex training system. This suggests that the complex training strategy may be best suited for highly trained individuals using RM loads in the weight training portion of the complex. The review of the literature demonstrates that the benefits of the complex/contrast method cannot be assumed to be general to all athletic populations. At worst a complex training programme can be utilised to save on workout time and results in the same gains as a more traditional programme combining plyometrics with weight training. With respect to chronic adaptation resulting from PAP, some evidence exists to suggest that complex training is at least as beneficial as other comparable training methods designed to develop power. However studies that have compared complex training to other training modalities have not examined PAP specifically. Further more, the studies appear to have been acute and therefore the results can not automatically be extrapolated to chronic adaptation resulting from PAP. Further research should examine the specificity of prior contractions taking into account type, intensity, duration and rest intervals on subsequent performances. Additionally research should also examine the effects of the specific types of exercises employed within a complex specifically: the effects of complex training on varying age groups, gender, training status particularly novice versus high performance athletes. Lastly, equating for equi-volume by taking into account the relationship between muscle lengthening and shortening velocity and force production may provide the researchers with additional guidelines.

## RECOMMENDATIONS

Previous studies and reviews have indicated heavy weight training generally resulted in greater improvements at the high force end of the force-velocity curve and that high velocity / high power training results in greater improvements towards the high velocity end. The results of Harris, Stone, O'Bryant, Proulx and Johnson (2000) lead support to this concept. Their high force group improved to a greater extent in high force output measures (1-RM values), whereas the high power group showed the greatest improvement in power/speed-related movements. The short-term MVC effects can be used to improve performance during warm-ups and breaks in competition by integrating MVCs into the team routines.

While muscular and neural adaptations could be responsible for high-velocity training responses (Almasbakk & Hoff, 1996; Behm & Sale, 1993a; Hakkinen, 1989; Sale & MacDougall, 1981), the principal stimuli for high-velocity training response are repeated attempts to perform ballistic contractions and the high rate of force of the ensuing contraction (Behm & Sale, 1993b). That is to say that the athletes could improve high-velocity strength performance by attempting rapid movements against high resistance. On a cautionary note, the potential for muscle injuries and tears caused by rapid force development to relatively high peak force necessitates consideration and that periodised training regimes are introduced to ensure gradual progression.

The rate of progression will be determined by the nature of the sport, periodisation of the training year and the athlete's training age and the athlete's individual needs. These variables all dictate what combinations of strength training exercises are most appropriate. Given the complexities of the training processes and the number of training variables the task facing the strength and conditioning coach in deciding the exact manipulation is a daunting one.

The reaction to a heavy resistance exercise stimulus intended to elicit PAP appears to also depend on training status. Chiu et al. (2003) have reported that in the 5 minutes following an acute heavy resistance stimulus, recreationally trained athletes may exhibit fatigue. PAP does appear to remain for 5 to 18.5 minutes in highly trained athletes however. Thus PAP appears to be a feasible means of optimising explosive movements in highly trained athletes but not recreationally trained individuals. When implementing a complex training programme the

principle of recovery is also important to consider. Since weight training and plyometrics are performed on the same day and within the same training venue, complex training is efficient. This decrease volume associated with a periodised programme reduces fatigue and allows the athletes to recover by allowing them to focus on other aspects of performance. Ebben and Blackard (1997) have suggested a recovery time of at least forty-eight hours and no more than ninety-six hours of recovery between complex training exercise sessions where the same muscle groups are exercised. They further recommend that using the guidelines, complex training should only be performed two to three times per week and that rest intervals between sets of complex training exercises should range from two to five minutes. W. Ebben (personal communication, July 06, 2002) commented that in a recent study which evaluated complex training rest interval (optimal rest time between high load and plyometric condition) the researchers found a non-significant trend towards improved performance when plyometrics were performed four minutes after the high load portion. They also found a performance decrement when the plyometrics were performed immediately after the high load.

While complex training is a practical and perhaps optimal training strategy for the development of athlete power, prior to implementing a complex training programme athletes and coaches are advised to consult strength and conditioning personal. Reddin (1999) goes to pains to stress that complex training is an advanced form of training and it should only be used with experienced athletes. A minimum of two years foundation strength and plyometric development is recommended prior to commencing this form of training.

Yessis (1995) also described a routine for complex training aimed at assisting athletes prevents over-training and burnout. The guidelines included:

- Barbell squats followed by full power jump exercises in the magnitude of 3, 5 or 10 repetitions.
- Barbell work at 90% 1-RM followed by 30% 1-RM performed explosively.
- 90% 1-RM for 5 – 8 squats followed by 2-10 repetitions of vertical jump with 30% 1-RM loads.
- 4 - 6 weeks of strength followed by 4 – 6 weeks of plyometric and depth jumps.

Baker (2000) appears to be one of the proponents of contrast/complex loading and training modalities. In his presentation to the Australian Coach 2000 conference, he has discussed the "... nature of the contrast ..." as well as recent lower and upper body trends and recommendations for implementing contrast loading. Baker also pointed out that those athletes who require ballistic limb movement to generate their power should be aware that weak antagonists may be the limiting factor in producing the power and speed required. Using traditional methods or complex training to strengthen the agonists may not always lead to an increase in power output. The alternative is to train using a complex made up of agonist-antagonist exercises (Baker & Newton, 2005). In particular Baker recommends the following training regime examples for upper body throwing power athletes:

- Agonist v agonist: Bench press (60 -70% 1RM) followed by bench throw (30 – 50% 1RM) followed by medicine ball push/punch (3 – 5 kg) x 2 – 3 repeats.
- Agonist v antagonist: Bench pulls/rows (10 – 30% 1RM) followed by throws (overweight or underweight) x 2 – 3 repeats.
- Agonist power v agonist strength v antagonist strength: Bench throw (30 – 50% 1RM) followed by DB bench press (70 – 80% 1RM) followed by seated rows (70 – 80% 1RM).
- Agonist power v antagonist strength: Incline bench throw (30 – 50% 1RM) followed by close grip pull-down (70 – 80% 1RM).

Strength and conditioning coaches are encouraged to prescribe training sessions using one or more of the training regime examples and to determine if there are any PTP effects following an acute intervention on the speed of a softball in overhand throwing. Jacobs (1987) points out that while velocity of a softball throw is determined by the muscular forces applied to the release of the ball, the level of ball speed is reliant on four factors, these being: distance from the end of the backswing to the release point, the greater the number of body parts contributing force - the greater the velocity, the speed of each particular contributing segment and the synchronisation of these body parts in the correct sequence. While strength and conditioning coaches can prescribe the ideal resistance programme taking into account the specific joint angles, range of motion, and/or the speed of the throwing motion, exercises must be included that simulate the sporting event which will specifically prepare the athlete for competition. The athlete must be able to produce efficient eccentric, concentric and isometric



contractions of the various hip and leg structures in addition to the upper body (Jacobs, 1987; Robertson, 1998; Watkinson, 1997).

The papers viewed and the results obtained from the current study indicate that adequate rest between complex activities is important. Recommendations are 4 minutes rest between exercise because generally strength and power training requires adequate rest between sets to allow the body to replenish the anaerobic energy sources needed for performing high-velocity contractions at high-power output. The acute potentiation has shown power to increase after 4 minutes post-exercise and to last for at least 10 minutes. Previous discussions have indicated that it may last as long as 18 minutes. Further increases in power from the PAP before decay requires further investigation. It could be suggested that over time training with complex might result in chronic improvements in performance than that currently obtained through acute complex training methods. This suggestion is purely speculative and was not examined in this study. The number of combinations particularly utilising agonist and antagonist muscle exercises during complex training within an exercise session is extensive. Therefore it is recommended that experimentation by athletes using different combinations and orders of exercises may lead to an augmentation in power performance.

## REFERENCES

- Abernethy, P., Wilson, G. & Logan, P. (1995). Strength and power assessment: Issues, controversies and challenges. *Sports Medicine*, 19 (6), 401 – 417.
- Adams, K., O'Shea, J. P., O'Shea, K. L. & Climstein, M. (1992). The effects of six weeks of squat, plyometric and squat-plyometric training on power production. *Journal of Applied Sport Science Research*, 6 (1), 36 – 41.
- Aleman, J. A., Pandorf, C. E., Montain, S. J., Castellani, J. W., Tuckow, A. P. & Nindl, B. C. (2005). Reliability assessment of ballistic jump squats and bench throws. *Journal of Strength and Conditioning Research* 19 (1), 33 – 38.
- Almasbakk, B. & Hoff, J. (1996). Co-Ordination, the determinant of velocity specificity? *Journal Applied Physiology*, 80 (5), 2016 – 2052.
- Atha, J. (1981). Strengthening muscle. In D. I. Miller (Ed.) *Exercise Sports Science Reviews*, 9, 1 – 73. The Franklin Institute, United States of America.
- Bagonzi, J. A. (1978). *The effects of graded weighted baseballs, free weight training, and simulative isometric exercise on the velocity and accuracy of a thrown baseball*. Unpublished doctoral thesis. Indiana, Indiana University.
- Baheti, N. D. & Harter, R. A. (2001). In season surgical tubing strengthening programme improves throwing velocity among high school pitchers. *Journal of Athletic Training*, 36 (2), 54.
- Baker, D. (2003). Acute effects of alternating heavy and light resistances on power output during upper-body complex power training. *Journal of Strength and Conditioning Research*, 17 (3), 493 – 497.
- Baker, D. (2001). A series of studies on the training of high-intensity muscle power in rugby league football players. *Journal of strength and Conditioning Research*, 15 (2), 198 – 209.
- Baker, D. (2000). Increase power output through contrast loading. *Proceedings of the Sports Coach 2000 Conference*. Canberra, A.C.T: Australian Sports Commission.
- Baker, D. (1996). Improving vertical jump performance through general, specific, and specific strength training: A brief review. *Journal of Strength and Conditioning Research*, 10 (2), 131 – 136.
- Baker, D. & Newton, R. U. (2005). Acute effect on power output of alternating an agonist and antagonist muscle exercise during complex training. *Journal of Strength and Conditioning Research*, 19 (1), 202 – 206.

- Batterham, A. M. & Hopkins, W. G. (2005). Making meaningful inferences about magnitudes. *Sportscience* 9, 6 -13, [sportsci.org/jour/05/ambwgh.htm](http://sportsci.org/jour/05/ambwgh.htm)
- Behm, D. G. & Sale, D. G. (1993a). Intended rather than actual movement velocity determines velocity-specific training response. *Journal of Applied Physiology*, 71, 359 – 368.
- Behm, D. G. & Sale, D. G. (1993b). Velocity specificity of resistance training. *Sports Medicine*, 15 (6), 374 – 388.
- Berger, R. A. (1962). Optimal repetitions for the development of strength. *The Research Quarterly*, 33 (3), 334 – 338.
- Blakey, J. B. & Southard, D. (1987). The combined effects of weight training and plyometrics on dynamic leg strength and leg power. *Journal of Applied Sports Science Research* 1(1), 14-16.
- Blanpied, P., Levins, J. & Murphy, E. (1995). The effects of different stretch velocities on the average force of the shortening phase in the stretch-shortening cycle. *Journal of Sport Physical Therapy*, 21 (6), 345 - 352.
- Blattner, S. E. & Noble, L. (1979). Relative effects of isokinetic and plyometric training on vertical jumping performance. *Research Quarterly*, 50, 583 – 588.
- Bompa, T. O. (1993a). *Periodisation of strength: The new wave in strength training*. Toronto, Ontario, Veritas Publishing Inc.
- Bompa, T. O. (1993b). *Power training for sport: Plyometrics for maximum power development*. Coaching Association of Canada. Oakville, Ontario, Mosaic Press.
- Bompa, T. O. (1983). *Theory and Methodology of Training: The Key to Athletic Performance*. (3<sup>rd</sup> ed.). Dubuque, Iowa, Kendall Hunt Publishing Company.
- Bompa, T. O. & Cornacchia, L. J. (1998). *Serious Strength Training: Periodisation for Building Muscle Power and Mass*. Champaign, Illinois, Human Kinetics.
- Bosco, C. (1997). The effect of pre-stretch on skeletal muscle behaviour. *Journal of Applied Biomechanics*, 13, 426 – 429.
- Brose, D. E. & Hanson, D. L. (1967). Effects of overload training on velocity and accuracy of throwing. *Research Quarterly for Exercise and Sport*, 38 (4), 528 - 533.
- Brylinsky, J., Moore J.C., & Frosch, M. (1992). The effect of using a weighted softball on pitching velocity, wrist strength and handgrip. *Journal of Applied Sports Science Research*, 6 (3), 170-173.
- Burger, T. (1999). *Complex training compared to combined weight training and plyometric training programme*. Unpublished masters' thesis. College of Graduate Studies, Idaho, University of Idaho.

- Brumitt, R. J., Meira, E. & Davidson, G. (2005). In-season functional shoulder training for high school baseball pitchers. *Strength and Conditioning Journal*, 27 (1), 26 – 32.
- Charniga, A. (1987). Roundtable: Periodisation part 3. *National Strength and Conditioning Association Journal*, 9 (1), 16 – 26.
- Chiu, L. Z. F., Fry, A. C., Weiss, L. W., Schilling, B. K., Brown, L. E. & Smith, S. L. (2003). Postactivation potentiation in athletic and recreationally trained individuals. *Journal of Strength and Conditioning Research*, 17 (4), 671 – 677.
- Chu, D. (1996). *Explosive power and strength: Complex training for maximal results*. Champaign, Illinois, Human Kinetics.
- Chu, D. A. (1992). *Jump into plyometrics*. Champaign, Illinois, Human Kinetics.
- Chu, D. A. (1983). Plyometrics: The link between strength and speed. *National Strength and Conditioning Association Journal*, 5 (2), 20 – 21.
- Clements, A. S., Ginn, K.A. & Henly E. (2001). Correlation between muscle strength and throwing speed in adolescent baseball players. *Physical Therapy in Sport*, (2), p. 123 – 131.
- Clutch, D., Wilton, M., McGown, C. & Bryce, G. R. (1983). The effect of depth jumps and weight training on leg strength and vertical jump. *Research Quarterly for Exercise and Sport*, 54 (1), 5 – 10.
- Cohen, J. (1988). *Statistic Power Analysis for the Behavioral Sciences* (2<sup>nd</sup> ed.). Hillsdale, New Jersey, Erlbaum.
- Cronin, J. B. (1999). Strength training for sport. Part 6: Developing power. *The New Zealand Coach*, Spring, 16 – 18.
- Cronin, J. B. & Crewther, B. (2004). Training volume and strength and power development. *Journal Science and Medicine in Sport*, 7 (2), 144 – 155.
- Cronin, J. B., McNair, P. J. & Marshall, R. N. (1999, November). *Is velocity strength training important in improving functional performance?* Paper presented at the Fifth Olympic Congress for Sport Scientists Conference, Sydney.
- Cronin, J. B., McNair, P. J. & Marshall, R. N. (2001). Velocity specificity, combination training and sport specific tasks. *Journal of Science and Medicine in Sport*, 4 (2), 168 – 178.
- Dagenais, M. (2001). Research Findings: The efficiency of overloading & underloading for baseball pitchers. *Softball Performance.com*. Retrieved September 23, 2001, from [http:// www. softballperformance.com/articles/overunder- loading.shtml](http://www.softballperformance.com/articles/overunder-loading.shtml)

- De Renne, C. (1987). Implement weight training programmes. *National Strength and Conditioning Journal*, 9 (3), 35 – 37.
- De Renne, C., Ho, K. W. & Murphy, J. C. (2001). Effects of general, specific and specific resistance training on throwing velocity in baseball: A brief review. *Journal of Strength and Conditioning Research*, 15 (1), 148 -156.
- De Renne, C., Buxton, B. P., Hetzler, R. K. & Ho, K. W. (1995). Effects of weighted bat implement training on bat swing velocity. *Journal of Strength and Conditioning Research*, 9 (4), 247 – 250.
- De Renne, C., Buxton, B. P., Hetzler, R. K. & Ho, K. W. (1994). Effects of under-and-overweighted implement training on pitching velocity. *Journal of Strength and Conditioning Research*, 8 (4), 247 – 250.
- De Renne, C., Ho, K.W. & Blitzblau, A. (1990). Effects of weighted implement training on throwing velocity. *Journal of Applied Sports Science Research*, 4 (1), 16 - 19.
- De Renne, C., Tracey, R. & Dunn-Rankin, P. (1985). Increasing throwing velocity. *Athletic Journal*, 65 (9), 36 – 39.
- Doherty, D., Robbins, D. & Hodgson, M. (2004). Complex training revisited: A review of its current status as a viable training approach. *Strength and Conditioning Journal*, 26 (6), 52 – 57.
- Doherty, T. J. & Campagna P. D. (1993). The effects of periodised velocity-specific resistance training on maximal and sustained force production in women. *Journal of Sport Sciences*, 11, 77 - 82.
- Dons, B., Bollerup, K., Bonde-Petersen, F. & Hancke, S. (1979). The effect of weight-lifting exercise related to muscle composition and muscle cross-sectional area in humans. *European Journal of Applied Physiology*, 40, 95 – 106.
- Duthie, M., Young, W. B. & Aitken, D. A. (2002). The acute effects of heavy loads on jump squat performance: An evaluation of the complex and contrast methods of power development. *Journal of Strength and Conditioning Research*, 16 (4), 530 – 538.
- Ebben, W. P. (2002). Complex training: A brief review. *Journal of Sports Science and Medicine*, 2, 42 - 46.
- Ebben, W. P. (2001). Maximum power training and plyometrics for cross-country running. *Strength and Conditioning Journal*, October, 47 – 50.
- Ebben, W. P. & Blackard, D. O. (1997). Complex training with combined explosive weight training and plyometric exercises. *Olympic Coach*, 7 (4), 11-12.
- Ebben, W. & Blackard, D. O. (1997). Developing a Strength-Power Programme for Amateur Boxing. *Strength and Conditioning*, 42 - 51.

- Ebben, W. P., Jensen, R. L. & Blackard, D. O. (2000). Electromyographic and kinetic analysis of complex training variables. *Journal of Strength and Conditioning Research*, 14 (4), 451 - 456.
- Ebben, W. P., Blackard, D. O. & Jensen, R. L. (1999). Quantification of medicine ball vertical impact forces: Estimating effective training loads. *Journal of Strength and Conditioning Research*, 13 (3), 271 - 274.
- Ebben, W. P. & Watts, P. B. (1998). A review of combined weight training and plyometric training modes: Complex training. *Strength and Conditioning*, 20 (5), 18 – 27.
- Elias, J. (1964). *The effect of overload training on speed in baseball pitching*. Unpublished masters' thesis. Springfield, Massachusetts, Springfield College.
- Enoka, R. M. (1994). *Neuromechanical basis of kinesiology*. Champaign, Illinois, Human Kinetics.
- Farley, C. T. (1997). Role of the stretch-shortening cycle in jumping. *Journal of Applied Biomechanics*, 13, 436 – 439.
- Fatouros, I.G., Jamurtas, A. Z., Loentsini, D., Taxildaris, K., Aggelousis, N., Kostopoulos N. & Buckmeyer, P. (2000). Evaluation of plyometric exercise training, weight training, and their combination on vertical jumping performance and leg strength. *Journal of Strength and Conditioning Research*, 14 (4), 470 – 476.
- Fees, M. A. (1997). Complex training. *Athletic Therapy Today*, 2 (1), 18.
- Fleck, S. J. (1999). Periodised strength training: A critical review. *Journal of Strength and Conditioning Research*, 13 (1), 82 – 89.
- Fleck, S. J. & Kontor, K. (1986). Complex training. *National Strength and Conditioning Association Journal* 8, (5), 66 – 68.
- Fleck, S. J. & Kraemer, W. J. (1997). *Designing resistance training programmes*. (2<sup>nd</sup> ed.). Champaign, Illinois, Human Kinetics.
- Ford, H. T., Puckett J. R., Drummond, J. P., Sawyer, K., Gantt, K. & Fussell, C. (1983). Effects of three combinations of plyometric and weight programmes on selected physical fitness test items. *Perceptual and Motor Skills*, 56, 919 – 922.
- Fredrick, G. A. & Szymanski, D. J. (2001). Baseball (Part 1): Dynamic flexibility. *Strength and Conditioning Journal*, 23 (1), 21 - 30.
- Gehri, D.J., Richard, M.D., Kleiner, D. M. & Kirkendall, D. T. (1998). A comparison of plyometric training techniques for improving vertical jump ability and energy production. *Journal of Strength and Conditioning Research*, 12 (2), 85 – 89.

- Glasser, J., Caterisano, A., & Brown, W. (1999). Off-season training for women's softball. *Strength and Conditioning Journal*, 21 (4), 54 - 59.
- Goubel, F. (1997). Series elasticity during the stretch-shortening cycle. *Journal of Applied Biomechanics*, 13, 439 – 443.
- Gourgoulis, V., Aggelousis, N., Kasimatis, P., Mavromatis, G. & Garas, A. (2003). Effect of a submaximal half-squats warm-up programme on vertical jumping ability. *Journal of Strength and Conditioning Research*, 17 (2), 342 – 344.
- Gronbech, C. E. (1997). Off-season and pre-season specificity training for throwing. *Strength and Conditioning Journal*, February, 20 – 22.
- Gullich, A. & Schmidtbleicher, D. (1996). MVC-induced short term potentiation of explosive force. *New Studies in Athletics*, 11(4), 67 – 81.
- Hakkinen, K. (1989). Neuromuscular and hormonal adaptations during strength and power training: A review. *Journal of Sports Medicine and Physical Fitness*, 29 (1), 9 – 26.
- Harman, E. (1993). Strength and power: A definition of terms. *National Strength and Conditioning Journal*, 15 (6), 18 – 20.
- Harris, G. R., Stone, M. H., O'Bryant, H. S., Proulx, C. M. & Johnson, R. L. (2000). Short-term performance effects of high power, high force, or combined weight training methods. *Journal of Strength and Conditioning Research*, 14 (1): 14 - 20.
- Hedrick, A. (2000). Training the trunk for improved athletic performance. *Strength and Conditioning Journal*, 22 (3), 50 – 61.
- Hedrick, A. (1996). Training greco-roman wrestlers at the U.S. Olympic training center. *Strength and Conditioning Association Journal*, 18 (5), 54 – 61.
- Hedrick, A. (1994). Strength/power training for the national speed skating team. *National Strength and Conditioning Association Journal*, 16 (5), 33 - 39.
- Herrick, A. (1993). Literature review: High speed resistance training. *National Strength and Conditioning Journal*, 15 (6), 22 – 30.
- Hedrick, A. & Anderson, J. C. (1996). The vertical jump: A review of the literature and a team case study. *Strength and Conditioning*, 18 (1), 7 - 12.
- Hoff, J. & Almasbakk, B. (1995). The effects of maximum strength training on throwing velocity and muscle strength in female team-handball players. *Journal of Strength and Conditioning Research*, 9 (4), 255- 258.
- Hopkins, W. G. (2005). A spreadsheet for analysis of fully controlled cross over trials. *Sportscience* 9, 24, [sportsci.org/jour/inbrief.htm#copyrig.htm](http://sportsci.org/jour/inbrief.htm#copyrig.htm)

- Hopkins, W. G. (2004). How to interpret changes in an athletic performance test. *Sportscience* 8, 1 - 7, [sportsci.org/jour/04/wghtests.htm](http://sportsci.org/jour/04/wghtests.htm)
- Hopkins, W. G. (2003). A spreadsheet for analysis of straightforward controlled trials. *Sportscience* 7, [sportsci.org/jour/03/wghtrials.htm](http://sportsci.org/jour/03/wghtrials.htm)
- Hopkins, W. G. (2002). Probabilities of clinical or practical significance. *Sportscience* 6, [sportsci.org/jour/0201/wghprob.htm](http://sportsci.org/jour/0201/wghprob.htm)
- Hopkins, W. G. (1997). A new view of statistics. *Internet Society for sports Science*: <http://www.sportssci.org/resource/stats.2.8> MB.
- Hopkins, W., G., Hawley, W. G. & Burke, L. M. (1999). Design and analysis of research on sport performance enhancement. *Medicine and Science in Sport and Exercise* 31, 472 – 485.
- Hrysomallis, C. & Kidgell, D. (2001). Effect of heavy dynamic resistance exercise on acute upper-body power. *Journal of Strength and Conditioning Research*, 15 (4), 426 – 430.
- Huber, J. (1987). Increasing a diver's vertical jump through plyometric training. *National Strength and Conditioning Journal*, 9 (1), 34 – 36.
- Jackson, J. B. (1994). *The effects of weight training on the velocity of a thrown baseball*. Unpublished masters' thesis. Central Michigan University, Michigan.
- Jacobs, P. (1987). The overhand baseball pitch: A kinesiological analysis and related strength-conditioning programming. *National Strength and Conditioning Association Journal*, 9 (1), 5 - 13, 78 - 79.
- Jensen, R. L. & Ebben, W. P. (2003). Kinetic analysis of complex training rest interval effect on vertical jump performance. *Journal of Strength and Conditioning Research*, 17 (2), 345 - 349.
- Jones, D. A. & Rutherford, D. M. (1987). Human muscle strength training: The effects of three different regimes and the nature of the resultant changes. *Journal Physiology*. 391, 1 – 11.
- Jones, K., Hunter, G., Fleisig, G., Escamilla, R. & Lemak, L. (1999). The effects of compensatory acceleration on upper-body strength and power in collegiate football players. *Journal of Strength and Conditioning Association*, 13 (2), 99 – 105.
- Jones, P. & Lees, A. (2003). A biomechanical analysis of the acute effects of complex training using lower limb exercises. *Journal of Strength and Conditioning Research*, 17 (4), 694 – 700.



- Kaufman, T. M. (1999). Weight room considerations for the throwing athlete. *Strength and Conditioning Journal*, 21 (4), 7 – 10.
- King, I. (1993). Plyometric training: In perspective part 2. *Sports Science Periodical on Research and Technology in Sport*, 13(6).
- Komi, P. V. (1983). Elastic potentiation of muscle and its influence on sport performance. In: Baumann W (Ed.), *Biomechanics and Performance in Sport*. Schorndorf, Germany: Hoffmann 59- 70.
- Komi, P.V. & Bosco, C. (1978). Utilisation of stored elastic energy in leg extensor muscles by men and women. *Medicine and Science in Sports*, 10 (4), 261 – 265.
- Kuhn, J. E., Bey, M. J., Huston, L. J., Blasier, R. B. & Soslowsky, L. (2000). Ligamentous restraints to external rotation in the late-cocking phase of throwing: A cadaveric biomechanical investigation. *The American Journal of Sports Medicine*, 28 (2), 200 – 205.
- Lachowetz, T., Evon, J. & Pastiglione, J. (1998). The effect of an upper body strength program on intercollegiate baseball throwing velocity. *Journal of Strength and Conditioning Research*, 12 (2), 116 – 119.
- Lord, P. & Campagna, P. (1997). Drop height selection and progression in a drop jump programme. *Strength and Conditioning*, 19 (6), 65 - 69.
- Lundin, P. & Berg, W. (1991). Plyometrics: A review of plyometric training. *National Strength and Conditioning Association Journal*, 13 (6), 22 – 30.
- Lyttle, A. D. (1995). Maximising power development: A summary of training methods. *Strength and Conditioning Coach*, 2 (3), 16 – 19.
- Lyttle, A. D., Wilson, G. J. & Ostrowski, K, J. (1996). Enhancing performance: Maximal power versus combined weights and plyometric training. *Journal of Strength and Conditioning Research*, 10 (3), 173 – 179.
- MacKenzie, B. (2002) Sports Coach: *Complex Training*. Retrieved March 03, 2002 from <http://www.brianmac.demon.co.uk/complex.htm>
- Marandino, R. (2003). Strength training for power. *NSCA's Performance Training Journal*, 1 (9), 15 – 20.
- Masamoto, N., Larson, R., Gates, T. & Faigenbaum, A. (2003). Acute effects of plyometric exercises on maximal squat performance in male athletes. *Journal of Strength and Conditioning Research*, 17 (1), 68 – 71.
- Masley, J. W., Hairabedian, A. & Donaldson, D. N. (1952). Weight training in relation to strength, speed and co-ordination. *The Research Quarterly*, 308 – 315.

- Mayhew, J. L., Ware, J. S., Johns, R. A. & Bemben, M. G. (1997). Changes in upper body power following heavy-resistance strength training in college men. *International Journal of Sports Medicine* 18, 516 - 520.
- McBride, J. M., Nimphius, S. & Erickson, T. M. (2005). The acute effects of heavy-load squats and loaded countermovement jumps on sprint performance. *Journal of Strength and Conditioning Research*, 19 (4), 893 – 897.
- McBride, J. M., Triplett-McBride, T., Davie, A. & Newton, R. U. (1999). A comparison of strength and power characteristics between power lifters, Olympic lifters and sprinters. *Journal of Strength and Conditioning Research*, 13 (1), 58 – 66.
- McDermott, A. (1986). Plyometric training for throwing events. *National Strength and Conditioning Association Journal*, 8 (4), 52 - 55.
- McEvoy, K. P. & Newton, R. U. (1998). Baseball throwing speed and base running speed: The effects of ballistic resistance training. *Journal of Strength and Conditioning Research*, 12 (4), 216 – 221.
- McLester, J. R., Bishop, P. & Guilliams, M. E. (2000). Comparison of 1 day and 3 days per week of equal-volume resistance training in experienced participants. *Journal of Strength and Conditioning Research*, 14 (3), 273 - 281.
- Morrissey, M. C., Harman, E. A. & Johnson, M. J. (1995). Resistance training modes: Specificity and effectiveness. *Medicine and Science in Sports and Exercise*, 27 (5), 648 – 660.
- Olsen, P. D. & Hopkins, W. G. (2003). The effect of attempted ballistic training on the force and speed of movements. *Journal of Strength and Conditioning Research*, 17 (2), 291 – 298.
- Newton, R. U., Kraemer, W. J. & Hakkinen, K. (1999). Effects of ballistic training on preseason preparation of elite volleyball players. *Medicine and Science in Sports and Exercise*, 31 (2), 323 - 330.
- Newton, R. U., Kraemer, W. J., Hakkinen, K., Humphries, J. & Murphy, A. J. (1996). Kinematics, kinetics, and muscle activation during explosive upper body movements. *Journal of Applied Biomechanics* 12, 31 - 43.
- Newton, R. U. & McEvoy, K.P. (1994). Baseball throwing velocity: A comparison of medicine ball training and weight training. *Journal of Strength and Conditioning Research*, 8 (3), 198 203.
- Newton, R. U. & Kraemer, W. J. (1994). Developing explosive muscular power: Implications for a mixed methods training strategy. *Strength and Conditioning*, 16 (5), 20 – 30.

- Newton, R.U. & McEvoy, K. P. (1994). Baseball throwing velocity: A comparison of medicine ball training and weight training. *Journal of Strength and Conditioning Research*, 8 (3), 198 – 203.
- Parker, R. (1988). The development of trunk stability in athletic movements. *National Strength and Conditioning Association*, 10 (6), 16 – 19.
- Panariello, R. A. (1992). Arm deceleration training for baseball. *National Strength and Conditioning Association Journal*, 14 (6), 19 – 25.
- Pate, T. R. (2000). A conditioning programme to increase vertical jump. *Strength and Conditioning Journal*, 22 (2), 7 - 11.
- Pearson, D., Faigenbaum, A., Conley, M. & Kraemer, W. J. (2000). The National Strength and Conditioning Association's basic guidelines for the resistance training of athletes. *National Strength & Conditioning Association*, 22 (4), 14 – 27.
- Polhemus, R., Osina, M., Burkhardt, E. & Patterson, M. (1980). The effects of plyometric training with ankle and vest weights on conventional weight training programmes for men. *Track and Field Quarterly Review*, 80 (4), 59 - 61.
- Poliquin, C. (1997). *The Poliquin principles: Successful methods for strength and mass development*. Napa Valley, California, Dayton Writers Group.
- Poliquin, C. (1992). Applied strength training. Part 1: Short-term periodisation. *Sports Coach*, July-September, 25 – 28.
- Pretz, R. (2004). "Ballistic six" plyometric training for the overhead throwing athlete. *Strength and Conditioning Journal*, 26 (6), 62 – 66.
- Radcliffe, J. C. & Radcliffe, J. L. (1996). Effects of different warm-up protocols on peak power output during a single response task [Abstract]. *Medicine and Science in Sports and Exercise*, 28, S189.
- Reddin, D. (1999) Complex Training for Power Development. *National Coaching Foundation*, 3, 24 – 25.
- Renfro, G. J. (1999). Summer plyometric training for football and its effect on speed and agility. *Strength and Conditioning Journal*, 21 (3), 42 – 44.
- Rhea, M. R., Alvar, B.A. Ball, S.D. & Burkett, L.N. (2002). Three sets of weight training superior to 1 set with equal intensity for eliciting strength. *Journal of Strength and Conditioning Research*, 16 (4), 525 - 529.
- Robertson, T. (1998). Preparing a professional baseball player for spring training camp. *Strength and Conditioning*, 20 (4). 4 - 29.
- Roque, E. (1999). Complex Training. *Volleyball (Placentia, California)*, 10 (7), 60 - 65.

- Robbins, D. W. (2005). Postactivation potentiation and its practical applicability: A brief review. *Journal of Strength and Conditioning Research*, 19 (2), 453 – 458.
- Rudolph, B. S. & Smith, A. L. (1999). Strength training for the windmill softball pitcher. *Strength and Conditioning Journal*. 21 (4), 27 - 33.
- Sale, D.G. (1991). Testing strength and power. In J. D. MacDougall, H.A. Wenger and H. J. Green (Ed.), *Physiological testing of the high performance athlete* (pp. 21 – 106). Champaign, Illinois, Human Kinetics.
- Sale, D. & MacDougall, D. (1981). Specificity in strength training: A review for the coach and athlete. *Canadian Journal of Applied Sport Sciences*, 87 – 91.
- Santana, J. C. (2000). Strength you can use: The paradox of strength development. Part 2. *Strength and Conditioning Journal*, 22 (4), 59 - 61.
- Schenau, G. J., Bobbert, M. F. & de Hann, A. (1997). Does elastic energy enhance work and efficiency in the stretch-shortening cycle? *Journal of Applied Biomechanics*, 13, 389 – 415.
- Schmidtbleicher, D. (1985). Strength training: Part 2. Structural analysis of motor strength qualities and its application to training. *SPORTS, Science Periodical On Research and Technology in Sport*, September, 1 – 10.
- Scott, S. L. & Docherty, D. (2004). Acute effects of heavy preloading on vertical and horizontal jump performance. *Journal of Strength and Conditioning Research*, 18 (2), 201 – 205.
- Sergo, C. & Boatwright, D. (1993). Training methods using various weighted bats and the effects on bat velocity. *Journal of Strength and Conditioning Research*, 7 (2), 115 – 117.
- Shenk, B. S. (1990). *Effect of two strength training programmes on throwing velocity*. Unpublished doctoral dissertation. Charlottesville, University of Virginia.
- Smilios, I., Pilianidis, K., Sotiropoulos, M. & Tokmakidis, S. P. (2005). Short-term effects of selected exercise and load in contrast training on vertical jump performance. *Journal of Strength and conditioning Research*, 19 (1), 135 – 140.
- Spassov, A. (1988). Special considerations when programming for strength and power for athletes: Part 1. *National Strength and Conditioning Association Journal*, 10 (4), 58 – 61.
- Sullivan, W. J. (1970). *The effects of three experimental training factors upon baseball throwing velocity and selected strength measures*. Unpublished doctoral thesis. Indiana University, Indiana.
- Summers, R. B. (1999). Complex training at Ponderosa High. *Strength and Conditioning Journal*, 21 (5), 46 – 47.

- Szymanski, D. J. & Fredrick, G. A. (1999). College baseball/softball periodised torso programme. *Strength and Conditioning Journal*, 21 (4), 42 - 47.
- Szymanski, D. J. & Fredrick, G. A. (2001). Baseball (Part 11): A periodised speed programme. *Strength and Conditioning Journal*, 23 (2), 44 - 52.
- Tohji, H., Suei, K. & Kaneko, M. (1997). Effects of combined training loads on relations among force, velocity, and power development. *Canadian Journal of Applied Physiology*, 22 (4), 328 - 336.
- Tohji, H., Suei, K. & Kaneko, M. (1991). Effects of combined training programmes on force-velocity relation and power output in human muscle. *Journal of Health, Physical Education and Recreation*, 39, 311 - 312.
- Tohji, H., Suei, K. & Kaneko, M. (1997). Effects of combined training loads on relations among force, velocity and power development. *Canadian Journal of Applied Physiology*, 22 (4): 328 - 336.
- Toyoshima, S., Hoshikawa, T., Miyashita, M. & Oguri, T. (1974). Contribution of the body parts to throwing performance. In: Nelson, R. C., Morehouse, C. A. (Eds.), *Biomechanics IV*. Baltimore, University Park Press.
- Van Den Tillaar, R. (2004). Effect of different training programs on velocity of overarm throwing: A brief review. *Journal of Strength and Conditioning Research* 18 (2), 388 – 396.
- Vaughn, R. E. (1996) Mechanics of the baseball throw. *Gatorade Sports Science Institute: Coaches' Corner*. Retrieved January 17, 2001, from <http://www.gssiweb.com/references/s0000000200000015/s00000.../d0000000200000037.htm>
- Verkhoshansky, Y. (1986). Speed-strength preparation and development of strength endurance athletes in various specializations. *Sovet Sports Review*. 21, 120 - 124.
- Vossen, J. F., Kramer, J. F., Burke, G. & Vossen, D. P. (2000). Comparison of dynamic push-up training and plyometric push-up training on upper-body power and strength. *Journal of Strength and Conditioning Research*, 14 (3), 248 – 253.
- Waller, M. A. & Piper, T. J. (1999). Plyometric training for the personal trainer. *Strength and Conditioning Journal*, 21 (2), 9 – 14.
- Wathen, D. (1993). Literature Review: Explosive/Plyometric exercises. *National Strength and Conditioning Journal*, 15 (3), 17 - 19.
- Watkinson, J. (1998). Performance testing for baseball. *Strength and Conditioning Journal*, 20 (4), 16 – 21.

- Watkinson, J. (1997). A strength, speed, power approach to improving throwing velocity in baseball. *Strength and Conditioning*, 19 (5), 42 - 47.
- Wilks, R. (1996). Limitations in applied strength training research: Current dilemmas and recommendations for future studies. *Strength and Conditioning Coach*, 3 (2), 17 – 20.
- Wilson, G. J. (1994). The principles of strength training part 1: Overload and specificity. *Strength and Conditioning Coach*, 2 (1), 3 – 6.
- Wilson, G. J. (1993). How to maximise the use of elastic energy in sport: State of the art review. *National Sports Research Centre*, June, 4 – 15.
- Wilson, G. J., Elliot, B. C. & Wood, G. A. (1992). Stretch shorten cycle performance enhancement through flexibility training. *Medicine and Science in Sports and Exercise*, 24, 116 – 123.
- Wilson, G. J., Elliot, B. C. & Wood, G. A. (1990). The use of elastic energy in sport. *Sports Coach*, July – September, 8 - 10.
- Wilson, G. J., Newton, R. U., Murphy, A. J. & Humphries, J. (1993). The optimal training load for the development of dynamic athletic performance. *Medicine and Science in Sports and Exercise*, 25 (11), 1279 – 1286.
- Yessis, M. (1994). Training for Power Sports: Part 1. *Strength and Conditioning Journal* 16 (5), 42 - 45.
- Yessis, M. (1995). Training for power sports: Part 2. *Strength and Conditioning Journal* 17 (1), 68 - 73.
- Yessis, M. (1981). The role of specificity in “strength” training for track, gymnastics and other sports. *National Strength and Conditioning Association Journal*, 3 (5), 20 – 21.
- Young, W. (1997). Short term enhancement of power performance from high load exercise. *Strength and Conditioning Coach*, 5 (2), 5 – 7.
- Young, W. (1993). Training for speed/strength: heavy versus light loads. *National Strength and Conditioning Association Journal*, 15 (5), 34 – 42.
- Young, W. (1991). The planning of resistance training for power sports. *National Strength and Conditioning Association Journal*, 13 (4), 26 – 29.
- Young, W. B., Jenner, A. & Griffiths, K. (1998). Acute enhancement of power performance from heavy load squats. *Journal of Strength and Conditioning Research*, 12 (2), 82 – 84.
- Zatsiorsky, V. M. (1995). *Science and practice of strength training*. Champaign, Illinois, Human Kinetics.

Zatsiorsky, V. M. (1992). Intensity of strength training facts and theory: Russian and Eastern European approach. *National Strength and Conditioning Association Journal*, 14 (5), 46 – 57.

## APPENDICIES

### APPENDIX 1: RECRUITMENT LETTER

K M Sheehy  
Senior Lecturer  
Faculty of Health  
Auckland University of Technology  
Private Bag 92006  
AUCKLAND.

March 2004

The President  
Ramblers Softball Club  
AUCKLAND.

Dear Sir,

**Reference:** Master of Health Science Thesis  
*Short-term effects of weight training on softball throwing velocity.*

As previously discussed on several occasions, I am in the process of completing my Masters Degree at Auckland University of Technology. Part of the degree requires completion of a thesis, which should contain original research and be of interest to several parties including Auckland University of Technology, Sport and Exercise Science New Zealand, Sports Science Journals and the Sporting Community of New Zealand.

I have chosen the topic "Short-term effects of weight training on softball throwing velocity." To enable me to gather sufficient information I require the assistance of eight participants who will be tested on specialised weight training equipment and assessed for maximum throwing velocity. In the interests of safety, all volunteers will require to meet the following criteria:

- Be male
- Must have a minimum of two years strength training experience (based on pre-screen questionnaire). Weight training is defined as a minimum of an average of two training sessions per week during the pre-season conditioning phase and one session of maintenance per week during the competitive phase over the last two years. This ensures that the athletes will at least have a basic strength base from which to move into the ballistic and plyometric work.
- Premier Men Softball Grade
- Age minimum 18, maximum 35

Volunteers will be randomly selected to one of two groups, and will perform two different methods of weight training.



**Familiarisation and Pre-testing**

Volunteers will be required for approximately 1 hour for pre testing and familiarisation training. During this time the participants will provide descriptive data, specifically their age, height, body mass and weight training history. On completion of this data, the participants will complete a familiarisation phase, which will allow them to get accustomed to the testing equipment. At this point the participants will be tested for maximum upper body strength (1 RM) bench press [BP] and power output with various barbell loads to determine their maximal power output (Pmax). The 1 RM strength assessments will involve bench-pressing to failure.

**Training Methods**

Volunteers will then return on two occasions for further weight training and testing. The testing will involve bench press throw away and maximal softball throwing velocity using a Jugs radar gun.

The full description and methods of testing, questions regarding commitment to the project etc are attached and can be taken away for further reading. A diagram of the process is also included.

It is requested that copies of this project are distributed to the Premier Men so that we can recruit the required number of players. Please ask interested players to advise either yourself or contact me at AUT 917 9999 ext 7500, at home 416 7613 or mobile 0274 759 905.

Thank you for your support.  
Kind regards,

Kevin Sheehy

## APPENDIX 2: CONSENT TO PARTICIPATE IN RESEARCH

### Consent to Participation in Research

This form is to be completed in conjunction with, and after reference to, the AUTEK Guidelines (Revised January 2003).

Title of Project: Short-term effects of weight training on softball throwing velocity.  
Project Supervisor: Will Hopkins  
Researcher: Kevin Sheehy

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- I have read and understood the information provided about this research project (Information Sheet dated April 2004).
- I have had an opportunity to ask questions and to have them answered.
- 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.
- I agree to take part in this research.
- I wish to receive a copy of the report from the research.

Participant signature: .....

Participant name: .....

Participant Contact Details (if appropriate):

.....  
.....  
.....  
.....

Date:

Approved by the Auckland University of Technology Ethics Committee on 8 June 2004 AUTEK Reference number 04/92

### **APPENDIX 3: PRE-ASSESSMENT QUESTIONNAIRE / TRAINING STATUS**

To ensure a quiet reassuring atmosphere for the testing processes, the athletes were invited into the laboratory at AUT the day prior to the formal testing. This familiarisation allowed the athletes a full discussion with the testing protocols and a chance to ask questions about the procedures and the test environment. The athletes were also informed of the risks, hazards and the nature of the testing to be performed.

The athletes completed pre-screen / medical forms and were advised of the crisis /emergency plan. Details of their next of kin / person to contact in an emergency were also obtained. A cell phone was on hand for emergency calls as required. Following the testing, the athletes were monitored for 10 minutes and encouraged to drink the water provided (2 cups).



Sports Performance Centre

Facsimile: 64-9-917-9960  
 Telephone: 64-9-917-9999 ext. 7500

**Section 1 - Personal Details**

Name: D.O.B.: / / Sex: M / F  
 Address: Work Phone: ( )  
 Home Phone: ( )  
 Mobile Phone: ( )  
 E-mail: Occupation:  
 GP: GP Telephone:  
 Emergency Contact: Telephone: ( )

**Section 2 - Medical**

- 1 Have you ever had any injury or illness that may be aggravated by vigorous exercise? Yes / No
- 2 Do you suffer from any of the following: Have you ever had: arthritis, asthma, diabetes, epilepsy, ulcer, or dizziness? Yes / No
- 3 Have you ever been diagnosed with a heart condition, high blood pressure, stroke, or high cholesterol? Yes / No
- 4 Have any immediate family members been diagnosed with heart problems prior to age 60? Yes / No
- 5 Have you been hospitalized within the last three months? Yes / No
- 6 Are you taking or have you previously taken any prescribed medication? Yes / No
- 7 Do you have any physical limitations that may limit your ability to participate in vigorous maximal exercise? Yes / No
- 8 Have you been taking part in moderate to vigorous exercise in the last three months? Yes / No
- 9 Is there any reason not mentioned above that may affect your ability to perform physical exercise? Yes / No
- 10 Have you ever been advised not to partake in physical exercise? Yes / No
- 11 Do you suffer from any allergies? Yes / No
- 12 Have you previously or do you currently use nutritional supplements? Yes / No

**Please expand on any 'YES' answers:**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_



Sports Performance Centre

Facsimile: 64-9-917-9960  
Telephone: 64-9-917-9999 ext. 7500

**Have you sustained any previous injuries? Please provide details:**

.....  
 .....  
 .....

**Do you have any current injuries? Please provide details:**

.....  
 .....  
 .....

**Have you had any surgery/operations? Please provide details:**

.....  
 .....  
 .....

**Section 3 - Sport/Physical Activity**

**Sport/Physical Activity:**

**Please list any goals you are working towards achieving within the next year:**

.....  
 .....  
 .....

**Please indicate the current amount of training being undertaken:**

	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total Hrs
am								
pm								

**Please indicate the time that you work each day:**

Mon	Tue	Wed	Thu	Fri	Sat	Sun



Sports Performance Centre

Facsimile: 64-9-917-9960  
 Telephone: 64-9-917-9999 ext. 7500

**Please list up to five major events that you would like to do in the next year:**  
 (1= most important; 3= somewhat important; 5= least important)

_____	Date:	/	/	Priority:	1	2	3	4	5
_____	Date:	/	/	Priority:	1	2	3	4	5
_____	Date:	/	/	Priority:	1	2	3	4	5
_____	Date:	/	/	Priority:	1	2	3	4	5
_____	Date:	/	/	Priority:	1	2	3	4	5

**Please list the times that you are able to train each week:**

	Mon	Tue	Wed	Thu	Fri	Sat	Sun	Total Hrs
am								
pm								

**What do you perceive as your current physical strengths?**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**What do you perceive as your current physical weaknesses?**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**List your previous level of weight training experience over the last five years including the number of hours per week during pre-competition and competition phases.**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**Please provide any additional information you think maybe relevant:**

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

## APPENDIX 4: PARTICIPANT INFORMATION SHEET

### Participant Information Sheet

**Date Information Sheet Produced:** April 2004

**Project Title**

Short-term effects of weight training on softball throwing velocity.

**Invitation**

Premier Men from Auckland and the North Shore leading softball clubs are invited to take part in this project. To be eligible to participate the men must have a minimum of two years weight training experience (based on pre-screen questionnaire) and be aged between 18 and 35 years old.

**What is the purpose of the study?**

One of the issues to be considered when developing strength and power in sport is specific training, especially in the off-season. In New Zealand sport specific training is often de-emphasised in softball and instead basic generic strength and speed exercises are used to establish a training base. Recently some researchers have suggested that throwing velocity is an important determinant of success in baseball. Athletes and coaches alike have explored this parameter. Nevertheless, few studies in New Zealand have investigated the development of softball throwing velocity.

As part of a Master of Health Science Thesis, we aim to provide more evidence that the use of variations of weight training methods and complex/contrast training will enhance short-term performance in particular softball throwing velocity. The complex/contrast training is characterised by the use of heavy and light loadings of biomechanically similar exercises in the same set during weight training.

**What happens in the study?**

A training method which is attracting considerable interest, is termed combination or contrast training. This type of training is a combination of traditional resistance training and ballistic (rebound) techniques. The training usually combines a heavy resistance exercise with a power movement and has been shown to enhance performances for a short time. It may be that this type of training is more appropriate for improving throwing velocity. While this may be so, some researchers have reported that there is limited research, particularly for upper body plyometric movements, to support this practice. However a number of training studies which have examined combined weight and plyometric training programmes and one stated that the power increases achieved through complex training were up to three times more effective than conventional training programmes.

This study will investigate two methods of weight training followed by testing of upper body power and throwing velocity. We aim to increase exercise performance and to investigate possible physiological mechanism that may contribute to performance change. Thus, we can advise New Zealand Softball of ways to assist in obtaining maximal throwing velocity that will optimise your training by decreasing the amount of time required to develop power in the weight room.

You will be pretested and posttested for throwing velocity and power output using an exercise known as the benchpress throw. You will then be randomly selected to one of two groups. After the warm-up period you will then perform either one of the two training systems. This weight training system will comprise of three sets of heavy bench pressing, followed by a functional exercise involving medicine ball chest passing. The second method will involve power bench pressing using your individual maximum power ( $P_{max}$ ) load followed by a functional exercise involving medicine ball chest passing.

This testing strategy is designed to gather data concerning the short-term effect, if any, that the training methods may have on consequent throwing velocity and power output during the posttesting occasion.

Your maximum throwing velocity will be assessed over a distance of 18.4-m, the distance between home plate and the first base. The recorder will stand 2-m directly to the left and behind home plate with a radar gun held at chest height and aimed at the ball trajectory from the your hand release point to the catching point at home plate. Velocity will be recorded on a hand-held 3 digit signal processing (DSP) Jugs Cordless radar gun. A regulation (30 cm) yellow Mizuno softball weighing 150 grams will be utilised for throwing assessments.

At the completion of the familiarisation phase, you will be tested for maximum upper body strength (1 RM bench press [BP]) and power output with various barbell loads to determine your maximal power output (Pmax). The 1 RM strength assessment will involve bench-pressing to failure.

A 12 minute rest will follow. The Pmax will be assessed during a flat BP activity performed within the Smith Machine. For the BP, you will perform 1 rebound consecutive stretch-shortening cycle repetitions against loads of 20, 30, 40, 50, 60, 70 and 80 kg (BT P 20, BT P30, BT P40, BT P50, BT P70, and BT P80), performed in order, with approximately 1-minute rest between loads.

The results will be collected from the bench press throw by computer and we will record your peak power, mean power, peak velocity and mean velocity.

You will be instructed to begin with the weighted barbell held at arms length, then lower the bar to the chest and immediately push it upward, attempting to project the bar for maximal height. No pause will be permitted between the eccentric and concentric phases and the trial will be rejected if you 'bounce' the bar off your chest. The mean of the best two power outputs will be chosen for further analysis.

You will have a further 12 minutes rest.

Following the rest period you will perform the pretest which will consist of using a weight comparable to your Pmax, and once again the variables will be collected on a computer from the bench press throw. You will be instructed to propel the barbell as explosively as possible and will be given verbal encouragement throughout. Once again, the mean of the best two power outputs will be chosen and recorded for further analysis.

After 4 minutes rest, you will move into the stadium area and commence your warm-up for the maximum softball throwing velocity test.

After an adequate general warm-up consisting of five minute jogging and muscle stretches specific to throwing, you will be allowed an unlimited number of warm-up throws. You will then throw with their front foot positioned behind the tape placed on the ground (representative of first base) to home plate where the receiver will stand on the home plate to catch the ball. Five recorded throws will be made with the mean of the best two throws recorded in meters per second (m.s-1).

You will be asked to return -2 days later

Once more you will be required to perform the following standardized warm-up before commencing the testing session. First a five minute warm up on a stationary bike at 60 RPM, followed by full body static stretches for 15 seconds each, following an instructional demonstration; a set of 10 repetitions sub-maximal bench press throws. You will be instructed to throw the bar as high as possible in an explosive fashion.

The first treatment design (heavy weight) strategy will then be performed. Which actual treatment will be by random selections. The two treatments consist of you (a.) performing the three sets with loadings of 90 – 100% 1RM and 3 repetitions and a functional activity comprising of three sets of 12 repetitions involves a very light resistance (medicine ball chest throws) performed for maximum speed (b.) the second treatment will comprise three sets of your previous determined Pmax for 5 – 8 repetitions followed again by a functional activity comprising of three sets of 12 repetitions involves a very light resistance (medicine ball chest throws) performed for maximum speed.

There will be a 4 minute rest between sets.



After the acute training interventions, the exact same testing procedures will be replicated. After 4-minutes of rest, you will perform the maximum softball throwing velocity test. During the recording of the softball velocity readings will be taken at the 4 minute, 6 minute, 8 minute and 10 minute marks to record the decaying effects of the potentiation expected from the interventions.

You will return once more to the weight room where you will repeat the first treatment design. After the acute training interventions, the exact same testing procedures will be replicated.

After further 4-minutes of rest, you will perform the Pmax power training test. During the recording of the Pmax readings will be taken at the 4 minute, 6 minute, 8 minute and 10 minute marks to record the decaying effects of the potentiation expected from the interventions.

Thus after warm-up, you will have performed a post test maximal throwing velocity and a Pmax power output test with an intervention of either a maximal heavy weight training, Pmax power training, medicine ball plyometric training and a descending complex/contrast training intervention.

You will return two days later where you will repeat the full processes; however the training method will be the second intervention.

#### **What are the discomforts and risks?**

Physical injury (muscle strains) due to inadequate warm-up

#### **How will these discomforts and risks be alleviated?**

You will be required to perform a standardized warm-up before commencing each testing session. First a five minute warm up on a stationary bike at 60 RPM, followed by full body static stretches for 15 seconds each, following an instructional demonstration; a set of 10 repetitions sub-maximal bench press throws. You will be instructed to throw the bar as high as possible in an explosive fashion.

You will be screened to assess your suitability and if it is found that you have a history of injuries that may interfere with performance or be aggravated by the nature of the methods required will not be selected.

You will be instructed to use correct warm-up procedures and will also be given familiarisation with the testing equipment and lifting methodology prior to the testing.

#### **What are the benefits?**

More certainty about the benefits of various forms of weight training for performance. Understand what's going on might help us to work out how to use our time more effectively.

#### **What compensation is available for injury or negligence?**

Only the usual ACC compensation.

#### **How will my privacy be protected?**

We don't put your name in the computer with your data. Hard copies of data are kept in a locked filing cabinet and are eventually destroyed.

#### **How do I join the study?**

Let your coach or Kevin Sheehy know.

#### **What are the costs of participating in the project? (including time)**

The daily sessions for testing and training takes an hour. There are three visits to AUT Sport and Recreation Center altogether. The cost of traveling to and from will be at your own expense and travel time will be dependant on your own personal living or work situations.

#### **Opportunities to consider invitation**

We need to get started as soon as possible if we are to finish the writing of the study before Christmas, so we need a quick decision. You can change your mind about being part of the study at any time right through

the study. Your participation is entirely voluntary. You can ask Will or any other independent person for more information about the project before or after signing up.

**Opportunities to receive feedback on results and research?**

We will provide you with your own results and the average results of all the study members.

**Participants Concerns**

Any concerns concerning the nature of this project should be notified in the first instance to the Project Supervisor. Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEK, Madeline Banda, [Madeline.banda@aut.ac.nz](mailto:Madeline.banda@aut.ac.nz), 917 9999 ext 8044.

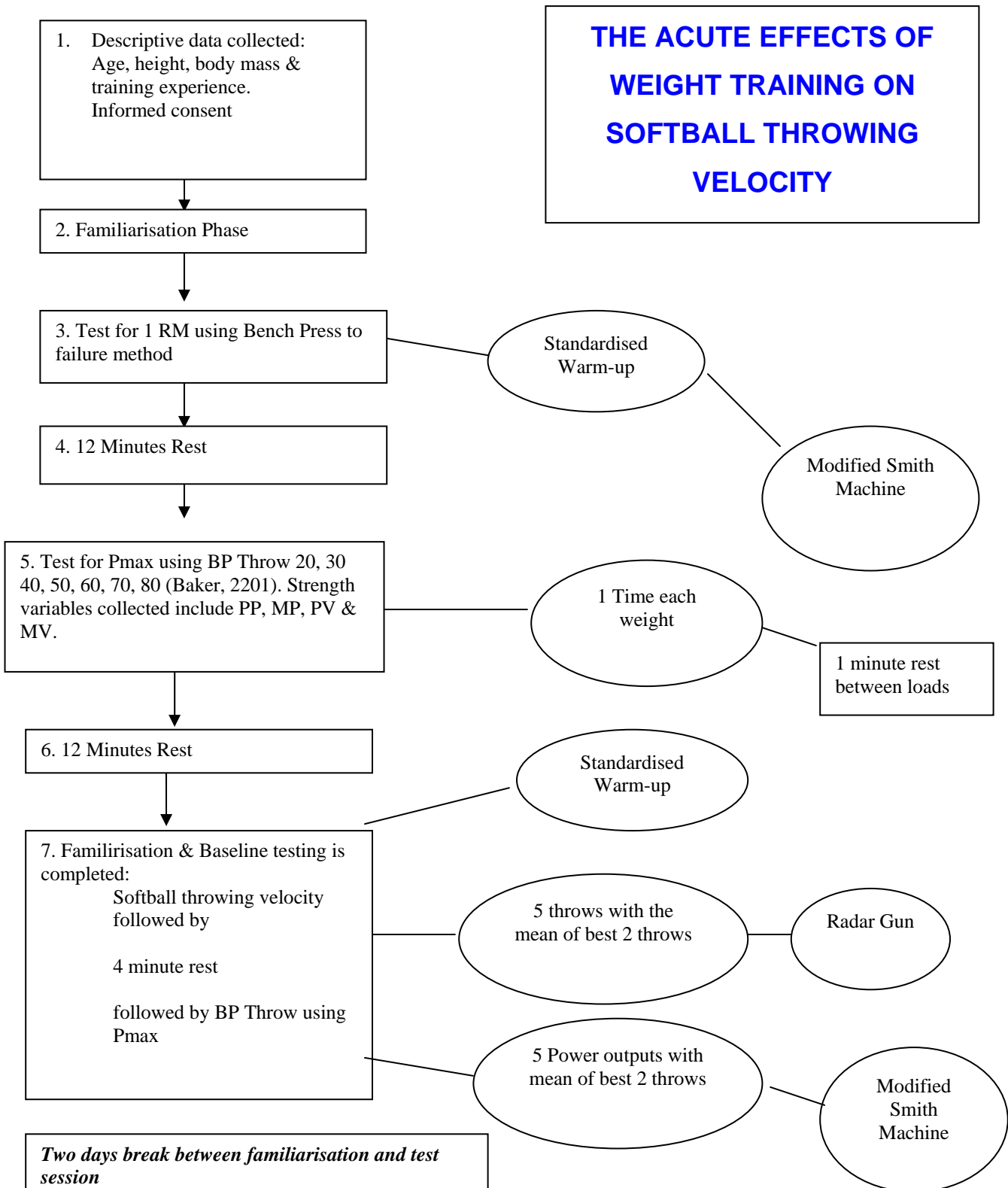
**Researcher Contact Details:**

Will Hopkins, Division of Sport and Recreation, Faculty of Health, Auckland University of Technology. Phone 917 9793, mobile 027 227 6262.

**Approved by the Auckland University of Technology Ethics Committee on 8 June 2004**  
**AUTEK Reference number 04/92**

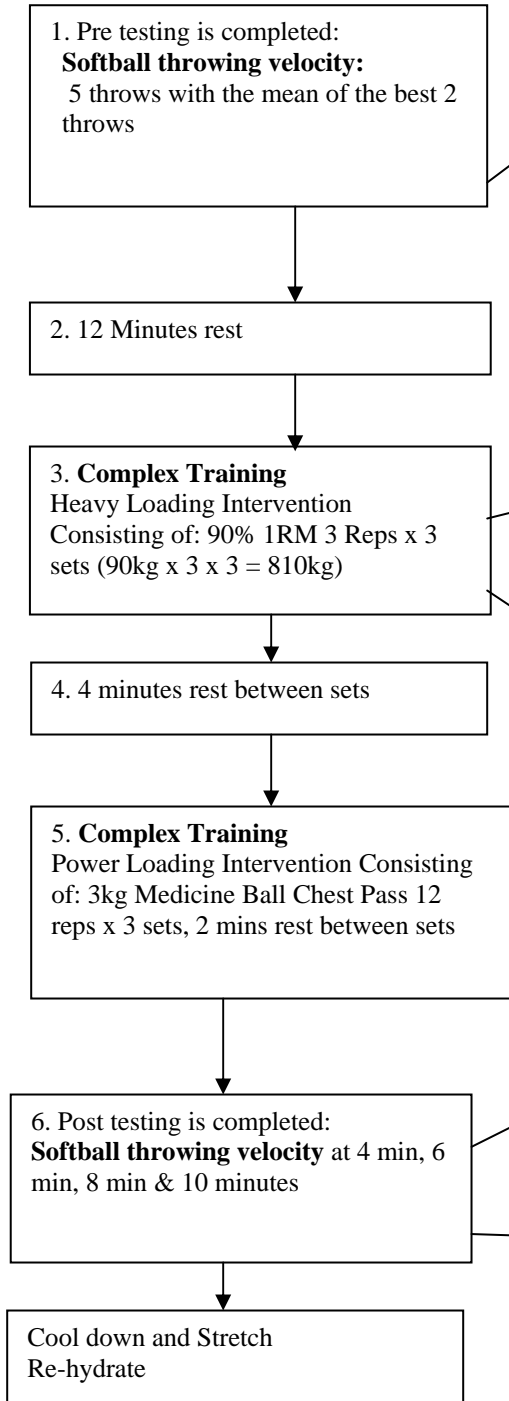
## APPENDIX 5: FULL STUDY DESIGN

### Day One



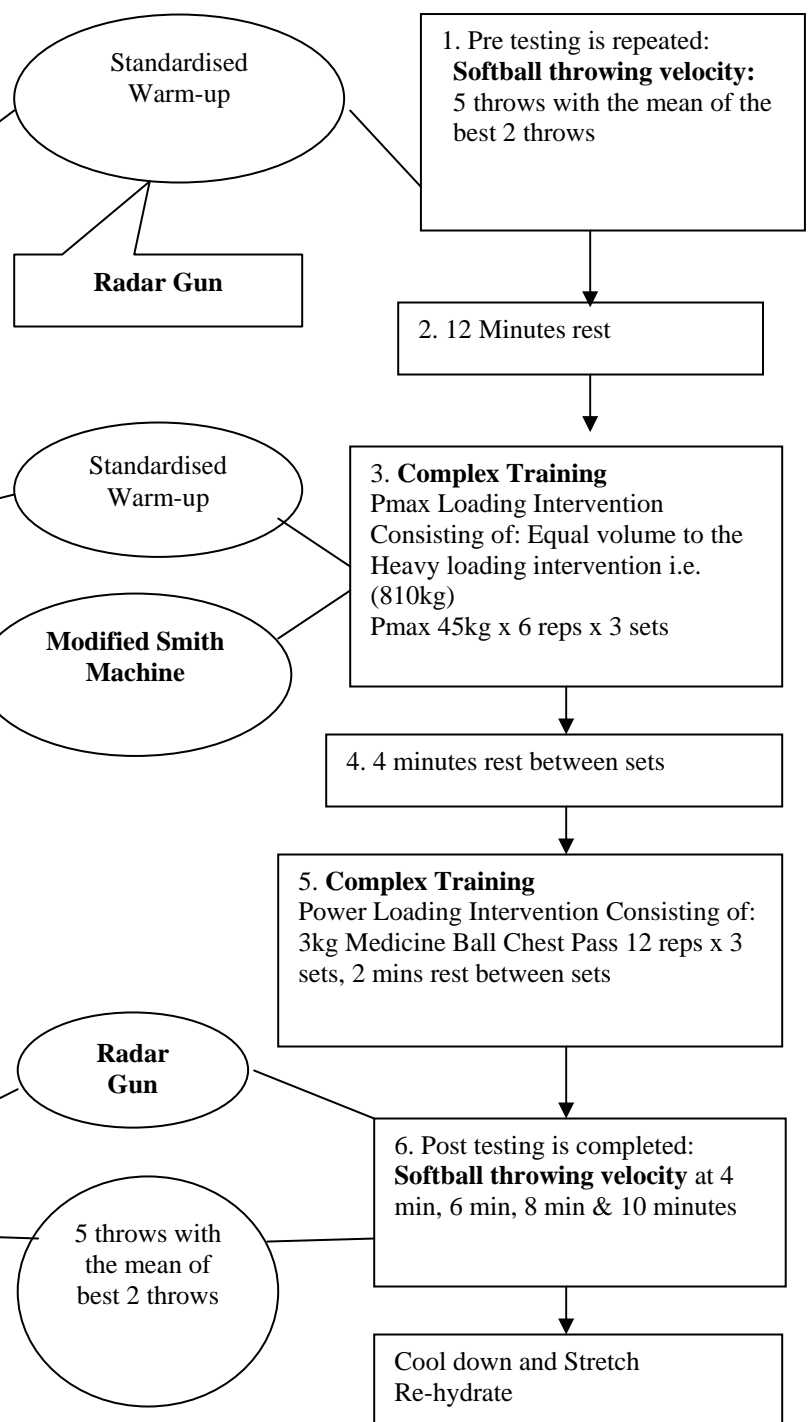
**Day One Treatment**

**Intervention A.**



**Day Two Treatment**

**Intervention B.**



**30 minutes rest between A and B interventions**

**APPENDIX 6: SUBJECT CHARACTERISTICS**

<b>Subject</b>	<b>Age (yr)</b>	<b>Height (cm)</b>	<b>Weight (kg)</b>	<b>1-RM (kg)</b>	<b>Pmax (kg)</b>	<b>Pmax (% 1-RM)</b>
1	31	174.2	75	80	42.1	52.6
2	23	172.5	98	95	55.1	58
3	34	190	111.6	100	61.7	61.7
4	25	172	69.2	80	36.4	45.5
5	29	180.5	100.4	115	60.6	52.7
6	26	179.8	77	120	54.8	45.7
7	32	183.5	93.2	120	53.8	44.8
8	28	174.8	85	120	57.3	47.8
<b>Mean</b>	28.5	178.4	88.7	103.8	52.7	51.1
<b>SD</b>	3.7	6.2	14.6	17.5	8.9	6.3

## APPENDIX 7: INDIVIDUAL SUBJECT REBOUND BENCH PRESS THROW DATA

Athlete 1.	Velocity Max m/s	Velocity Mean m/s	Force Max (N)	Force Mean (N)	Power Max (W)	Power Mean (W)	Work (N.m)	Impulse (N.s)
20kg	1.97	1.26	375	213	542	253	189	149
30kg	1.71	0.95	543	293	641	281	231	240
40kg	1.42	0.84	634	392	681	330	279	329
50kg	1.17	0.72	748	489	649	355	299	411
60kg	0.89	0.57	810	588	588	335	331	579
70kg	0.59	0.35	875	686	438	240	357	1015
80kg	0.57	0.17	919	784	483	135	387	2238

Athlete 2.	Velocity Max m/s	Velocity Mean m/s	Force Max (N)	Force Mean (N)	Power Max (W)	Power Mean (W)	Work (N.m)	Impulse (N.s)
20kg	2	1.06	332	196	530	209	188	176
30kg	1.76	1.01	596	295	628	299	238	233
40kg	1.54	0.9	695	392	772	351	265	294
50kg	1.32	0.79	645	392	593	310	244	307
60kg	1.12	0.7	895	589	770	410	326	465
70kg	0.93	0.62	1093	685	698	426	374	599
80kg	0.89	0.54	1157	785	823	423	425	785

Athlete 3.	Velocity Max m/s	Velocity Mean m/s	Force Max (N)	Force Mean (N)	Power Max (W)	Power Mean (W)	Work (N.m)	Impulse (N.s)
20kg	2	1.1	415	196	520	216	183	165
30kg	1.75	1.03	607	293	651	303	232	224
40kg	1.51	0.91	720	391	700	357	278	303
50kg	1.32	0.78	837	491	771	383	299	380
60kg	1.14	0.67	913	587	768	394	317	470
70kg								
80kg								

Athlete 4.	Velocity Max m/s	Velocity Mean m/s	Force Max (N)	Force Mean (N)	Power Max (W)	Power Mean (W)	Work (N.m)	Impulse (N.s)
20kg	1.63	0.89	314	196	398	174	158	177
30kg	1.35	0.85	658	293	477	249	196	230
40kg	1.08	0.69	653	391	490	270	215	311
50kg	0.8	0.57	884	491	427	278	243	427
60kg	0.05	0.02	640	588				
70kg	0.03	0.01	729	687				
80kg	0.1	0.03	882	785				

<b>Athlete</b> <b>5.</b>	<b>Velocity</b> <b>Max m/s</b>	<b>Velocity</b> <b>Mean m/s</b>	<b>Force</b> <b>Max (N)</b>	<b>Force</b> <b>Mean (N)</b>	<b>Power</b> <b>Max (W)</b>	<b>Power</b> <b>Mean (W)</b>	<b>Work</b> <b>(N.m)</b>	<b>Impulse</b> <b>(N.s)</b>
<b>20kg</b>	2.25	1.59	481	235	664	334	213	133
<b>30kg</b>	2.03	1.17	681	294	825	344	266	226
<b>40kg</b>	1.72	1.03	828	392	850	405	292	281
<b>50kg</b>	1.51	0.92	953	490	917	452	318	343
<b>60kg</b>	1.3	0.81	1029	586	907	474	347	428
<b>70kg</b>	1.13	0.7	1136	685	898	479	412	586
<b>80kg</b>	0.96	0.58	1154	782	881	453	428	741

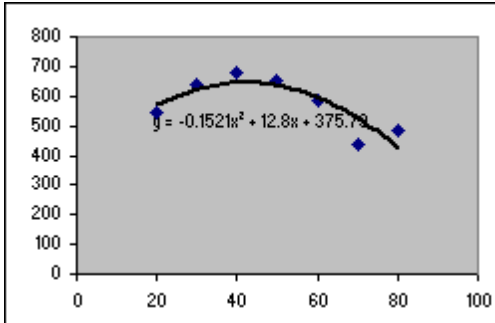
<b>Athlete</b> <b>6.</b>	<b>Velocity</b> <b>Max m/s</b>	<b>Velocity</b> <b>Mean m/s</b>	<b>Force</b> <b>Max (N)</b>	<b>Force</b> <b>Mean (N)</b>	<b>Power</b> <b>Max (W)</b>	<b>Power</b> <b>Mean (W)</b>	<b>Work</b> <b>(N.m)</b>	<b>Impulse</b> <b>(N.s)</b>
<b>20kg</b>	2.22	1.54	447	228	651	319	217	140
<b>30kg</b>	2.07	1.19	666	293	838	350	280	235
<b>40kg</b>	1.79	1.09	863	392	886	427	328	300
<b>50kg</b>	1.51	0.92	956	490	879	453	335	360
<b>60kg</b>	1.27	0.82	1088	587	854	482	368	446
<b>70kg</b>	1.05	0.71	1244	686	837	489	398	556
<b>80kg</b>	0.92	0.57	1156	783	813	447	419	732

<b>Athlete</b> <b>7.</b>	<b>Velocity</b> <b>Max m/s</b>	<b>Velocity</b> <b>Mean m/s</b>	<b>Force</b> <b>Max (N)</b>	<b>Force</b> <b>Mean (N)</b>	<b>Power</b> <b>Max (W)</b>	<b>Power</b> <b>Mean (W)</b>	<b>Work</b> <b>(N.m)</b>	<b>Impulse</b> <b>(N.s)</b>
<b>20kg</b>	2.29	1.57	474	238	713	337	219	138
<b>30kg</b>	2.05	1.31	611	310	855	390	293	222
<b>40kg</b>	1.75	1.03	701	391	884	403	305	296
<b>50kg</b>	1.5	0.92	994	488	928	452	348	375
<b>60kg</b>	1.26	0.77	938	586	844	451	355	460
<b>70kg</b>	1.1	0.67	962	684	874	457	366	547
<b>80kg</b>	0.92	0.53	1034	782	818	415	407	766

<b>Athlete</b> <b>8.</b>	<b>Velocity</b> <b>Max m/s</b>	<b>Velocity</b> <b>Mean m/s</b>	<b>Force</b> <b>Max (N)</b>	<b>Force</b> <b>Mean (N)</b>	<b>Power</b> <b>Max (W)</b>	<b>Power</b> <b>Mean (W)</b>	<b>Work</b> <b>(N.m)</b>	<b>Impulse</b> <b>(N.s)</b>
<b>20kg</b>	2.08	1.12	489	196	578	220	179	159
<b>30kg</b>	1.82	1.02	661	294	704	301	213	207
<b>40kg</b>	1.76	0.99	834	393	985	390	268	267
<b>50kg</b>	1.48	0.87	856	489	890	426	398	340
<b>60kg</b>	1.35	0.83	1044	587	915	488	351	420
<b>70kg</b>	1.13	0.7	1083	686	882	482	353	501
<b>80kg</b>	0.91	0.59	1105	783	838	460	393	666

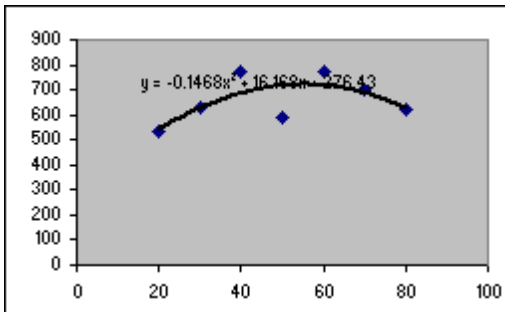
## APPENDIX 8: INDIVIDUAL SUBJECT PMAX QUADRATIC POLYNOMIAL

Subject 1.



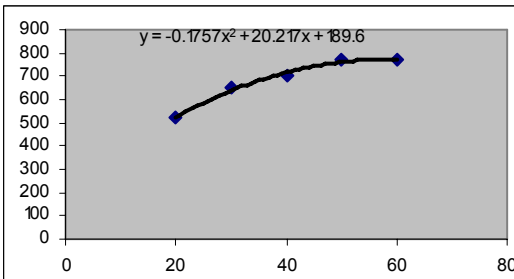
Maximum  
occurs at value is  
**42.1**    **645.0**

Subject 2.



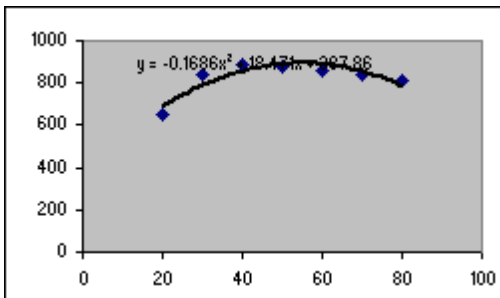
Maximum  
occurs at value is  
**55.1**    **721.6**

Subject 3.



Maximum  
occurs at value is  
**61.7**    **786.5**

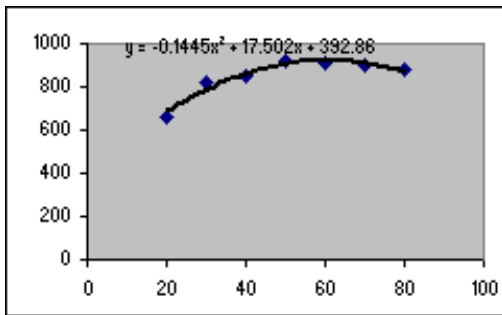
Subject 4.



Maximum  
Occurs at value is  
**36.4**    **493.1**

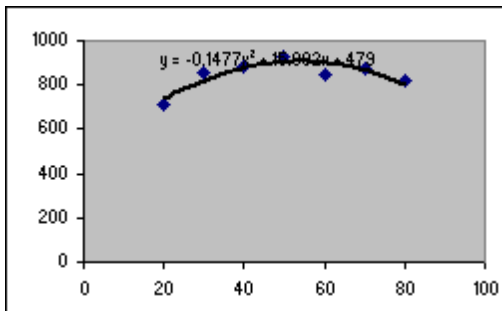


Subject 5.



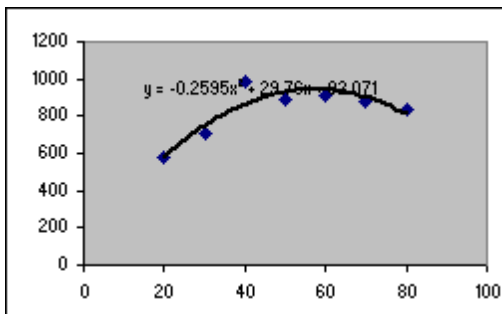
Maximum  
occurs at value is  
**60.6** 645.0

Subject 6.



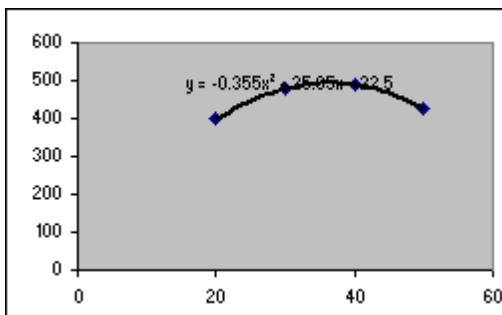
Maximum  
occurs at value is  
**54.8** 893.9

Subject 7.



Maximum  
occurs at value is  
**53.8** 906.4

Subject 8.



Maximum  
occurs at value is  
**57.3** 425

## APPENDIX 9: INDIVIDUAL SUBJECT SOFTBALL THROWING DATA

### Pre-test

Subjects						Mean of Best 2 Throws km·h <sup>-1</sup>	m·s <sup>-1</sup>
1	83	87	86	85	86	86.5	<b>24.02</b>
2	90	91	95	100	101	100.5	<b>27.91</b>
3	93	97	98	101	101	101	<b>28.05</b>
4	94	97	97	100	102	101.5	<b>28.19</b>
5	100	103	103	101	103	103	<b>28.61</b>
6	103	106	106	111	113	112.5	<b>31.25</b>
7	104	105	110	109	109	109.5	<b>30.41</b>
8	95	95	97	104	102	103	<b>28.61</b>

### Pre-treatment 1.

Subjects						Mean of Best 2 Throws km·h <sup>-1</sup>	m·s <sup>-1</sup>
1	80	74	84	80	84	84	<b>23.34</b>
2	93	94	94	98	98	98	<b>27.23</b>
3	98	98	102	103	103	103	<b>28.61</b>
4	96	98	98	99	100	99.5	<b>27.64</b>
5	101	103	103	103	103	103	<b>28.61</b>
6	107	110	109	113	113	113	<b>31.38</b>
7	106	108	108	110	110	110	<b>30.55</b>
8	97	104	100	105	103	104	<b>28.89</b>

### Pre-treatment 2

Subjects						Mean of Best 2 Throws km·h <sup>-1</sup>	m·s <sup>-1</sup>
1	83	79	80	83	84	83.5	<b>23.19</b>
2	84	90	95	98	95	96.5	<b>26.80</b>
3	101	101	104	103	104	104	<b>28.89</b>
4	91	93	97	99	101	100	<b>27.78</b>
5	101	101	103	103	105	104	<b>28.89</b>
6	104	106	107	107	111	109	<b>30.28</b>
7	110	110	110	110	112	111	<b>30.84</b>
8	97	95	100	98	102	101.5	<b>28.19</b>

## APPENDIX 10: INDIVIDUAL SUBJECT THROWING VELOCITY PRE AND POST-TREATMENT

Subjects	Pre-treatment	Heavy-load			
		4 min	6 min	8 min	10 min
1	84	84	85	85	89
	84	84	86	84	88
2	98	95	94	95	98
	98	90	94	95	100
3	99	100	105	107	108
	101	103	107	108	108
4	103	109	109	112	111
	103	109	109	112	111
5	103	103	102	104	109
	105	100	103	106	107
6	104	116	117	119.6*	121.3*
	108	117	117	119.6*	121.3*
7	110	111	110	112	109
	112	111	112	111	109
8	100	97	101	102	106
	102	101	100	102	105
<b>Mean</b>	101	102	103	105	106
<b>SD</b>	7.7	11.4	10.8	11.8	10.5

\* Predicted Throwing velocity: see Appendix 11

Subjects	Pre-treatment	Pmax			
		4 min	6 min	8 min	10 min
1	83	81	83	84	86
	84	83	83	82	87
2	98	88	94	100	101
	95	91	94	100	102
3	99	103	105	107	110
	101	102	106	107	110
4	104	111	110	108	110
	104	111	110	108	110
5	103	103	103	107	110
	103	102	103	107	109
6	113	110	115	115	117
	113	110	115	115	117
7	110	111	114	115	115
	110	113	114	116	115
8	104	95	97	98	106
	105	98	97	99	105
<b>Mean</b>	102	101	103	104	107
<b>SD</b>	8.8	11.2	11.7	11.7	10.6

## APPENDIX 11: INDIVIDUAL SUBJECT THROWING VELOCITY CHANGE SCORES

The following table displays individual subject change scores between the heavy load and Pmax treatments. The table specifically relates to discussion regarding the observed individual response of subjects to the weight training treatments.

**Table 6:** Individual throwing velocity change scores (%) between heavy-load and Pmax treatment.

Subject Number	Heavy-load			Pmax		
	HL <sub>-ve</sub>	HL =	HL <sub>+ve</sub>	Pm <sub>-ve</sub>	Pm =	Pm <sub>+ve</sub>
1		1.6			0.1	
2	- 2.9				-0.3	
3			7.3			5.8
4			5.8			6.3
5		0.3				2.5
6			12.6		1.3	
7	- 0.4					4.1
8		0.8		-5.1		
<b>Mean</b>	<b>- 2.9</b>	<b>0.57</b>	<b>8.56</b>	<b>- 1.75</b>	<b>0.36</b>	<b>4</b>
<b>SD</b>	<b>nil</b>	<b>0.84</b>	<b>3.6</b>	<b>2.9</b>	<b>0.83</b>	<b>2.1</b>
<b>Group %</b>	<b>12.5 %</b>	<b>50 %</b>	<b>37.5 %</b>	<b>12.5 %</b>	<b>37.5%</b>	<b>50 %</b>

Negative change scores =  $\geq - 2.00$ ; Minimal change scores = - 2.00 to + 2.00;  
Positive change scores =  $\geq + 2.00$

**Table 7:** Individual throwing velocity change scores km.h<sup>-1</sup> for heavy-load and Pmax treatment for the 6 minutes post intervention periods.

Subject Number	Heavy-load			Pmax		
	HL <sub>-ve</sub>	HL =	HL <sub>+ve</sub>	Pm <sub>-ve</sub>	Pm =	Pm <sub>+ve</sub>
1			4.4			7.1
2			6.5			5.5
3			2.4			2.8
4			6.0			8.6
5			6.3			4.8
6			4.3			13.1
7	- 1.5				-1.4	
8			6.2			6.8
<b>Mean</b>	<b>nil</b>	<b>- 1.5</b>	<b>4.98</b>	<b>nil</b>	<b>- 1.4</b>	<b>6.96</b>
<b>SD</b>	<b>nil</b>	<b>nil</b>	<b>1.58</b>	<b>nil</b>	<b>nil</b>	<b>3.59</b>
<b>Group %</b>	<b>0%</b>	<b>12.5%</b>	<b>87.5 %</b>	<b>25 %</b>	<b>25 %</b>	<b>87.5 %</b>

Negative change scores =  $\geq - 2.00$ ; Minimal change scores = - 2.00 to + 2.00;  
Positive change scores =  $\geq + 2.00$

**Table 8:** Individual throwing velocity ( $\text{km}\cdot\text{h}^{-1}$ ) mean change scores for Heavy-load and Pmax treatments using pre-tests.

Subject	Pre-Test	Post-Test	Heavy-load
1	84.0	85.6	1.6
2	98.0	95.1	-2.9
3	103.0	110.3	7.3
4	100.0	105.8	5.8
5	104.0	104.3	0.3
6	106.0	118.6	12.6
7	111.0	110.6	-0.4
8	101.0	101.8	0.8
			Pmax
1	83.5	83.6	0.1
2	96.5	96.2	-0.3
3	104.0	109.8	5.8
4	100.0	106.3	6.3
5	103.0	105.5	2.5
6	113.0	114.3	1.3
7	110.0	114.1	4.1
8	104.5	99.4	-5.1
<b>Mean</b>	101.34		2.47
<b>SD</b>	8.2		4.33

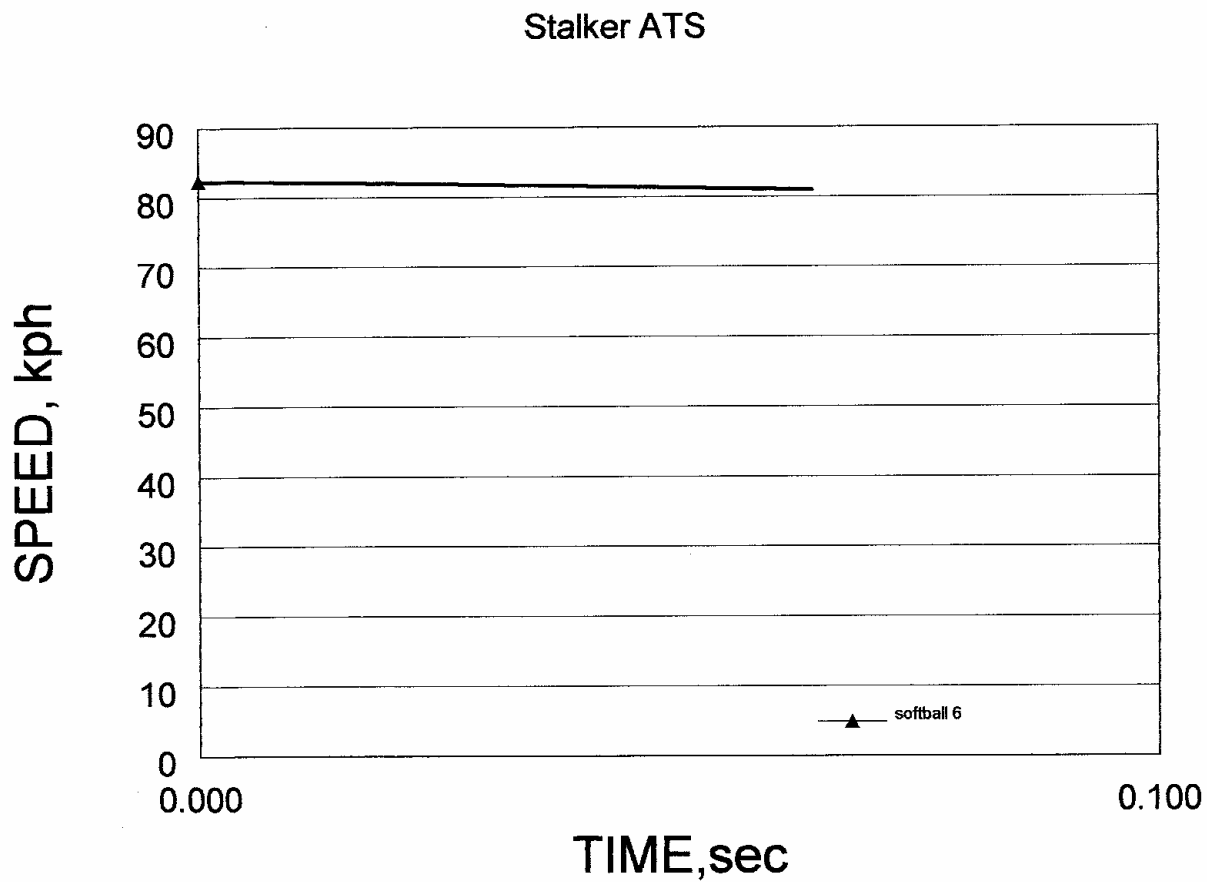
Individual differences overall between pre-testing throwing velocity and post treatments can be found in Table 8. The mean for the pre-test was  $101.34 \pm 8.2 \text{ km}\cdot\text{h}^{-1}$  and the typical variation from subject to subject in the pre-test derived via log transformation was 8.9%. The overall change in the mean for both treatments showed an increase of  $2.47 \pm 4.33 \text{ km}\cdot\text{h}^{-1}$

**Table 9:** Individual throwing velocity percent (%) change scores for Heavy-load and Pmax treatments between 4 and 10 min in the post tests.

<b>Subject</b>	<b>Heavy-load</b>	<b>Pmax</b>
1	4.4	7.1
2	6.5	5.5
3	2.4	2.8
4	6.0	8.6
5	6.3	4.8
6	4.3*	13.1
7	-1.5	-1.4
8	6.2	6.8
<b>Mean</b>	4.3	5.9
<b>SD</b>	2.7	4.2

Subject number 6 results for the heavy-load treatment are shown as the mean for the average change of the group because he failed to complete the post-testing after 6 minutes due to arm fatigue. He had a large change score for the Pmax and was on target to repeat the performance for the heavy-load treatment. The results from Table 9 show therefore a mean change of 4.3% when it would have in fact been higher and possibly similar to the Pmax hence the variation between the two means. The SD for the heavy-load treatment would have been wider range as well.

## APPENDIX 12: STALKER ATS RADAR GUN RECORDING



Stalker ATS Statistics

	Peak Speed	0-30 mph	0-60 mph
Trial	mph	sec	sec
softball 6	81.79		