FORCE AND POWER DEVELOPMENT IN FREE WEIGHT RESISTANCE TRANING VS. BAND RESISTANCE TRAINING

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Abstract

Force and velocity determine the power output that athletes can produce. This study examined the differences in force production and power output gains during squatting, based on training with different modes of resistance.

Twenty-one University of Detroit Mercy athletes participated in a five week training program and were randomly assigned to either a free weight group (FWR) or a band resistance group (VR). Pre- and post-testing of force production, power output and velocity during the squat were conducted in each group using a band resistance test and a free weight resistance test. All participants tested with both resistances as to eliminate familiarity of resistance mode.

Results of the band testing found no significant difference in power output, force production or velocity for either group (FWR or VR) ($p > 0.05$). The band testing did however find the VR group showed a trend of making more gains in all three categories as compared to the FWR group. Results of the free weight testing found that force production increased by an average of 45.64 ± 38.16 N ($p < 0.05$) in FWR group and 70.46 ± 59.28 N ($p < 0.05$) in the VR group. Power output significantly increased by an average of 247.90 ± 217.91 W ($p< 0.05$) in the FWR group and 184.00 ± 216.57 W ($p < 0.05$) in the VR group. The change in velocity for the two groups showed an average increase in the FWR group of 0.17 ± 0.13 m/s ($p < 0.05$) and in the VR group of 0.17 ± 0.13 m/s ($p < 0.05$).

One significant finding came from this study. It found that using both bands and free weights separately as resistance will produce similar chronic gains in force production and power output after a five week resistance training program. This study also found a trend that using variable resistance during squatting can allow for greater gains in the velocity of the concentric portion of the squat, which aids in greater gains in power output.

CHAPTER 1: INTRODUCTION

Strength and conditioning professionals are continually working to improve upon current training practices that will translate into improved performance on the court or field. Proper progression of exercise and the appropriate amount of stimuli can aid in the improvement of speed, quickness, and power (Fleck, 2004). The use of variable resistance, specifically resistance bands, has gained popularity for improving force production and power output. Current research has examined the use of variable resistance to augment traditional constant resistance training modalities (Page & Ellenbecker, 2011). However, it is unclear if variable resistance training can be used as a separate mode of resistance training to supplement phases of the periodization process. Gaining a better understanding of the physiological effects of this type of training on the body is an important tool for strength and conditioning coaches in order to design more effective programs and reduce injury.

This study examined muscle force production and power output following two types of resistance training, variable resistance, band (VR) and constant resistance, free weight (FWR) during the squat. Determining which mode of resistance training produces the most force and power at the greatest velocity during squatting could allow for the development of more effective training programs.

Problem Statement

The purpose of this study was to determine differences in force production gains, power output gains, and velocity increases following a five week band resistant training program and a five week free weight resistant training program.

Research Hypothesis

The research hypothesis of this study was that the band group would make significantly greater gains than the free weight group in force production, power output, and velocity after a five-week training program.

Null Hypothesis

The null hypothesis for this study was that both the band and free weight group would make similar gains in force production, power output, and velocity after a five-week training program.

Operational Definitions

Chronic Adaptations- Physiological changes that occur after a prolonged training program such as changes in force production, power output, or velocity after the five week training program.

Force Production- The ability of a muscle to generate force is determined by neural control, muscle cross-sectional area, muscle fiber arrangement, muscle length, joint angle, joint angular velocity, muscle contraction velocity, and body size (Stauber, 1989).

Power Output- Moving a resistance as quickly as possible. In this study, this was seen when the force production was multiplied by the velocity at which this force was produced.

Variable Resistance- Performing strength training exercises where the amount of resistance or tension changes through the range of motion (Page & Ellenbecker, 2011). In this study, variable resistance was seen in the form of elastic bands. Bands were used for training during all exercises and to test the progress of the training program during the squat.

Constant Resistance- Where the resistance or amount of tension does not change throughout the range of motion, as during free-weight exercises. In this study, constant resistance was seen in the form of free weights. Free weights were used for training during all exercises and to test the progress of the training program during the squat.

Limitations

One limitation of this study was the low sample size. This was due to some of the participants not completely fulfilling the attendance requirements set by this study. Because of these requirements, the number of participants went from twenty-one to fourteen. Another limitation was the early morning scheduled training time, which may have affected attendance and adherence to the program. This limitation was due to the fencing teams scheduled training time. This study was conducted at a University, so training times were scheduled around practice time and class schedules. A final limitation was that the participants could not be monitored at all times to ensure that their training stimulus was only coming from this study's program. Because of this, some participants could have trained outside of the study and affected the results of the study.

Assumptions

The most important assumption that was made during this study was that the participants would exert a maximal effort during the testing periods and throughout the training program. Another assumption was that the participants were refraining from doing any other outside resistance training. If participants were resistance training outside of the program, then the results could have been skewed. The last assumption for this study was that the trainer would coach each group to maximal effort regardless of the resistance training modality.

Delimitations

This study was delimited to the University of Detroit Mercy male and female fencing teams. Participants who missed more than one training session in any one week of the five weeks or missed one training session in more than two weeks, were excluded from the study. Generalizations could not be made to other populations based on the findings of this study due to the specific population of fencing athletes that were be used for this studies data collection.

Significance of the Study

The present study will attempt to determine if force production, power output, and velocity gains can be made while using band resistance and free weight resistance separately during training programs. Attaching bands or chains to barbells allows for a variable resistance thereby increasing power output gains through the ability to produce more force and velocity

during the concentric contractions of many lifts (McCarthy, Wood, Bolding, Roy & Hunter, 2012). There is little published information that separates these two modes of resistance and explains why these gains are made when they are combined. This study is significant because it examines each mode of resistance separately.

This is significant to the field of strength and conditioning because when on the competitive field, there are many instances where athletes need to move as fast as possible while generating as much force as possible. This can be seen when a lineman fires off the ball to block an opponent, a baseball player hits a baseball, a volleyball player attacks a spike or a cheerleader does a back handspring. Many movements in athletics are more affective when more power can be applied to that movement. This principal is trainable in the weight room. Training power through maximizing force production and velocity of the movement is not a new concept, however the idea of using bands for variable resistance to train is still relatively new and limited research has been conducted.

Information gained during this study, could determine if a band-resisted training program for in-season athletes could help maintain previously gained force production and power outputs. It could also provide a way to increase force and power without putting excess amounts of strain on the body. Therefore, using bands for resistance could potentially benefit athletes on two levels, injury prevention and performance enhancement.

CHAPTER 2: REVIEW OF LITERATURE

Variable Resistance Training vs. Constant Resistance Training

Training to develop the ability to recruit more muscle fibers is one of the basic principles behind resistance training. Power output increases when muscle fibers are recruited to move heavy resistances with as much velocity as possible. This present study is examining how to generate greater power outputs by using different types of resistance to produce ideal levels of force production at ideal velocities. To increase the velocity of the movements during exercise, research is examining the effects of ballistic movements over static movements and optimal intensity recommendations during resistance training (García, Requena, Villarreal, Cronin, 2011) (Zaras et al., 2013).

Force is produced when individuals push or pull on objects. When force is performed at a maximal effort, additional muscle fibers are recruited from the available muscle pool. Fatigue is a good indicator of muscle fiber recruitment, and it could be an indication of how forcefully a person is contracting a muscle (Hansen, Kvornign, Kagaer & Sjogaard, 2001). A study by Walker et. al (2013) used fatigue as a measure of how much force certain modes of resistance could produce (Walker et al., 2013). It discussed how using variable resistance devices such as bands, where the external resistance changes in line with the force-angle relationship, has been shown to cause greater acute neuromuscular fatigue and larger serum hormone responses. This in turn can lead to greater muscle adaptations (Walker et al., 2013). This would suggest that variable resistance training could produce greater muscle adaptations during long-term resistance training. The Walker study consisted of three groups, a control which did no resistance training, a constant resistance group, and a variable resistance group. Pre- and post-testing was performed by the participants to determine changes caused by the training. The testing consisted of a bilateral leg press one repetition maximum test to determine strength, a repetition to failure test using 75% 1RM to determine strength-endurance, and measured lower limb lean mass and vastus lateralis cross-sectional area. After a twenty-week training stimulus, only the variable resistance training group improved the total number of repetitions (41.0 ± 46) and volume load (75% of 1 RM) (52.0 ± 37) during the repetition to failure test ($P < 0.05$). This meant that only the variable resistance training group improved in both overall muscle strength and muscle strength-endurance (Walker et al., 2013). These findings imply that band resistance training would be more beneficial for improving force production than free weight resistance training.

The Walker et al. (2013) study also looked at acute loading-induced responses. These were assessed by measuring concentric and isometric force, serum hormone concentrations and phosphorylation of intramuscular signaling proteins before and after training sessions. Greater acute decreases in force, and greater increases in serum testosterone, cortisol concentration, and ERK 1/2 phosphorylation were observed following variable resistance loading. Increases in these numbers mean that greater training-induced improvements of avoiding fatigue occurred in the variable resistance training group. This could be due to greater acute fatigue and physiological responses during variable versus constant resistance loadings (Walker et al., 2013).

A study by Aboodarda, George, Mokhtar, and Thompson (2011) compared the effects of repeated near maximal contractions by elastic resistance training to free weight resistance

training on indicators of muscle damage including: maximal strength decrement, rate of muscle soreness, concentration of plasma creatine kinase and increased high muscle signal on T2 weighted images using magnetic resonance imaging (Aboodarda, George, Mokhtar, & Thompson, 2011). Nine healthy male subjects completed the two modalities of exercise in a counterbalance cross-over study design. This design called for three weeks of resistance training using one of the modalities, a three-week recovery period before beginning the next training cycle, and then three weeks of resistance training with the other mode of resistance. The average of applied forces demonstrated significantly higher values. The free weight resistance group showed higher average applied forces compared to elastic resistance (362.0 ± 34.2 N and 266.7 ± 44.6 N respectively, $p < 0.05$) throughout the 5 sets of dynamic exercise. Despite this difference, the indicators of muscle damage exhibited a very similar response across both modes of training. Plasma CK increased significantly following both modes of training with the peak value occurring on day 3 ($p < 0.05$), from 147.0 ± 26.0 IU/L to 705.0 ± 185.0 IU/L in the free weight group, and 167.0 ± 54.0 IU/L to 595.0 ± 147.0 IU/L in the elastic group (Aboodarda, George, Mokhtar, & Thompson, 2011). These findings indicated that regardless of the resistance mode being used, similar damage will be seen in the activated muscles.

The Importance of Velocity in the Power Output Equation

Velocity of the movement is critical in increasing power output gains. Fukumoto et al (2013), examined how the velocity of movement can lead to greater gains in power output. It consisted of randomly assigning forty-six women to either a high-velocity or low-velocity eight-week rehabilitation program. The high-velocity group was instructed to use a band and perform the concentric part of their rehabilitation exercises as rapidly as possible while the low-velocity group was instructed to take three seconds to perform the concentric motion. The results of this study found that high-velocity training increased force production, power output, and overall physical performance more than low-velocity training. Greater significant improvements ($P < 0.05$) in the time for performing the Timed Up and Go test (mean changes: high-velocity group -0.46 ± .027 seconds, low-velocity group -0.23 ± 0.39 seconds) and echo intensity of the gluteus maximus (mean changes: high-velocity group -6.8 ± 9.0, low-velocity group -1.0 ± 7.5) were seen in the high-velocity group than in the low-velocity group (Fukumoto et al., 2013). The Timed up and Go test consisted of timing how long it took the participants to stand up from a chair, walk three meters, turn around, and return to sitting in the chair. Echo intensity was used to evaluate skeletal muscle power through muscle quality as determined by ultra sound images (Cadore et al., 2012). Fukumoto's study suggests that training at greater velocities can increase the ability to generate more power output when using a mode of resistance that allows for greater velocities during the concentric portion of the exercise. Velocity is one of the two factors that can acutely increase power output. By continuously producing a maximal power output during every repetition, muscles will adapt and begin to produce improved force, velocity and power outputs (Jones, Bishop, Hunter & Fleisig, 2001). When this is done on a consistent basis, greater gains in all of these variables can be achieved in the long term.

Incorporating ballistic movements into different exercises is one way to ensure that the velocity of the movement is greater than it would be during none-ballistic exercise. García, Requena, Villarreal and Cronin (2011) used traditional and ballistic squats to determine if there

is a relationship between vertical jumping and maximal sprinting at different distances (García, Requena, Villarreal & Cronin, 2011). The study found that traditional squat strength is not correlated to vertical jump performance however, relative 1RM was positively correlated ($p < 0.01$) in all power outputs measured during ballistic squat testing ($r = 0.53 - 0.90$), underlying the importance of strength and power to explosive movements such as sprinting (García, Requena, Villarreal & Cronin, 2011). The study suggests that traditional squats that are not done with speed may not be as beneficial to power production as performing ballistic squats. This suggests that to produce the most gains in power, the squat should be performed with a resistance that allows for greater force productions based on optimal acceleration-resistance. The use of resistance bands could facilitate the development of more power output. When there is a greater load on a person during the amortization phase of the squatting movement, it is less likely that the concentric portion of the movement will begin with speed. This would be the case when using free weights for resistance, and may be detrimental to the ability to produce force and power. When the resistance during this same motion is provided by bands attached to the floor, there is less resistance while transitioning through the amortization phase and a greater ability to accelerate more quickly while coming out of the bottom of the squat. Due to the increase in tension of the bands as they lengthen, variable resistance allows for an increase in resistance as the squatter ascends through the squat. This means the individual will be able to accelerate more quickly during the concentric motion and be able to move greater resistances at greater velocities, which will result in greater force production and power output.

Zaras et al. (2013), investigated the effects of a six week strength training program comparing static strength and ballistic power movements (Zaras et al., 2013). Ballistic training was utilized because of its continued acceleration throughout the range of motion of the exercises (Zaras et al., 2013). The idea was that emphasizing the importance of velocity during any movement will equate to greater power outcomes. The results of the study showed that muscular strength significantly ($P < 0.05$) improved more for the traditional movement group, assessed by 1 RM leg press, while power output, assessed by the vertical jump test, improved more for the ballistic movement group. In the leg press, the static group improved by $43.1 \pm 3.9\%$ while the ballistic group improved by $20.9 \pm 3.2\%$. In the vertical jump test, the ballistic group improved by $8.5 \pm 2.4\%$, and did not significantly increase in the static group (Zaras et al., 2013). This study showed that performing resistance training with greater velocity will produce greater gains in power output, while performing resistance training without making velocity an emphasis will produce greater gains in force production.

By using ultrasonography, Zaras' study also revealed that strength training induced an increase in muscle thickness of vastus lateralis by 10%, whereas no significant changes were found in the vastus lateralis of the ballistic group. This means that even though both groups made improvements in muscle strength, only the slower, static group made significant gains in hypertrophy.

In weight rooms and training facilities, training with variable resistance can be seen by implementing chains, or in the case of the current study, bands. The limitation of using chains is that the variable resistance is only effective when working against gravity and performing vertical exercises (Page & Ellenbecker, 2011). With bands the variable resistance can also be incorporated into lateral and anterior/posterior movements. Using bands allows for resistance to be used in all three planes of motion (Page & Ellenbecker, 2011). Another benefit of using

bands is the potential for greater velocity to be accomplished during training. Velocity of movement is directly correlated to power output, so using bands to train and allowing for training at optimal speeds is essential to develop those gains in power output.

There is a lack of research available on how variable resistance can be used to produce greater power outputs. Current research has focused on training programs using a combination of both bands and free weights, which may imply that the use of the two separately could have their own specific benefits. Anderson, Sforzo and Sigg (2008), examined whether combined elastic and free weight resistance (CR) provided different strength and power adaptations than free weight resistance (FWR) training alone. Forty-four Cornell University athletes from the men's basketball and wrestling teams and women's basketball and hockey teams performed a 1RM back squat and bench press to measure strength and power output before and after the seven week training cycle. To determine if there was any difference between training with different modes of resistance, the test groups consisted of a group that trained with free weights only and a group that trained with a combination of bands and free weights. The results of this study showed that training with CR provided significantly ($p < 0.05$) greater gains in strength and power during the back squat and in strength during the bench press as compared to FWR. The data showed that the CR group improved in strength by nearly three times during back squat testing (16.47 ± 5.67 vs. 6.84 ± 4.42 kg increase) and two times during bench press testing (6.68 ± 3.41 vs. 3.34 ± 2.67 kg increase). It also showed the power output in the CR group improved by nearly three times during back squat testing (68.55 ± 84.35 vs. 23.66 ± 40.56 watt increase) (Anderson, Sforzo & Sigg, 2008). The authors suggest that the ability to progressively increase the resistance during the exercise allowed for participants to increase the velocity of the movement during the ascension which allowed for greater gains in power output.

Stretch Shortening Cycle

The stretch shortening cycle (SSC) is a key component of developing power output during a squat. During the SSC, counter-movements are used to load or stretch agonist muscles and tendons resulting in more powerful concentric contractions from those agonists (Bosco, Komi & Ito, 1981). McCarthy, Wood, Bolding, Roy and Hunter (2012), performed a study and claimed that potentiation of concentric force and acceleration only occurs early during the SSC (McCarthy, Wood, Bolding, Roy & Hunter, 2012). Twenty-one male runners performed ballistic leg press throws by pressing the platform of the leg press machine until it lost contact with the participant's feet. Finding SSC measurements during this motion and during the concentric contraction only allowed for the researchers to establish at what point of the motion the most power output was produced. Once these tests were performed, potentiation (strength of the nerve impulse of the muscle) of contractions was calculated by finding the difference between the SSC test and the concentric test. The findings showed eccentric force measured during the last 100 milliseconds of eccentric motion was related to potentiated force during the initial 200 milliseconds of concentric motion ($r = 0.44$, $p < 0.05$) and potentiated mean power across the full concentric ROM ($r = 0.62$, $p < 0.01$) (McCarthy, Wood, Bolding, Roy & Hunter, 2012). This meant that in contrast to power and velocity, potentiation of force and acceleration only occurred early during the concentric phase of a SSC ballistic leg press. In addition to this, the results also showed that late eccentric phase contractions directly lead to the potentiation

generated during the early concentric contraction in the SSC (McCarthy, Wood, Bolding, Roy & Hunter, 2012). This study concluded that the muscle contraction which occurs at the beginning of the concentric phase is the only time that the muscle generates force during this phase. Finding this measurement during a ballistic leg press allowed the study to eliminate gravity while examining how the muscles respond during the action. By doing this, the researchers were able to focus strictly on what occurs during the SSC phases, and eliminate any potentiation that occurred due to stabilizing an external resistance.

Optimal Resistance for Producing the most Power Output

There is still debate on the level of training intensity that will optimize the relationship between force production and velocity to produce the most power output. Different organizations and studies have recommended light, medium, and heavy intensities (Cormie, McGuigan, & Newton, 2011) (NSCA, 2014) (Verkhoshansky & Siff, 2009) (Zink, Perry, Robertson, Roach & Signorile, 2006). Despite these differing recommendations, the idea of moving the resistance with as much velocity as possible remains consistent. When discussing the force-velocity curve, high-velocity areas (power at high velocities against low loads) will produce greater gains in power, while heavier loads will enhance muscular strength in the high-force portion of the curve (power at low velocities against heavy loads) (Appendix A). The load that maximizes power in multi-joint, sports-specific movements varies depending on the type of movement involved.

Cormie, McGuigan, and Newton described the optimal load typically ranging from 0% of a one repetition max (1 RM) squat in the jump squat up to 70-80% of 1 RM measurements in the snatch and clean (Cormie, McGuigan, & Newton, 2011). Optimal loads vary significantly across different exercises because power output is influenced by the nature of the movement involved. Ballistic exercises such as plyometrics allow for high forces to be generated in light load situations due to the continued acceleration throughout the movement (Cormie, McGuigan, & Newton, 2011). When comparing bands and free weights as modes of resistance, an advantage can be seen in power production when using bands as they allow for a quicker acceleration at the beginning of the concentric movement while advantages in force production gains may be seen when using free weights as they allow for a heavier stimulus (Zaras et al., 2013).

Based on the guidelines set forth by the National Strength and Conditioning Association (NSCA), the recommended sets, repetitions and intensities for training for maximal power outputs are as follows, three to five sets of two to five repetitions at an intensity of 75-90% of the subject's 1 RM (NSCA, 2014).

Yuri Verkhoshansky, one of the leaders in the field of strength and conditioning, explains that when training to develop power, lifts should be done for 3-5 sets of 1-5 repetitions at an intensity of 70-100% of the individuals 1 RM (Verkhoshansky & Siff, 2009). With regards to making gains in strength, he recommends that lifts should be done for 4-7 sets of 1-5 repetitions at 80-100% of the individuals 1 RM (Verkhoshansky & Siff, 2009). He also states that lifting a heavy weight for low repetitions and high sets will aid in strength gains. This suggests that free weight resistance training will produce more gains in force production.

A different idea about what level of intensity is optimal for producing the most gains in power output was seen in a study which tested twelve experienced male lifters in the back

squat while using various percentages of their 1 RM. The results of this study where not significant ($P > 0.05$), however they did show that 40-50% of the individual's 1 RM is where the most peak power was observed. During this percentage of 1 RM, the participants reached 91 ± 7%- 92 ± 11% of their max power output. The next closest percents were at 30% and 60% of 1 RM being 87 ± 10% and 86 ± 10% of the participants peak power output, respectively (Zink, Perry, Robertson, Roach & Signorile, 2006).

The general consensus of this section was that a greater resistance will aid in producing more force production while a lesser resistance will aid in producing more power output.

CHAPTER 3: METHODS

Research Design

This study used a pre-test/post-test design with an intervention period between the two testing dates to examine the chronic adaptations of FWR and VR training on force production, power output, and velocity. Before beginning the intervention, participants were assigned to either a group that trained for five weeks with resistance being provided by free weights during squatting and squatting related lifts or a group that trained for five weeks with resistance being provided by bands during squatting and squatting related lifts. These groups were established by using a simple random sampling technique, which involved blindly placing an equal number of males and females in each group. IRB approval was obtained from the University of Detroit Mercy and Morehead State University for this study.

Subjects

A sample of twenty-one members of the University of Detroit Mercy's male and female fencing teams (n=21) was chosen to participate in the study. The subjects consisted of members from both the male and female fencing teams. The decision to use the fencing team was based on the need to use a team that had similar resistance training experiences. In this case, none of them had been taught to squat or to squat properly before, so they all had a young training age with regards to that exercise. The athletes involved with this study were all expected to complete a resistance training program through obligations of being a part of the University of Detroit Fencing team. All teams at the University of Detroit Mercy have sport-specific training programs. Based on the size of the teams, the absence of scheduling conflicts, and the young training age, the fencing athletes best fit the training parameters of the study. The training program consisted of having the athlete's resistance train three days a week, with a day or two off between training sessions. If a participant missed more than one training session in any one of the five weeks, or missed a training session in multiple weeks, then that participant's data would not be used.

Before any subject's data was collected, all subjects signed an informed consent form (Appendix B). The informed consent form described the purpose of the study, the selection of the subjects, the protocol that was used, and the risks and benefits involved with allowing this study to use the pre- and post-testing data collected. It also explained that the participant's information would be reported confidentially and presented in aggregate form. Each participant was then briefed on what was expected of them as a participant and how the use of the data would be beneficial to both parties.

Instruments

A PASCO® force plate was used to measure the force during the squat test. Prior to use, the equipment was calibrated based on the manufacturer's recommendations (PASCO Scientific, 1996-2014). The use of this type of force plate is an accepted method for measuring force production during jumping and squatting movements (Samozino, Morin, Hintzy & Belli, 2008).

A PASCO® motion sensor was used to measure the velocity of movement during the squat. The sensor was mounted above the participant as the squat tests were performed. It

calculated velocity by measuring displacement of the participant's head (PASCO Scientific, 1996-2014). By using the velocity of the movement and the force production data, power output was calculated. This number was compared to the data collected during the Keiser squat test and used to establish validity during the two tests.

Rate of Perceived Exertion (RPE) was used to ensure proper intensities were achieved. Due to band resistance causing a variable resistance during the range of motion of a squat, and free weight resistance staying consistent throughout the squat, the use of the Borg (1998) RPE scale was used.

The bands used for this study were made and manufactured by The Web® and were used to create variable resistance during the exercises in the program (Appendix C). This product was used due to the accessibility to the product. They were able to be measured by using a standard weight scale and stretching to the bands to desired distances. This was done to find the distance the bands would need to be stretched to make sure all participants band tested with about 75 pounds of resistance.

Preparation

A two week preparatory period was included as part of the training program. This ensured all the participants understood proper squatting technique and allowed for the participants to accurately follow the rate of perceived exertion (RPE) scale during the squatting exercises. All of the participants were instructed to limit training to the training program provided by the study and team practices. The participants were also instructed by a certified strength and conditioning coach during this study, so proper lifting technique was an emphasis for all lifts during this program.

Procedure/Testing

This study consisted of a pre-test/post-test evaluation, which showed the progress of each participant after the five week intervention. All participants performed two different tests during the pre- and post-testing evaluations, which measured power output and force production. Each participant performed squatting tests with resistance provided by free weights and by bands, separately. The resistances used for the free weight test was 75 pounds and the resistance used for the band resisted test was an estimation of 75 pounds (Appendix D). This estimation was determined based off of the poundage established by the manufacturers of the bands when stretched to six feet and by the height of the participant. Participants over 5'10 performed the test with the bands stretched an extra three inches from ground level and participants under 5'10 performed the test with the bands stretched an extra six inches from ground level (Appendix E). For the free weight test, the resistance was added to a 45 pound barbell until the resistance was 75 pounds. For the band resisted-test, a PVC pipe was used in place of the forty-five pound barbell and the bands were attached to the outside ends of the pipe. The PVC pipe was used in an effort to try to eliminate the effect of using any free weight resistance. The pipe weighed four pounds. When the bands were attached to the pipe and the participant stood tall, the total resistance was around 75 pounds. This was done by adjusting where the band was attached to on the squatting rack. Using the PVC pipe allowed for the same motion to be used during the testing with the two different resistance types and was sturdy enough to support the resistance of the bands without significantly bending the

pipe. Both of these tests consisted of having the participants perform three squats on the PASCO® force plate which measured the force being exerted into the ground during the action. The PASCO® motion sensor was also used during this testing process to measure the velocity of the movement. By knowing the velocity of the ascension and the force being produced, power output could be calculated.

Participants followed NSCA recommendations for squatting during the training and testing of this study. Participants were instructed to begin by standing tall, taking a deep breath of air to fill the abdominal cavity, and then hold that breath while descending into the bottom portion of the motion, which meant having the knees flex as much as possible. During this action, cues included keeping the chest upright, pushing the participant's bodyweight backward, so the knees were above the midsection of the foot and the hips were reaching posteriorly, which would cause the area of base for the participant to be the midfoot to the hindfoot. During the ascending motion of the squat, the participants were instructed to drive upward as quickly as possible while getting into full extension with the knees and hips. The instructions for breathing during this action were to push the air in the abdomen against the abdominal wall for the first half of the ascension and release that abdominal pressure during the second half of the ascension. Cues during this stage included, explode up, keep the weight back, and keep the chest up (NSCA, 2014).

Training Program

Both training programs began each training session with a ten-minute dynamic warm-up that was performed to reduce the likelihood of injury as well as ensure the participant was prepared to perform the workout. This dynamic warm up consisted of variations of lunges, forward and lateral movements, and skipping movements that targeted each major muscle group of the lower body. The only difference in the free weight resistance program and the band resistance program was the mode of resistance used when performing the squats and squat variations at the beginning of each lift. This was done to ensure that any discrepancies in force production or power output gains were attributed to the mode of resistance used during the squats and squat variations. The programs consisted of having the participants perform the ten minute dynamic warm up before proceeding into a forty-five minute full body lift, and ending with a five minute cool down stretching period. The training sessions took place three days a week on Mondays, Wednesdays, and Fridays. The participants followed this training schedule for five weeks. Appendices F and G provide the training program for the FWR group and the VR group, respectively.

Having the participants lift three days per week allowed for at least forty-eight hours of recovery time between lifting sessions. This was done to ensure that the muscles used to perform the squats and squat variations were fully recovered and prepared to produce as much force as possible during the following lifting session (Budgett, 1990). The five-week program coupled with the prescribed intensity, set, and repetition schemes allowed for enough time to show physiological gains in strength, power, and hypertrophy. These prescriptions however were not too invasive to be concerned with over reaching or over training (Budgett, 1990).

Analysis

A dependent t-test was performed on the pre- and post-testing data of force production, power output, and velocity. Alpha was set at 0.05 a priori to establish significance differences in how the band group and the free weight group responded to resistance training with their assigned mode of resistance. Microsoft Excel 2010 was utilized for all statistical analysis.

The equation used to calculate power output during the band and free weight resisted test are as follows,

Power Output (in Watts or kgm^2/sec) = Force (in Newton's (kgm/sec^2) as measured by the force plate) x Velocity (in meters/second) as measured by the motion sensor)

CHAPTER 4: RESULTS

Participants

This study began with twenty-one participants and finished with fourteen. The FWR group finished with six participants (n=6) and the VR group finished with eight participants (n=8). This number decreased from the beginning of the study due to six of the participants not attending enough lifting sessions. These six participants, whose data was excluded from the results of this study, did not meet the attendance guidelines issued to be able to deem the effects of the program to the training stimulus. The seventh participant who did not complete the full training intervention had a pre-existing injury that became worse due to reasons not related to this study, and could not complete the program.

Chronic: Pre- and Post-Intervention Band Test

Comparison of changes in force production, power output, and velocity as determined by pre- and post-band resisted tests are documented in Table 1. Average peak force production and power output were established for each participant by calculating the average of the two greatest peak force productions and power outputs, respectively, during the testing. Velocity was established by finding the average of the two velocities at the previously determined peak power outputs. After analyzing the data, it was found that force production changed by an average of 28.80 ± 70.23 N ($p > 0.05$) in the FWR group and 40.82 ± 67.21 N ($p > 0.05$) in the VR group from pre- to post-testing, however these differences were not significant ($P > 0.05$). The data analysis also showed that power output changed by an average of 89.49 ± 252.90 W ($p > 0.05$) in the FWR group and 111.92 ± 259.24 W ($p > 0.05$) in the VR group, with no significant differences found. The changes in velocity in the FWR group (0.08 ± 0.13 m/s, $p > 0.05$) and the VR group (0.13 ± 0.22 m/s, $p > 0.05$) were not significant.

Chronic: Pre- and Post-Intervention Free Weight Test

Comparison of changes in force production, power output, and velocity as determined by pre- and post-free weight resisted tests are documented in Table 1. Average peak force production and power output were established for each participant by calculating the average of the two greatest peak force productions and power outputs, respectively, during the testing. Velocity was established by finding the average of the two velocities at the previously determined peak power outputs. Force production increased significantly by an average of 45.64 ± 38.16 N ($p < 0.05$) in the free weight group and 70.46 ± 59.28 N ($p < 0.05$) in the band group. Power output increased significantly by an average of 247.90 ± 217.91 W ($p < 0.05$) in the free weight group and 184.00 ± 217.19 W ($p < 0.05$) in the band group. The change in velocity for the two groups showed an average increase in the free weight group of 0.17 ± 0.13 m/s ($p < 0.05$) and in the band group of 0.17 ± 0.14 m/s ($p < 0.05$) , both of which were significant.

Table 1: Chronic Force Production, Power Output and Velocity Increases Based on Resistance Group						
BAND TESTING	**FORCE (Newtons)**		**POWER (Watts)**		**VELOCITY (m/s)**	
	FWR	*VR*	*FWR*	*VR*	*FWR*	*VR*
AVERAGE	28.80	40.82	89.49	111.92	0.08	0.13
STANDARD DEVIATION	70.23	67.21	252.90	259.24	0.12	0.22
FREE WEIGHT TESTING	**FORCE (Newtons)**		**POWER (Watts)**		**VELOCITY (m/s)**	
	FWR	*VR*	*FWR*	*VR*	*FWR*	*VR*
AVERAGE	45.64	70.46	247.90	184.00	0.17	0.17
STANDARD DEVIATION	38.16	59.28	217.91	216.57	0.13	0.14

Table 2 displays the significant findings of the testing data. All of these values are comparing the significance of the change from pre-testing data to post-testing data.

Table 2: Chronic Testing Significance Values						
VARIABLE	**FORCE**		**POWER**		**VELOCITY**	
GROUP	*FWR*	*VR*	*FWR*	*VR*	*FWR*	*VR*
BAND TESTING	0.361	0.130	0.426	0.262	0.157	0.152
FREE WEIGHT TESTING	0.033*	0.012*	0.039*	0.047*	0.027*	0.011*

*Significance value ($p < 0.05$)

Table 3 and Charts 1-3 (Appendix H) display the results of the band testing for each participant while Table 4 and charts 4-6 (Appendix I) display the results of the free weight testing for each individual .

CHAPTER 5: DISCUSSION

Pre- and Post-Intervention Band Test

The VR group showed a trend of making more gains in force production, power output, and velocity than the FWR group. Finding this trend for gains in power output and velocity was not unexpected as the assumption was that variable resistance would allow for the participant to generate greater velocities which would yield greater power outputs during training sessions and cause a similar chronic effect. Finding that this same trend occurred with regards to force production was interesting to find as force production is the ability to exert a force into the floor. Based on the findings of this study participants who trained with VR were able to make adaptations to exert a greater force into the floor during squats than the participants who trained with FWR.

Pre- and Post-Intervention Free Weight Test

The VR group and FWR group significantly increased force production, power output, and velocity, as determined by the free weight test, after the training intervention. When comparing the training groups, the VR group showed greater gains in force production and the FWR group showed greater power output development, while the increases in velocity were approximately equal. These significant findings showed that similar gains in force production and power output can be made when using either mode of resistance. The individuals who made the most gains in power output were those who increased the velocity of the movement the most (Table 4). This means that regardless of the resistance being used, optimizing velocity during the squatting motion will result in greater power outputs. This study confirmed that this can be done by utilizing variable resistance as opposed to constant resistance.

Comparing Pre- and Post-Intervention Testing Modes

Use of the free weight and band test for both groups was an attempt to rule out familiarity of the use of the mode of resistance. The data collection and data analysis showed that familiarity of the mode of resistance used during the intervention had little impact on the testing results. After reviewing the data analysis, all tests performed during the free weight resisted testing showed significant differences while all tests performed during the band resisted testing showed no significant differences. This could be due to the stabilization that needs to occur while controlling a resistance provided by bands. During the testing, participants were noticeably wavering more while standing tall before the dissension of the band resisted test than when standing tall with the free weight resistance. This could imply that more stabilization was needed during the band resisted testing which could have caused the participant to be uncomfortable during this testing. If a participant was uncomfortable or unsure during the band resisted testing, then the commitment to driving up during the squat could be compromised.

Practical Application

These findings are useful in the field of strength and conditioning because they can aid in programming for athletes within specific training macrocycles. Once the in-season period

begins, there is a shift from focusing on physical gains through resistance training to training for that specific sport. Actual sport practices take up more time than time spent on strength and conditioning. What commonly happens during this period is athletes begin to lose the force production and power output gains which were gained before the in-season period. Those who do continue to resistance train at the same level as before, are more susceptible to over-reaching and overtraining and are likely to have decreases in force production and power output. The stressors on the body and central nervous system can be too much for most athletes to handle. This can lead to muscles and ligaments becoming strained and athletes who are more likely to become injured during these times.

The findings of this study along with the information found in the Review of Literature provide evidence that a band resisted training program for in-season athletes could possibly not only facilitate in the maintenance of previously gained force production and power outputs, but do this in a way that puts less strain on the body than free weight resistance. With any exercise, the joints of the body may be put in vulnerable positions during portions of exercise. By using variable resistance, the load can be decreased during these vulnerable stages. Continuous excess tension on a tendon or ligament can lead to injury. If variable resistance is used to decrease this tension, then joints will be less likely to experience overuse injuries. The current study found that using bands for resistance resulted in similar force production and power output gains as training with free weight resistance. Based on these findings and the idea that variable resistance can aid in decreasing the stress put on an athlete's body, this type of training could be beneficial to training in-season athletes.

The findings of the McCarthy study demonstrated why band resistance training could potentially allow for more gains in force production and power output. It concluded that the most power output is generated during the beginning of the concentric phase of a ballistic leg press. During a squat, there is less resistance at the end of the eccentric phase and beginning of the concentric phase when resistance training with bands as opposed to free weights. Band resistance allows the individual to transition more easily between these phases, resulting in greater velocities during that important phase of the lift. While resistance training, muscles would then adapt to this and begin to recruit more muscle fibers during training sessions, which would result in more gains in force production and power output on a chronic level. Another implication of the SSC study was that after the beginning of the concentric contraction the muscles were not generating as much force. When using bands for resistance, this would not be possible. The bands would provide for an increase in resistance during the entire ascension of the motion which would result in a lengthened contraction as opposed to when using free weight for resistance.

Variable resistance also involves accommodating for a continuous resistance and forces individuals to engage the working muscles throughout the entire range of motion of the exercise. Free weight resistance training may allow for the resistance to gain momentum, which could result in times of submaximal muscle contraction. This type of free weight concentric training has its place in developing power in athletes however variable resistance training could accompany this training philosophy to enhance athletic potential. Variable resistance training could be used to develop this power a little differently which could aid in continuing to make power gains and the refraining of plateauing and overtraining.

Another consideration when programming is the stabilization action that occurs during the band resistance training compared to the free weight resistance training. One of the benefits of strength training with free weights is the openness and lack of a controlled environment that occurs while using this mode of resistance training. This allows for stabilizing muscles around joints to be strengthened which aids in injury prevention. Using bands can augment this aspect of joint stabilization which is an effective way to help athletes better prevent injuries.

Limitations

The main limitation of this study was the low sample size. In future studies, it would be advantageous to increase the pool to at least thirty participants per group. This would allow for more data points, which would increase the likelihood of significant findings due to the training effect. The data from this study however suggested there were not enough data points for statistical significance.

Another limitation of this study was the testing modes used to establish chronic adaptations to the training intervention. This study was designed to use both band and free weight resisted tests as pre- and post-testing parameters to address if any familiarity to the type of resistance trained occurred. This did not occur during the present study as the increases and decreases found by the participants from each group appeared to be random for both testing modalities. Future studies should focus on separating testing protocols from the training methods. For example, using a leg press to determine force production and a vertical jump test to determine power output, could help produce outcomes that are more clear.

Another limitation was the small size of the force plate that was used during the testing. The force plate was only sixteen inches across, which was about as wide as the participant's hips. This caused for stances that were narrower than would be recommended for squatting. This type of stance and foot placement has shown to be the best position to produce force and power output. In this study however, the young training age of the participants in conjunction with the familiarity of a wider stance used during the training session, may have made the participants uncomfortable and caused skewed data.

A final limitation was the possibility of participant lack of maximal effort during either the pre-testing or the post-testing. The administrators of the tests encouraged the participants to perform at a maximal effort, but this is not something that can be measured. In this particular study, loss of participants could be an indication that some participants gave varied efforts during the two testing days.

Future Directions

Future studies should include a larger sample size and a way to control pre- and post-testing effort. Controlling these aspects of the study will add to the strength of the validity and reliability of the findings.

Olympic lifting has been shown to produce the most power output gains on the chronic and acute levels as compared to power lifting. Future research could include examining the difference among power lifting with free weight resistance, with band resistance, and with Olympic lifting techniques. Understanding the different physiological effects these three forms

of resistance training cause would benefit strength and conditioning professionals and aid in the periodization programming process.

Conclusion

The purpose of this study was to determine differences in force production and power output gains when using a band resistant training program and a free weight resistant training program. The hypothesis was that the group who trained with band-resisted squats would make greater gains in force production and power output after the intervention training program. One significant finding came from this study. It found that using both bands and free weights separately as resistance will produce similar chronic gains in force production and power output after a five week resistance training program. This study also found a trend that using variable resistance during squatting can allow for greater gains in the velocity of the concentric portion of the squat, which aids in greater gains in power output.

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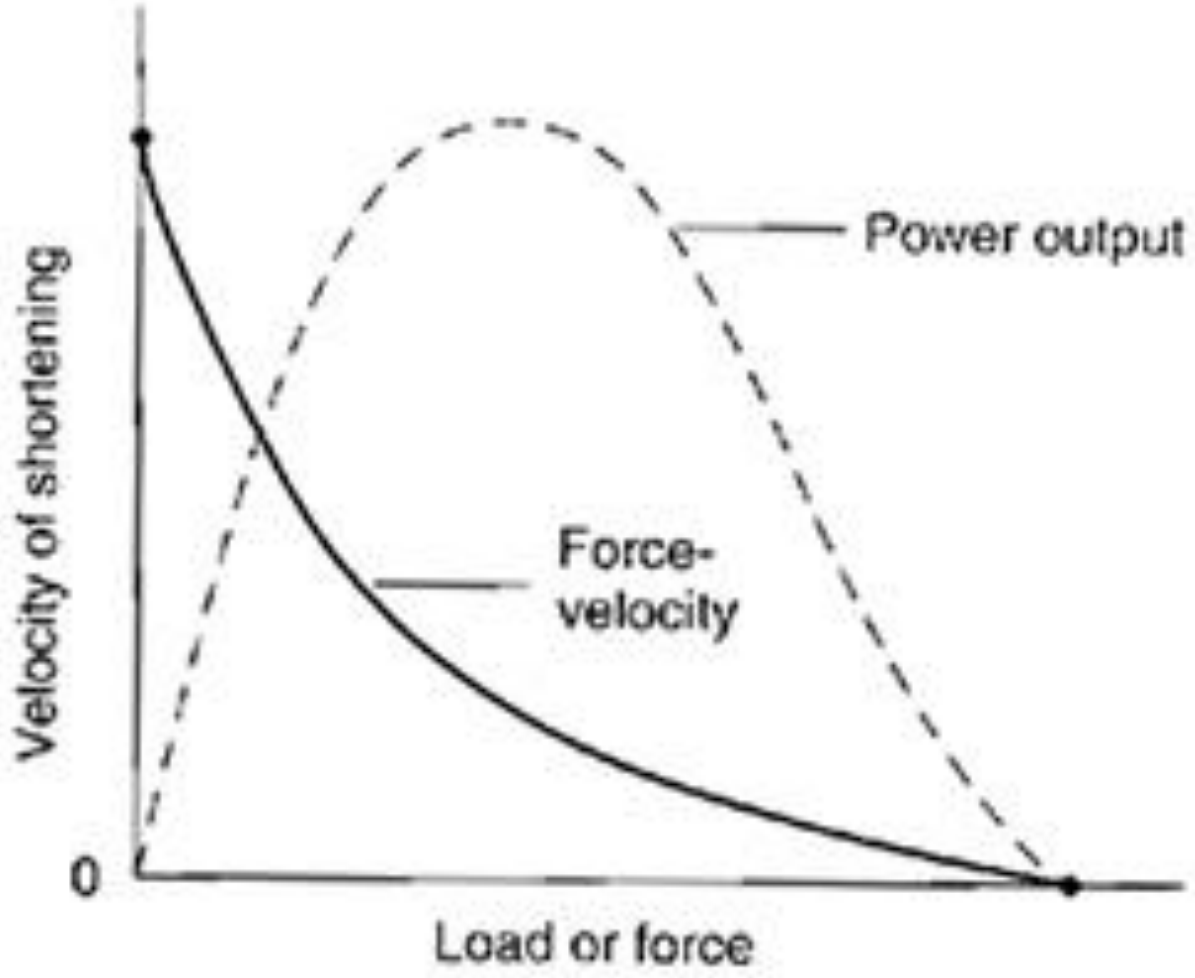
Appendix A- Force-Velocity Curve



(Quintic, 2013)

This graph illustrates the relationship of force and velocity and how these two variables produce power outputs.

Appendix B- Informed Consent

INFORMED CONSENT

Dear Participant/Student Athlete:

My name is Joe Jablonski, a graduate student at Morehead State University in the Department of Health, Wellness and Human Performance. I am requesting your assistance with a research project I am conducting on power output and force production gains made during resistance training through different modalities of resistance. Let me emphasize that you do not have to allow for your data to be used in this study. If you do not wish to take part in the study you can simply refuse. Allowing for your testing numbers to be used is voluntary.

You must be 18 years of age or older to allow us to use your testing data. ***(Researcher must verify that students are 18 years of age or older.)*** This study has been reviewed to determine that participants' rights are safeguarded and there appears to be minimal risk or discomfort associated with the completion of the study. Also, you need to understand that allowing your data to be used in this study has no impact on your status as an athlete with the University of Detroit Mercy coaching staff. Your decision to volunteer your data cannot hurt or help you.

As a participant, your only responsibility will be to allow for your testing numbers to be used. The **physical testing** within the program will consist of squatting with band resistance, squatting with free weight resistance, and squatting using a Keiser machine during pre and post training. You will complete **strength training for 5 weeks** between the pre and post testing sessions. As a member of the University of Detroit Mercy Fencing team, you will be expected to complete this training program. As a participant for this study you will be required to give permission to allow for you testing data to be used in the study. The strength training will be conducted by the University of Detroit Mercy Strength and Conditioning Coach/Staff.

The data you provide will be kept strictly confidential (completed data recording document and digital documents) will be stored in a locked filing cabinet in the principal investigators office, accessible only to the researchers. Please feel free to ask for help if something does not make sense to you or if you have any questions, you may contact Joe Jablonski***.***

If you decide to volunteer, please be sure to **PRINT YOUR NAME** on the form and **SIGN** it to indicate your willingness to allow your data to be used. That will be our indication that you understand the purpose of the study and that you are willing to allow your data to be used.

NAME *(please print)*: _____

Signature: _____

If you have any questions or concerns, you may contact the researcher: ***(Joe Jablonski, 734-347-1423, jrjablonski@moreheadstate.edu)***

Appendix C: WEB® Band Resistances

Figure 1: Band Resistances with Pictures

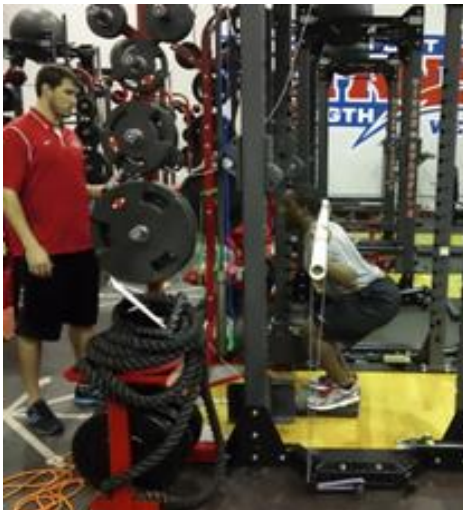
Band Resistances		
Name	**Color**	**Resistance**
Mini	Blue	5-25 lbs
Light	Black	30-50 lbs
Average	Grey	65-75 lbs

*Resistances are based off of being stretched six feet

These are the bands that were used during the training intervention by the band group and by all the participants during the band testing.

Appendix D- Band and Free Weight Resisted Test

Band Test- This test used two light bands and the PASCO® force plate and motion sensor to find force production and velocity of the movement. These two measurements were then used to calculate power output of the movement.



Free Weight Test-This test used free weights and the PASCO® force plate and motion sensor to find force production and velocity of the movement. These two measurements were then used to calculate power output of the movement.

Appendix E- Band Resisted Test Resistance Picture

The band was stretched across three pegs when the participant was under 5’10, to keep the resistance at the top of the squat around 75 pounds during the band resisted squat testing.

The band was stretched across two pegs when the participant was over 5’10, to keep the resistance at the top of the squat around 75 pounds during the band resisted squat testing.

Appendix F- Free Weight Resistance (FWR) Program

Prep Week 1

Free Weight Group

Monday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Iso Holds							
Circuit 2x30s Minute Break Between							
Run in Place							
Russian Twists							
Froggies							
Flutter Kicks							
X-C Skiers							
Mt. Climbers							
Planks							
Ice Skaters							
Supermans							
Frankensteins							

Wednesday							
EXERCISES	SETS/REPS	RPE					
PVC Roll							
Dynamic Warm Up							
Wall Squat Drill	5x5						
Band Abd SB Squat	3x5						
Push Up Progression	4x10		Band, Knees, Regular, Regular				
Band BO Row	3x10						
Flush Run	5 min						
Static Stretch							

Friday							
EXERCISES	SETS/REPS	RPE					
PVC Roll							
Dynamic Warm Up							
Iso Holds							
Band Front Squats							
MR FR, LR, RD							
Circuit 2x30s Minute Break Between							
Run In Place							
Burpees							
Butt Kicks							
Scissors							
X-C Skiers							
Mt. Climbers							
Side Planks							
Ice Skaters							
Other Side Planks							
Tempos							

Prep Week 2

Free Weight Group

Monday							
EXERCISES	SETS/REPS	RPE					
PVC Roll							
Dynamic Warm Up							
TB Reaction Drill	5 min						
SB Abd Squat	5x5						
Tempo Push Ups	4x10		Use Band if form is bad				
Band Front Squat	5x5						
Band BO Row X	4x10						
SB Hamstring Curls	3x10						
Flush Run	7 min						
Static Stretch							

Wednesday							
EXERCISES	SETS/REPS	RPE					
PVC Roll							
Dynamic Warm Up							
TB Jab	10 min						
3 Directional Lunge X Push Ups	3x8						
	4x10		Use Band if form is bad				
3 Direct Reach X Band Ret Holds X 1 Arm Band Row	2x8						
	2x20s						
	2x10						
Circuit 2x30s Minute Break Between							
Run in Place							
Russian Twists							
Froggies							
Flutter Kicks							
X-C Skiers							
Mt. Climbers							
Planks							
Ice Skaters							
Supermans							
Frankensteins							
Static Stretch							

Friday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Reaction X TB Jab	5 min						
Band Squats X Push Ups	3x10		Can Use Band for Extra Resistance				
Base BO Rows X SB Ham Curls	3x10						
	3x10						
Static Stretch							

Week 1

Free Weight Group

Monday

EXERCISES	SETS/REPS						
Dynamic Warm Up							
Testing	3x3	Keiser Squat, Force Plate Squat FW, Force Plate Squat Bands					
Stairs	15 min						

Wednesday

EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Drills	1x10		Reaction Catch, Jab Catch				
Back Squat	3x10	10 to 13	Somewhat Hard Intensity				
Push Ups	3x10						
3 Directional Lunge	2x5						
Band Ret Holds	3x20s						
Stab Ball Ham Curls	3x10						
Push Up Pro X Ret	3x10						
Band Hip Add X Abd	3x10						
Wrist Flex X Curl	3x10						
Core	5x20						

Friday

EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Line Jumps/Hops			1 foot, 2 feet, Lateral, Front/Back				
Ladder Drills							
Deadlift	3x10	10 to 13	Somewhat Hard Intensity				
Push Ups	3x15						
BB Lateral Lunges	3x5						
Band BO Row	3x10						
Stability Ball Hip Bridges	3x10						
Shoulder Routine	2x6		Band Ys,Ts				
Farmers Walks	2x40yrds						
Plank Series	2x20s		Front, Left, Right, Feet 6 inches				
Stairs	5 min						

Week 2

Free Weight Group

Monday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Drills	1x10		Reaction Catch, Jab Catch, Dodge				
Back Squat	3x10	10 to 13	Somewhat Hard Intensity				
Push Ups	3x10		Feet on Stability Ball if Strong Enough				
3 Directional Lunge	3x5						
Prt Band Ret/Lats	3x10	One Partner Hold Retration, the other does pulldowns					
Stability Ball Roll Ins	3x10						
Push Up Protraction X Retraction	3x10						
Band Hip Add X Abd	3x10						
Wrist Flex X Curl	3x10	Mini					
Core	5x20						

Wednesday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Line Jumps/Hops			1 foot, 2 feet, Lateral, Front/Back				
Ladder Drills							
Deadlift	3x10	10 to 13	Somewhat Hard Intensity				
Push Ups	3x10		Feet on Stability Ball if Strong Enough				
DB Lateral Lunges	3x5						
Band BO Row	3x10						
Stability Ball Hip Bridge	3x10						
Shoulder Routine	2x6		Band Y, T W				
Farmers Walks	3x40yrds						
Plank Series	2x20s		Front, Left, Right, Feet 6 inches				
Stairs	5 min						

Friday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Sumo Squat	3x10	10 to 13	Somewhat Hard Intensity				
Push Ups	3x10		Feet on Stability Ball if Strong Enough				
Plate Lunges	3x5						
Band 1 Arm Row	3x10						
SB Reverse Hypers X SB Back Extension	3x10						
Band Hip Abd	3x10						
Shlder Lat Raise, Frnt Raise, Rear Delt	2x10	Bands					
Partner Band Core	2x10		Paloffs, Square Rot, Lat Rot				
Band Runs	10 min						

Week 3

Free Weight Group

Monday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Drills	1x10		Reaction Catch, Jab Catch, Dodge				
Back Squat	4x8	13 to 16	Hard Intensity				
Band Floor Press	3x10						
3 Directional Lunge	3x5						
Prt Band Ret/Lats	3x10	One Partner Hold Retration, the other does pulldowns					
XXX Threat	3x5						
Push Up Protraction X Retraction	3x10						
SB Squeezes X Fire hydrants	3x8						
Wrist Flex X Curl	3x10	Band					
Flush Run	7 min						
Core	5x20						

Wednesday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Line Jumps/Hops			1 foot, 2 feet, Lateral, Front/Back				
Ladder Drills							
Deadlift	4x8	13 to 16					
Band Floor Press	3x10						
DB Lat Lunges	3x5						
Band BO Row	3x8						
XXX Threat	3x5						
Shoulder Routine	2x6		Band Y, T W				
Farmers Walks	2x40yrds						
Plank Series	2x20s						
Stairs	7 min						

Friday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Sumo Squat	4x8	13 to 16	Hard Intensity				
Band Floor Press	3x10						
Plate Lunges	3x40 yrds						
1 Arm Band Row	3x10						
SB Reverse Hypers X SB Back Ext.	3x10						
SB Squeezes X Fire hydrants	3x8						
Shlder Lat Raise, Frnt Raise, Rear Delt	2x10						
Partner Band Core	2x10		Paloffs, Square Rot, Lat Rot, Kites				
Band Runs	10 min						

Week 4

Free Weight Group

Monday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Drills	1x10		Reaction Catch, Jab Catch, Dodge				
Back Squat	4x8	13 to 16	Hard Intensity				
Band Floor Press	4x8						
DB 3 Directional Lunge	3x3						
Prt Band Ret/Lats	3x10	One Partner Hold Retration, the other does pulldowns					
XXX Threat	3x5						
Band Shoulder Press X Band Shrug	3x8						
Band Hip Add X Abd	3x10						
Wrist Flex X Curl	3x10	Mini					
Core	5x20						
Flush Run	10 min						

Wednesday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Line Jumps/Hops			1 foot, 2 feet, Lateral, Front/Back				
Ladder Drills							
Sumo DL	4x8	13 to 16					
Band Attack	3x3						
Band Retreat	3x3						
DB Lat Lunges	3x5						
Band BO Row	3x8						
XXX Threat	3x5						
Shoulder Routine	3x6		Band Y, T W				
Plank Series	2x30s						
Stairs	10 min						

Friday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Sumo Squat	4x8	13 to 16	Hard Intensity				
Push Ups	3xMax						
BB BO Row	3x8						
SB Reverse Hypers X SB Back Ext.	3x10						
Band Hip Add X Abd	3x10						
Shlder Lat Raise, Frnt Raise, Rear Delt	3x8						
Farmers Walk X Retraction Walk	3x40 yrds						
Band Core	2x10		Paloffs, Square Rot, Lat Rot, Kites				
Band Runs	10 min						

Week 5

Free Weight Group

Monday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Drills	1x10		Reaction Catch, Jab Catch, Dodge				
Back Squat	4x6	16 plus	Very Hard Intensity				
Band Resist. Push Up	4x8						
DB 3 Directional Lunge	3x3						
Prt Band Ret/Lats	3x10	One Partner Hold Retration, the other does pulldowns					
RDL	4x6						
Band Shoulder Press X Band Shrug	3x8						
SB Squeezes X Fire hydrants	3x8						
Wrist Flex X Curl	3x10	Mini					
Core	5x20						
Flush Run	12 min						

Wednesday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Line Jumps/Hops			1 foot, 2 feet, Lateral, Front/Back				
Ladder Drills							
Sumo DL	4x6	16 Plus					
Band Attack	4x3						
Band Retreat	4x3						
DB Lat Lunges	4x3						
Band 1 Arm Row	3x8						
RDL	4x6						
Shoulder Routine	3x6		Band Y, T W				
Plank Series	2x30s						
Stairs	12 min						

Friday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Sumo Squat	4x8	16 plus	Very Hard Intensity				
Push Ups	3xMax						
BB BO Row	4x6						
SB Reverse Hypers X SB Back Ext.	3x10						
SB Squeezes X Fire hydrants	3x8						
Shlder Lat Raise, Frnt Raise, Rear Delt	3x8						
Farmers Walks X Retraction Walk	3x40yrds						
Band Core	2x10		Paloffs, Square Rot, Lat Rot, Kites				
Band Runs	10 min						

Appendix G- Band Resistance (VR) Program

Prep Week 1

Band Group

Monday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Iso Holds							
Circuit 2x30s Minute Break Between							
Run in Place							
Russian Twists							
Froggies							
Flutter Kicks							
X-C Skiers							
Mt. Climbers							
Planks							
Ice Skaters							
Supermans							
Frankensteins							

Wednesday							
EXERCISES	SETS/REPS	RPE					
PVC Roll							
Dynamic Warm Up							
Wall Squat Drill	5x5						
Band Abd SB Squat	3x5						
Push Up Progression	4x10		Band, Knees, Regular, Regular				
Band BO Row	3x10						
Flush Run	5 min						
Static Stretch							

Friday							
EXERCISES	SETS/REPS	RPE					
PVC Roll							
Dynamic Warm Up							
Iso Holds							
Band Front Squats							
MR FR, LR, RD							
Circuit 2x30s Minute Break Between							
Run In Place							
Burpees							
Butt Kicks							
Scissors							
X-C Skiers							
Mt. Climbers							
Side Planks							
Ice Skaters							
Other Side Planks							
Tempos							

Prep Week 2

Band Group

Monday							
EXERCISES	SETS/REPS	RPE					
PVC Roll							
Dynamic Warm Up							
TB Reaction Drill	5 min						
SB Abd Squat	5x5						
Tempo Push Ups	4x10		Use Band if form is bad				
Band Front Squat	5x5						
Band BO Row X SB Hamstring Curls	4x10						
	3x10						
Flush Run	7 min						
Static Stretch							

Wednesday							
EXERCISES	SETS/REPS	RPE					
PVC Roll							
Dynamic Warm Up							
TB Jab	10 min						
3 Directional Lunge X Push Ups	3x8						
	4x10		Use Band if form is bad				
3 Direct Reach X Band Ret Holds X 1 Arm Band Row	2x8						
	2x20s						
	2x10						
Circuit 2x30s Minute Break Between							
Run in Place							
Russian Twists							
Froggies							
Flutter Kicks							
X-C Skiers							
Mt. Climbers							
Planks							
Ice Skaters							
Supermans							
Frankensteins							
Static Stretch							

Friday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Reaction X TB Jab	5 min						
Band Squats X Push Ups	3x10		Can Use Band for Extra Resistance				
Base BO Rows X SB Ham Curls	3x10						
	3x10						
Static Stretch							

Week 1

Band Group

Monday

EXERCISES	SETS/REPS						
Dynamic Warm Up							
Testing	3x3	Keiser Squat, Force Plate Squat FW, Force Plate Squat Bands					
Stairs	15 min						

Wednesday

EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Drills	1x10		Reaction Catch, Jab Catch				
Band Back Squat	3x10	10 to 13	Somewhat Hard Intensity				
Push Ups	3x10						
3 Directional Lunge	2x5						
Band Ret Holds	3x20s						
Stab Ball Ham Curls	3x10						
Push Up Pro X Ret	3x10						
Band Hip Add X Abd	3x10						
Wrist Flex X Curl	3x10						
Core	5x20						

Friday

EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Line Jumps/Hops			1 foot, 2 feet, Lateral, Front/Back				
Ladder Drills							
Band Deadlift	3x10	10 to 13	Somewhat Hard Intensity				
Push Ups	3x15						
BB Lateral Lunges	3x5						
Band BO Row	3x10						
Stability Ball Hip Bridges	3x10						
Shoulder Routine	2x6		Band Ys,Ts				
Farmers Walks	2x40yrds						
Plank Series	2x20s		Front, Left, Right, Feet 6 inches				
Stairs	5 min						

Week 2

Band Group

Monday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Drills	1x10		Reaction Catch, Jab Catch, Dodge				
Band Back Squat	3x10	10 to 13	Somewhat Hard Intensity				
Push Ups	3x10		Feet on Stability Ball if Strong Enough				
3 Directional Lunge	3x5						
Prt Band Ret/Lats	3x10	One Partner Hold Retration, the other does pulldowns					
Stability Ball Roll Ins	3x10						
Push Up Protraction X Retraction	3x10						
Band Hip Add X Abd	3x10						
Wrist Flex X Curl	3x10	Mini					
Core	5x20						

Wednesday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Line Jumps/Hops			1 foot, 2 feet, Lateral, Front/Back				
Ladder Drills							
Band Deadlift	3x10	10 to 13	Somewhat Hard Intensity				
Push Ups	3x10		Feet on Stability Ball if Strong Enough				
DB Lateral Lunges	3x5						
Band BO Row	3x10						
Stability Ball Hip Bridge	3x10						
Shoulder Routine	2x6		Band Y, T W				
Farmers Walks	3x40yrds						
Plank Series	2x20s		Front, Left, Right, Feet 6 inches				
Stairs	5 min						

Friday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Band Sumo Squat	3x10	10 to 13	Somewhat Hard Intensity				
Push Ups	3x10		Feet on Stability Ball if Strong Enough				
Plate Lunges	3x5						
Band 1 Arm Row	3x10						
SB Reverse Hypers X SB Back Extension	3x10						
Band Hip Abd	3x10						
Shlder Lat Raise, Frnt Raise, Rear Delt	2x10	Bands					
Partner Band Core	2x10		Paloffs, Square Rot, Lat Rot				
Band Runs	10 min						

Week 3

Band Group

Monday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Drills	1x10		Reaction Catch, Jab Catch, Dodge				
Band Back Squat	4x8	13 to 16	Hard Intensity				
Band Floor Press	3x10						
3 Directional Lunge	3x5						
Prt Band Ret/Lats	3x10	One Partner Hold Retration, the other does pulldowns					
XXX Threat	3x5						
Push Up Protraction X Retraction	3x10						
SB Squeezes X Fire hydrants	3x8						
Wrist Flex X Curl	3x10	Band					
Flush Run	7 min						
Core	5x20						

Wednesday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Line Jumps/Hops			1 foot, 2 feet, Lateral, Front/Back				
Ladder Drills							
Band Deadlift	4x8	13 to 16					
Band Floor Press	3x10						
DB Lat Lunges	3x5						
Band BO Row	3x8						
XXX Threat	3x5						
Shoulder Routine	2x6		Band Y, T W				
Farmers Walks	2x40yrds						
Plank Series	2x20s						
Stairs	7 min						

Friday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Band Sumo Squat	4x8	13 to 16	Hard Intensity				
Band Floor Press	3x10						
Plate Lunges	3x40 yrds						
1 Arm Band Row	3x10						
SB Reverse Hypers X SB Back Ext.	3x10						
SB Squeezes X Fire hydrants	3x8						
Shlder Lat Raise, Frnt Raise, Rear Delt	2x10						
Partner Band Core	2x10		Paloffs, Square Rot, Lat Rot, Kites				
Band Runs	10 min						

Week 4

Band Group

Monday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Drills	1x10		Reaction Catch, Jab Catch, Dodge				
Band Back Squat	4x8	13 to 16	Hard Intensity				
Band Floor Press	4x8						
DB 3 Directional Lunge	3x3						
Prt Band Ret/Lats	3x10	One Partner Hold Retration, the other does pulldowns					
XXX Threat	3x5						
Band Shoulder Press X Band Shrug	3x8						
Band Hip Add X Abd	3x10						
Wrist Flex X Curl	3x10	Mini					
Core	5x20						
Flush Run	10 min						

Wednesday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Line Jumps/Hops			1 foot, 2 feet, Lateral, Front/Back				
Ladder Drills							
Band Sumo DL	4x8	13 to 16					
Band Attack	3x3						
Band Retreat	3x3						
DB Lat Lunges	3x5						
Band BO Row	3x8						
XXX Threat	3x5						
Shoulder Routine	3x6		Band Y, T W				
Plank Series	2x30s						
Stairs	10 min						

Friday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Band Sumo Squat	4x8	13 to 16	Hard Intensity				
Push Ups	3xMax						
BB BO Row	3x8						
SB Reverse Hypers X SB Back Ext.	3x10						
Band Hip Add X Abd	3x10						
Shlder Lat Raise, Frnt Raise, Rear Delt	3x8						
Farmers Walk X Retraction Walk	3x40 yrds						
Band Core	2x10		Paloffs, Square Rot, Lat Rot, Kites				
Band Runs	10 min						

Week 5

Band Group

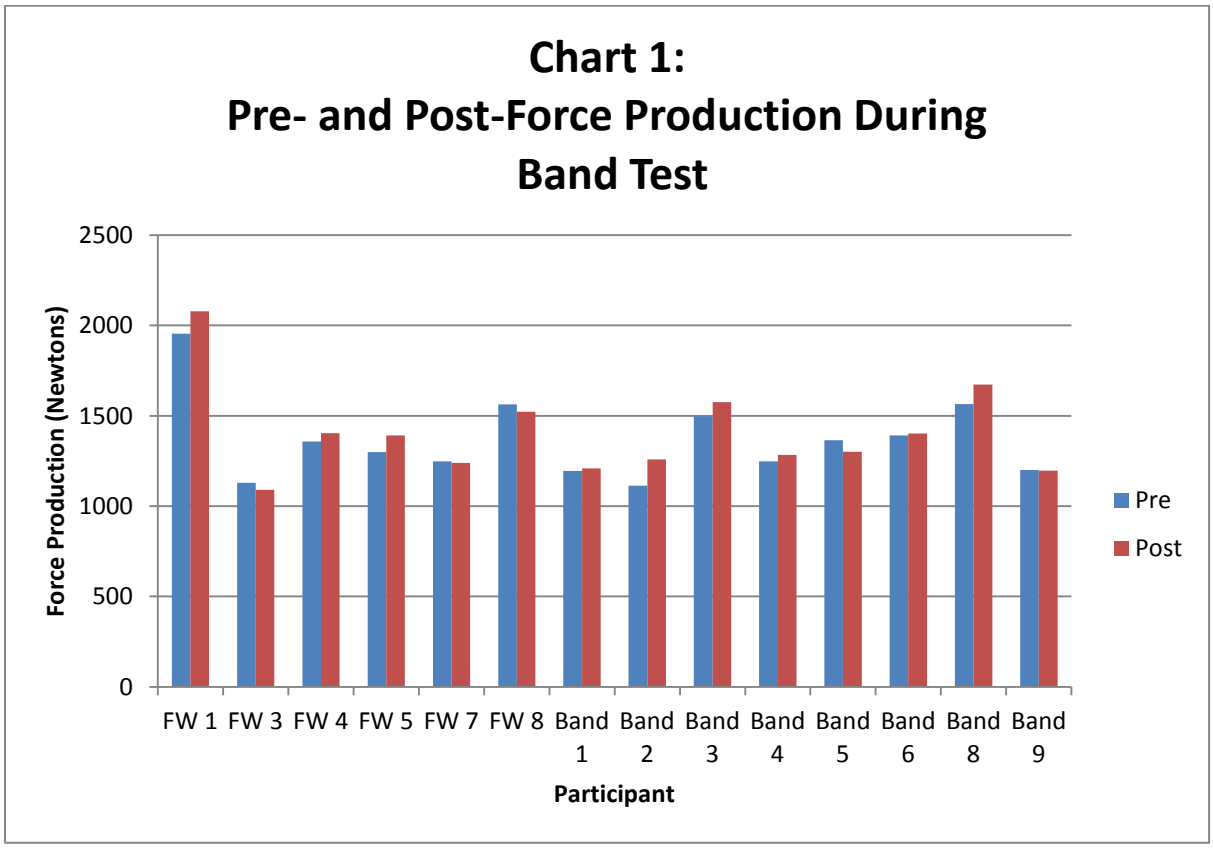
Monday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
TB Drills	1x10		Reaction Catch, Jab Catch, Dodge				
Band Back Squat	4x6	16 plus	Very Hard Intensity				
Band Resist. Push Up	4x8						
DB 3 Directional Lunge	3x3						
Prt Band Ret/Lats	3x10	One Partner Hold Retration, the other does pulldowns					
RDL	4x6						
Band Shoulder Press X Band Shrug	3x8						
SB Squeezes X Fire hydrants	3x8						
Wrist Flex X Curl	3x10	Mini					
Core	5x20						
Flush Run	12 min						

Wednesday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Line Jumps/Hops			1 foot, 2 feet, Lateral, Front/Back				
Ladder Drills							
Band Sumo DL	4x6	16 Plus					
Band Attack	4x3						
Band Retreat	4x3						
DB Lat Lunges	4x3						
Band 1 Arm Row	3x8						
RDL	4x6						
Shoulder Routine	3x6		Band Y, T W				
Plank Series	2x30s						
Stairs	12 min						

Friday							
EXERCISES	SETS/REPS	RPE					
Dynamic Warm Up							
Band Sumo Squat	4x8	16 plus	Very Hard Intensity				
Push Ups	3xMax						
BB BO Row	4x6						
SB Reverse Hypers X SB Back Ext.	3x10						
SB Squeezes X Fire hydrants	3x8						
Shlder Lat Raise, Frnt Raise, Rear Delt	3x8						
Farmers Walks X Retraction Walk	3x40yrds						
Band Core	2x10		Paloffs, Square Rot, Lat Rot, Kites				
Band Runs	10 min						

Appendix H: Pre- and Post-Intervention Band Test Table and Charts

Table 3: Force,Power, and Velocity During Band Testing									
Participant	Band Test								
	Pre			Post			Difference (Post-Pre)		
	Ave. Peak Force	Ave. Peak Power	Velocity at PP	Ave. Peak Force	Ave. Peak Power	Velocity at PP	Force	Power	Velocity
FW 1	1953.63	2786.74	1.71	2078.51	3218.19	1.97	124.88	431.45	0.26
FW 3	1129.94	1688.30	1.58	1090.18	1681.48	1.67	-39.75	-6.83	0.09
FW 4	1357.37	2076.42	1.62	1403.56	2386.05	1.70	46.19	309.64	0.08
FW 5	1299.78	2673.09	1.99	1392.11	2687.31	1.95	92.33	14.22	-0.03
FW 7	1247.66	1739.74	1.50	1238.22	1811.73	1.66	-9.44	72.00	0.16
FW 8	1563.74	2446.08	1.65	1522.32	2162.54	1.59	-41.43	-283.54	-0.06
Free Weight Average	1425.35	2235.06	1.67	1454.15	2324.55	1.75	28.80	89.49	0.08
Free Weight SD	295.79	471.21	0.17	340.58	572.14	0.16	70.23	252.90	0.12
Band 1	1194.72	1799.46	1.60	1208.17	1791.53	1.61	13.45	-7.93	0.01
Band 2	1112.84	1209.72	1.11	1259.00	1479.00	1.57	146.16	269.28	0.47
Band 3	1497.44	1989.52	1.69	1574.93	2246.26	1.87	77.49	256.74	0.18
Band 4	1247.27	1367.53	1.32	1283.14	1978.10	1.75	35.87	610.57	0.43
Band 5	1364.71	2385.00	1.97	1301.45	2236.84	1.81	-63.26	-148.16	-0.16
Band 6	1390.52	2030.40	1.61	1401.57	2054.08	1.66	11.06	23.68	0.05
Band 8	1564.24	2465.38	1.63	1673.70	2535.30	1.70	109.46	69.91	0.07
Band 9	1199.92	2131.32	1.78	1196.24	1952.58	1.73	-3.68	-178.74	-0.05
Band Average	1321.46	1922.29	1.59	1362.27	2034.21	1.71	40.82	111.92	0.13
Band SD	158.75	447.14	0.27	175.54	319.48	0.10	67.21	259.24	0.22
Total Average	1365.98	2056.34	1.62	1401.65	2158.64	1.73	35.67	102.31	0.11
Total SD	223.76	467.82	0.23	251.86	450.66	0.13	66.09	246.82	0.18



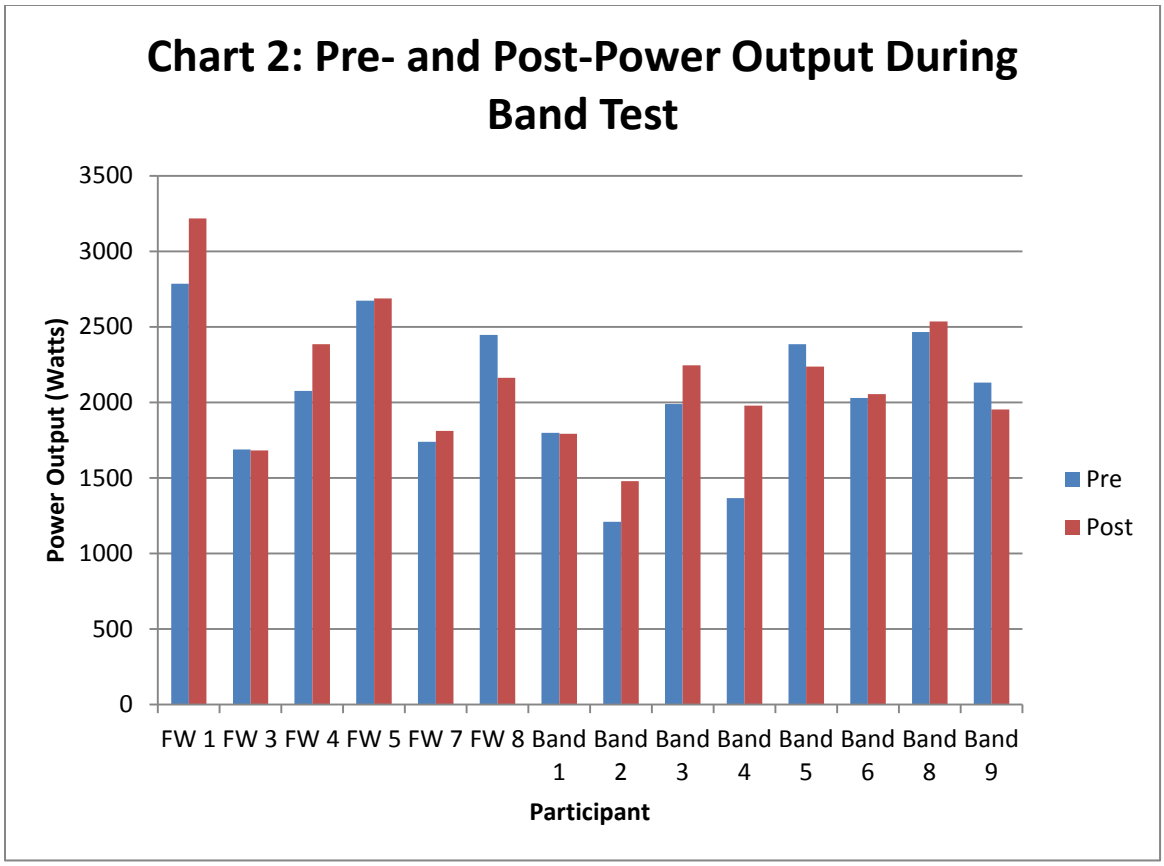


Chart 2: Pre- and Post-Power Output During Band Test
Power Output (Watts)
3500
3000
2500
2000
1500
1000
500
0
FW 1
FW 3
FW 4
FW 5
FW 7
FW 8
Band 1
Band 2
Band 3
Band 4
Band 5
Band 6
Band 8
Band 9
Participant
Pre
Post

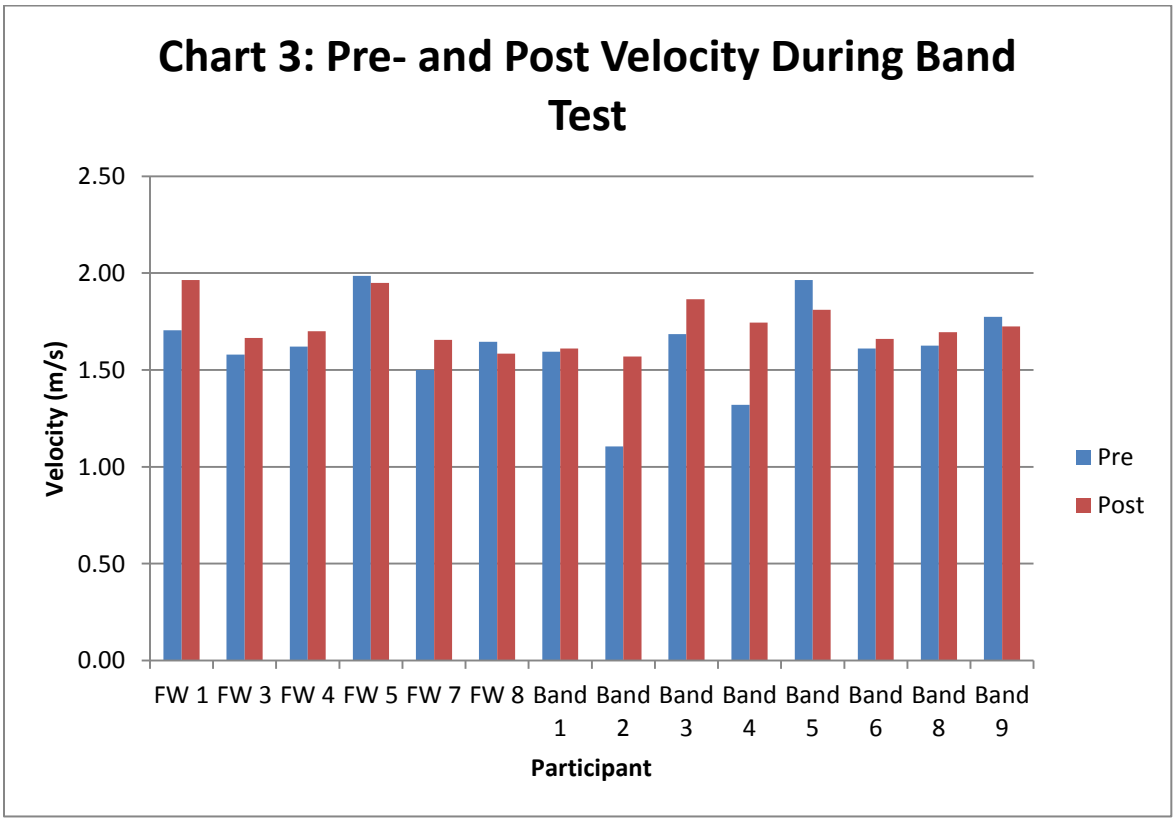
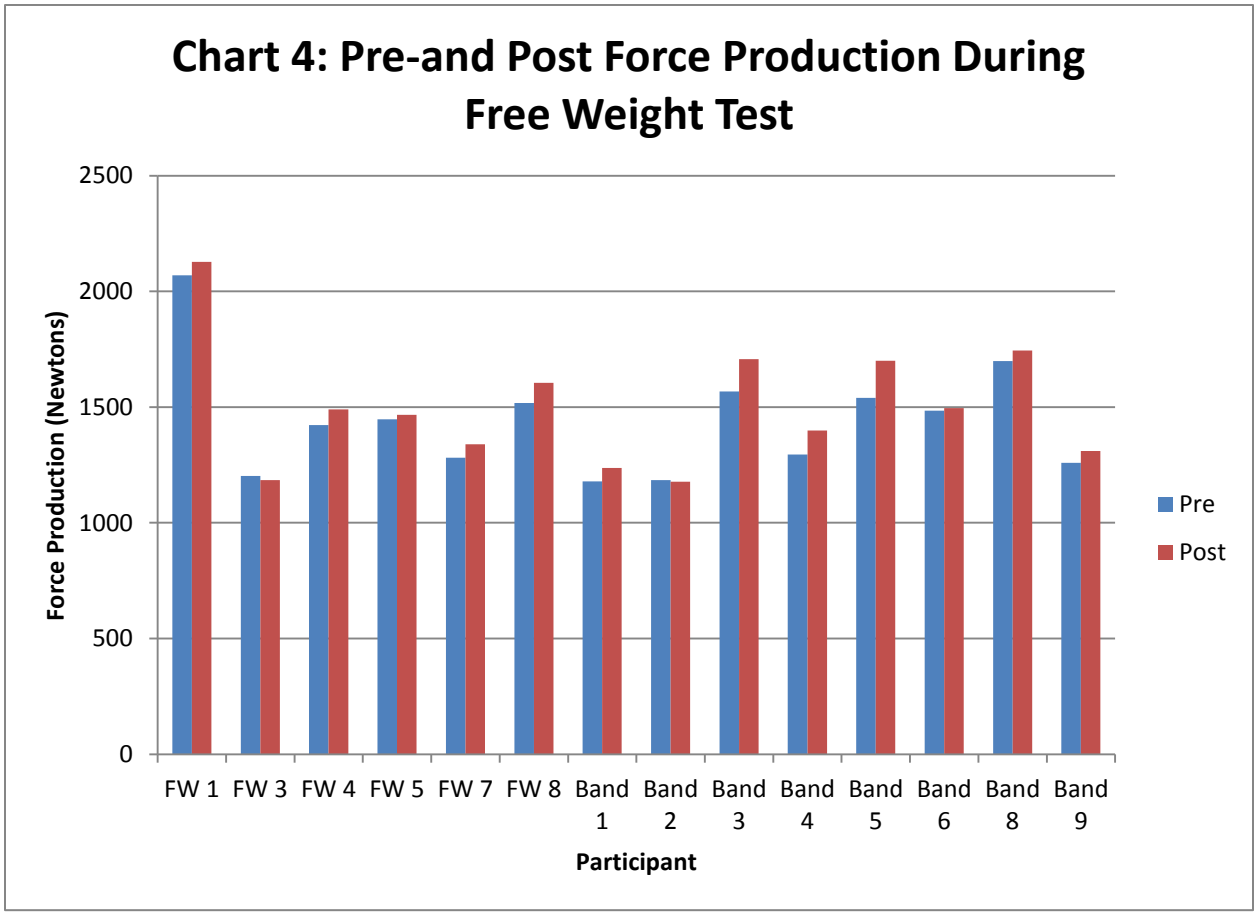


Chart 3: Pre- and Post Velocity During Band Test
Velocity (m/s)
2.50
2.00
1.50
1.00
0.50
0.00
FW 1
FW 3
FW 4
FW 5
FW 7
FW 8
Band 1
Band 2
Band 3
Band 4
Band 5
Band 6
Band 8
Band 9
Participant
Pre
Post

Appendix I: Pre- and Post-Intervention Free Weight Test Charts

Table 4: Force, Power, and Velocity During Free Weight Testing									
Participant	Free Weight Test								
	Pre			Post			Difference (Post-Pre)		
	Ave. Peak Force	Ave. Peak Power	Velocity at PP	Ave. Peak Force	Ave. Peak Power	Velocity at PP	Force	Power	Velocity
FW 1	2070.03	2519.94	1.50	2128.24	3087.12	1.67	58.21	567.18	0.17
FW 3	1202.10	1750.07	1.50	1184.08	1705.82	1.55	-18.02	-44.25	0.05
FW 4	1422.31	1641.50	1.32	1490.68	2037.56	1.63	68.37	396.06	0.31
FW 5	1447.51	2370.26	1.65	1467.28	2641.26	1.99	19.77	271.00	0.34
FW 7	1280.79	1375.34	1.22	1339.17	1587.15	1.32	58.38	211.81	0.10
FW 8	1517.65	1908.90	1.31	1604.79	1994.52	1.34	87.13	85.62	0.03
Free Weight Average	1490.06	1927.67	1.42	1535.70	2175.57	1.58	45.64	247.90	0.17
Free Weight SD	306.67	439.44	0.16	323.99	577.32	0.25	38.16	217.91	0.13
Band 1	1179.37	1245.66	1.09	1236.43	1310.52	1.13	57.06	64.85	0.04
Band 2	1184.73	1025.50	0.90	1177.97	1213.34	1.06	-6.75	187.84	0.16
Band 3	1568.24	2001.36	1.55	1707.86	2036.17	1.64	139.62	34.81	0.09
Band 4	1295.62	1428.75	1.23	1398.56	2129.56	1.70	102.94	700.81	0.47
Band 5	1539.31	2090.66	1.46	1700.44	2281.42	1.66	161.13	190.76	0.21
Band 6	1484.19	1788.54	1.21	1495.80	1875.31	1.48	11.61	86.77	0.27
Band 8	1699.12	2328.21	1.40	1745.12	2464.01	1.48	46.00	135.79	0.08
Band 9	1258.81	1795.80	1.43	1310.86	1866.15	1.50	52.06	70.35	0.07
Band Average	1401.17	1713.06	1.28	1471.63	1897.06	1.45	70.46	184.00	0.17
Band SD	196.44	445.40	0.22	225.60	440.05	0.24	59.28	216.57	0.14
Total Average	1439.27	1805.03	1.34	1499.09	2016.42	1.51	59.82	211.39	0.17
Total SD	242.97	439.59	0.20	262.41	502.91	0.24	51.13	211.17	0.13



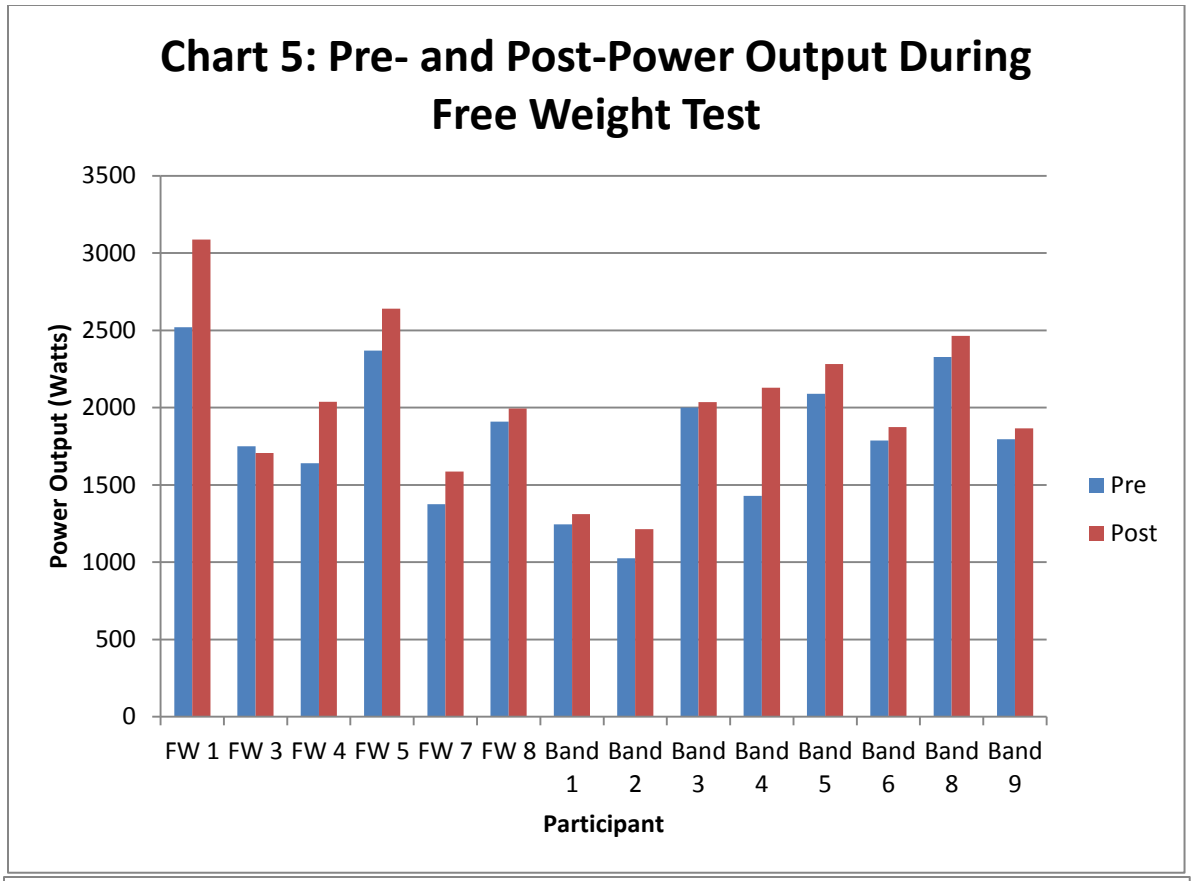


Chart 5: Pre- and Post-Power Output During Free Weight Test
Power Output (Watts)
3500
3000
2500
2000
1500
1000
500
0
FW 1
FW 3
FW 4
FW 5
FW 7
FW 8
Band 1
Band 2
Band 3
Band 4
Band 5
Band 6
Band 8
Band 9
Participant
Pre
Post

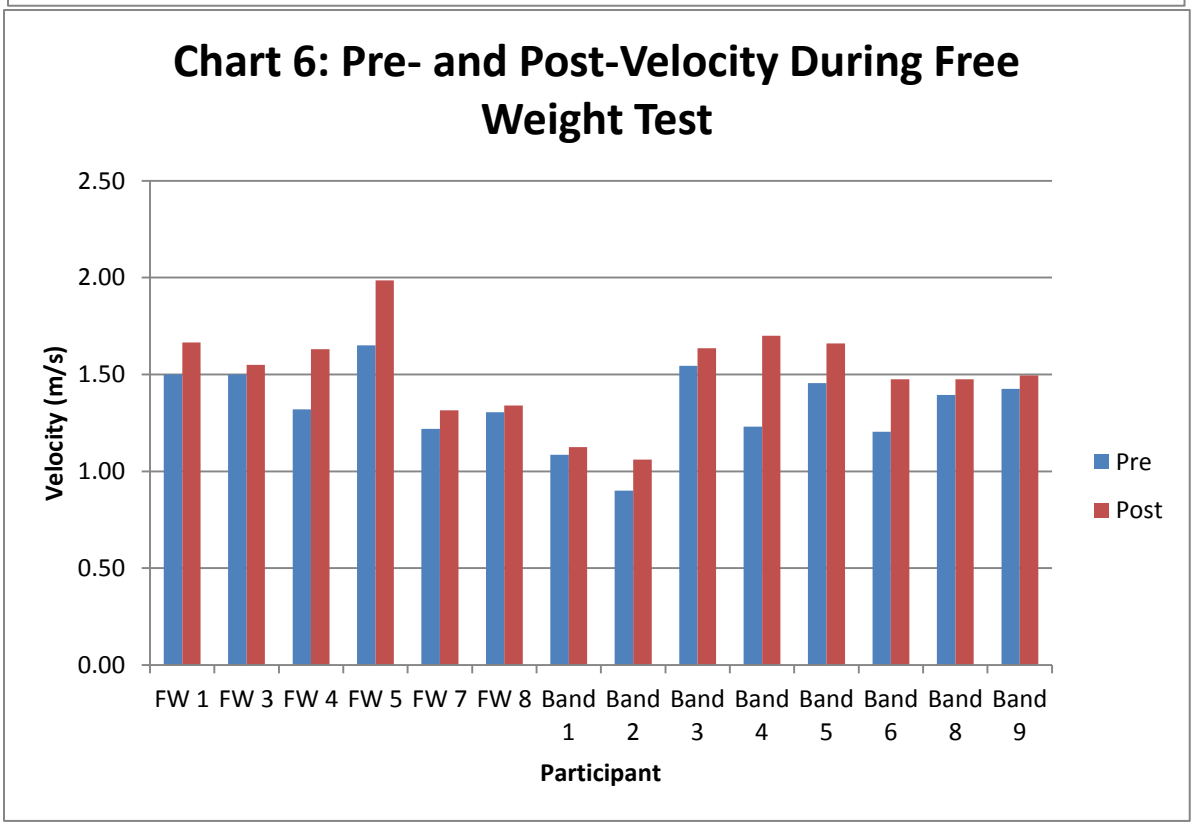


Chart 6: Pre- and Post-Velocity During Free Weight Test
Velocity (m/s)
2.50
2.00
1.50
1.00
0.50
0.00
FW 1
FW 3
FW 4
FW 5
FW 7
FW 8
Band 1
Band 2
Band 3
Band 4
Band 5
Band 6
Band 8
Band 9
Participant
Pre
Post