EFFECTS OF ELASTIC RESISTANCE ON
CONCENTRIC FORCE, CONCENTRIC POWER
AND ECCENTRIC VELOCITY DURING THE
BENCH PRESS

A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN PARTIAL
FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

MASTER OF SCIENCE

BY

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DECLARATION

The work presented in this thesis is, to the best of my knowledge and belief, original, except as acknowledged in the text, and the material has not been submitted, either in whole or in part, for a degree at this or any other university.

________________________________________

Michael A. Lawrence
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ABSTRACT

THESIS: The Effects of Elastic Resistance Bands on the Bench Press

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Elastic bands are becoming more popular in strength and power training. Although increases in strength and power have been anecdotally reported with high loads of elastic resistance, there is no research on large band tensions and their effects on force and power variables. The purpose of this study was to quantify peak concentric force, peak concentric power and peak eccentric velocity produced by the subject when using differing levels of elastic resistance (0%, 20%, 50% and 75% of the total load being elastic resistance) in the bench press. Seven experienced male powerlifters and body builders participated in this study. Prior to subject testing all elastic bands were calibrated for force output throughout the bench press range of motion. Each subject performed a single repetition maximum press to determine the total correct testing load (85% of maximum press). The subjects then performed four presses with various elastic band resistances, each having the total equivalent weight of 85% of the subject’s maximal press weight at lockout. Dependent variables were peak concentric force, peak concentric power, and peak eccentric velocity as produced by the subject. A one-way ANOVA was
used to determine the differences among the four levels of elastic resistance (ER) used in the study ($\alpha = 0.05$). Compared to the baseline condition ($2123.6 \pm 499.9$N), significantly lower average peak concentric force was observed with ER of 75% ($1451.2 \pm 151.0$N, 31.9% decrease) ($p = .010$) and with an ER of 50% ($1781.1 \pm 174.3$N, 16.4% decrease) ($p = .052$). When compared with baseline peak concentric power ($702.6 \pm 274.6$W), higher peak power was observed in all band trials: 20% ($895.2 \pm 187.7$W, 27.4% increase), 50% ($972.5 \pm 189.8$W, 38.4% increase) and 75% ($979.6 \pm 171.0$W, 39.4% increase) ($p = .009; p = .007; p = .033$, respectively). There was no significant difference in peak concentric power in any ER trials. No significant differences ($p = .080$) were seen in peak eccentric velocity. Therefore ER loads of 20, 50 and 75% provide greater stimuli for producing peak concentric power than no ER, with only a 20% load of ER maintaining the same peak concentric force production as baseline. ER loads of 50 and 75% may not be as effective a stimuli as free weights when the training objective is to increase force production.
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NOMENCLATURE

VRT – variable resistance training
FW – free weights
ER – elastic resistance

DEFINITION OF TERMS

Concentric – upward bar motion / pressing motion in the bench press
Eccentric – downward bar motion
Force- push or pull that causes an object to move
Power – rate at which force is applied
Velocity – rate of change of position
INTRODUCTION

The ability to produce high power output is vital in sport (40), but there is still much debate about how to best improve power output in athletes (5). Many methods have been experimented with during recent years. One method that has seen success in the field is variable resistance training (VRT). VRT involves resistance that is altered throughout the movement of the exercise. Almost all forms of VRT decrease the resistance throughout the eccentric portion and then subsequently increase resistance during the concentric portion of the exercise.
VRT has become increasingly popular in the strength and conditioning community over the past few years. One of the more popular methods utilizing VRT is to combine elastic resistance (ER) with free weights (FW). Increases in both strength and power have been seen both anecdotally and in the scientific literature (3, 35). Scientists have used several apparatuses to achieve the ER. In some studies bungee cords were used to provide the resistance (3, 12) while others have used elastic bands (35). Even though the principles are the same, the use of elastic bands are far more popular in the practical application. Some research indicates that success of achieving increased amounts of force and power may be dependent upon the percentage of load accounted for by elastic band tension (12, 35).

Significant increases in strength, force, and power were not present in studies when a small percentage of the overall load is achieved through the use of elastic bands (12, 15). Studies by Anderson and Wallace have used elastic band tensions of 20-35% of the load and have shown higher peak and average concentric power and concentric force when compared to FW alone (3, 35). In the scientific literature 20-35% range is the largest amount of tension tested. Even though Wallace suggested that there may be a point at which increasing band tension is not productive (35), competitive powerlifters have been known to use much higher band tensions in a complex training scheme and witnessed positive results from this training. Despite current practice, no studies have compared elastic band tensions above 35%. Wallace compared peak and average power at band tensions of 20 and 35%, finding 20% resulted in higher peak and average power (35). It is
noteworthy that Wallace used recreationally trained men and women as subjects and did not require any previous experience using elastic bands.

The bench press utilizes the entire upper body musculature and is widely used by both recreational and serious weight lifters. The bench press is also a competitive lift in powerlifting and is therefore extensively trained by powerlifters. The use of variable resistance training in the bench press has become more common since powerlifter Louie Simmons and Westside Barbell made it popular with their training methods (32). Since the time of Simmon’s article the use of elastic bands has increased dramatically.

**PURPOSE**

The purpose of this study is to examine the effects of varying loads of ER, 20%, 50%, and 75%, on the performance of a bench press in those individuals with experience in VRT. Peak concentric power and force applied by the person, as well as the peak velocity of the eccentric phase of the bench press, are the outcome measures that will be assessed.

**Expected Outcomes**

It is hypothesized that loads with higher band resistance will exhibit higher peak power outputs and greater peak eccentric velocities. Peak power is expected to be higher because the loads will be lighter at the beginning of the concentric portion, allowing for greater velocities to be reached. An increase in peak eccentric velocity is expected with ER, this is supported by the strong anecdotal evidence (32, 34). It is also hypothesized that the peak force will be approximately the same for all conditions. This is expected due
to the maximum amount of resistance will be constant for each trial, with 85% of the load being experienced at the lockout for all conditions.

**SIGNIFICANCE**

Past research has been shown that the addition of variable resistance can increase or decrease key kinetic variables. Specifically studies have shown both increases and decreases in average and peak concentric power and average and peak concentric force, of an exercise (3, 4, 31, 35). Currently no research has been done in which the load provided by the variable resistance exceeds 35% of the total load. The data gained from this study may help researchers, strength coaches, and athletes to better design exercise routines.

**METHODS**

**Participants**

Seven experienced healthy competitive male powerlifters and bodybuilders (aged 29.4 ± 5.8 years, body mass of 110.1 ± 14.5 kilograms) were recruited from a local powerlifting gym in Muncie, IN. Healthy was defined as having no previous (within the last two years) or present upper extremity injuries and no cardiovascular risk factors. After initial recruitment, participants were stepped through procedures, potential risks, and benefits associated with study participation. Once the recruit agreed to participate, he signed an informed consent form and filled out a health history document and a training history document. It was also required that the subject be able to bench press a
minimum of three hundred pounds and have had previous experience with ER bands in his training protocol. The subject was also assigned a subject number at this time.

**Method of Subject Recruitment**

Subjects were recruited from the members of a local powerlifting gym (DC Barbell) which consists of competitive bodybuilders and powerlifters.

**Calibration of the Elastic Bands**

A new set of ER bands was used for the testing procedure. The set was calibrated prior to the testing session using an AMTI force plate (Watertown, Massachusetts) set to collect at 2400 Hz. The bands were attached to a rack in the same manner as they would be in testing but over the AMTI force plate. The force plate was tared to the weight of wooden blocks used to stretch the bands. The force exerted by the bands was then recorded. The height of the blocks was increased approximately every 3.8 centimeters and the process repeated. The displacement of the bar was tracked by placing a reflective marker on each end of the bar. The markers were tracked using 15 VICON F-series cameras set to collect at 120 Hz. The range of the calibration exceeded the range of motion of all subject’s bench press. A calibration force-displacement curve was generated for each band using a custom MATLAB script. Using the data from the curves generated in MATLAB and the measured distance of each subject’s full extension, the band combination for each subject was determined.

**Testing Session**
Subjects were present for two different testing sessions that took place at least one week apart. The first session took place in the athletic weight room at Ball State University. The same model and brand of equipment was used for both testing sessions. The first session consisted of a single repetition maximum bench press test and a measurement of the height of the subject’s full arm extension. The measurement for the height of the full arm extension was defined as the vertical distance between the center of the end of the bar and the floor. ACSM guidelines (2) were followed to find the maximum bench press for each individual, which includes no prior exercise that day. Each subject’s maximal press was found in no more than four attempts. Using the data from the band curves, the subject’s maximal bench press, and the measured distance of the subject’s full extension, the appropriate band combination for each trial was determined.

The second testing session was performed in the Biomechanics Laboratory at Ball State University. Participants were allowed to warm up as they would for normal training or contest. Two reflective markers were placed on the ends of the bar and its position was recorded through fifteen F-series VICON cameras. The information from the cameras was collected and reconstructed with VICON Workstation software. The collection rate was set at 120 Hz. The elastic bands were set up using the “double looped” method.

The participants then completed a single repetition of the bench press with each of the four conditions, (0, 20, 50 and 75% load from elastic bands with a total load of 85% of the subject’s 1RM). The order of the conditions was determined by a Latin Square. Participants were allowed sufficient rest (4-5 minutes) between attempts (39).
**Data Collected for Concurrent Studies**

During the testing session participants had four EMG electrodes placed on them. One electrode each was placed on the medial tricep, short head of the biceps, anterior deltoid and pectoralis major on the right side of the body. EMG data were collected for further study but will not be analyzed in the current study.

**Data Reduction and Analysis/Statistics**

The point data was reconstructed, filtered, and gaps in the data were filled using a Woltering filter with predicted MSE of 20. Utilizing the position data from VICON Workstation, the known bar weight, and the force curves of the elastic bands generated through MATLAB (MathWorks, Boston, MA), the peak eccentric velocity, peak concentric force, and peak concentric power were calculated utilizing a custom MATLAB program.

One-way analysis of variances were used to determine the differences of peak power, peak force and peak eccentric velocity among the four levels of band resistance. When statistical significance was observed, pairwise comparisons were completed using the Least Significant Difference method. Significance was set at 0.05.

**LIMITATIONS**

As this study only deals with experienced lifters that can bench press a minimum of 300 pounds, the results will be specific to that population. Also, since there are so many different forms of VRT, these results will be specific to elastic bands which have been double looped. However, it may serve as a spring board for other studies to
investigate the remaining methods of VRT. This study will provide a sound basis to examine the use of VRT in other populations.

**DELIMITATIONS**

Subjects participating in this study will be limited to those who can bench press a minimum of three hundred pounds without using any assistive device. The subjects will also be required to have had previous experience using ER bands in their training. The age range of the subjects is set to 18-45 years of age.

**SUMMARY**

VRT is becoming more popular among both recreational and serious weight lifters as well as general athletics weight training protocols. Past research has been shown that the addition of variable resistance changes the kinetics of an exercise (3, 4, 31, 35). Currently no research has been done in which the load provided by the variable resistance exceeds 35% of the total load. Higher loads of variable resistance are common place in the sport of powerlifting and anecdotal strength and power gains have been reported. In this study four conditions were tested with variable resistance loads of 0%, 20%, 50% and 75%. The results of this study may be useful in understanding how greater loads of variable resistance alter the kinetics of experienced weight lifters.
CHAPTER 2

REVIEW OF LITERATURE

INTRODUCTION

While much research has been done on the effects of traditional resistance training little research has been conducted on a newer type of training called variable resistance training (VRT). The research that has been conducted often includes subjects with little or no previous training with the variable resistance. Also much of the research focuses on the squat or other lower body exercise. Even though the bench press is widely
considered the most popular exercise, little research has been conducted on the lift, and even less on the effects of variable resistance on the bench press.

This literature review will cover the current relevant literature over the bench press, important kinetic factors in the bench press, types of loading conditions and variable resistance training. Important and relevant anecdotal information, which fuels scientific research, will also be included.

**The Bench Press**

The bench press is a very popular lift for both recreational and serious weight lifters and has been described as the most popular weight training exercise by the National Strength and Conditioning Association (21, 37). The bench press is also a competition lift in powerlifting. The bench press as described by the International Powerlifting Federation involves taking the bar at arm’s length, with the elbows fully extended, moving the bar down to the chest, holding the bar motionless, and then returning the bar to a position with the arms fully extended (1). The bench press is a lift that is designed to develop the upper body musculature (37). The prime movers of the bench press include the triceps brachii, anterior deltoid, and pectoralis major (10).

Even though the bench press is a popular lift little scientific research has been presented about the kinetic aspects of the press. In a study by Wilson the differences between a sub maximal and a maximal effort press were described (37). Figure 1 displays the typical force curve of a sub maximal (81%) bench press (37). According to this graph, approximately two thirds of the time in the press is spent in a deceleration phase. During this deceleration the subject is applying less force than the equivalent bar weight.
Basically the subject produced large amounts of force (approximately 112% of the bar weight) during the acceleration phase and then “partially coasted” through the deceleration phase (37).

Figure 1- Sub maximal bench press force profile. (37)

Figure 2 shows the force profile of a maximum effort bench press from the same study by Wilson (37). In the maximum effort force profile, the deceleration phase is much smaller than in the sub maximal effort profile, yet it is still a significant phase consisting of approximately 23% of the total concentric movement (37). A sticking region also exists where the subject applies slightly less force than the bar weight. Wilson found this sticking region to last for 28% of the total concentric movement (37).
Figure 2- Maximal bench press force profile (37)

Duffey found that the kinematics of the bench press change when the subject is becomes fatigued (14). During repetitions to failure sub-maximal effort (75%) kinematics resembled maximal effort kinematics (lift time, peak velocity, time of peak velocity, mean concentric velocity, mean bar position, path length ratio, bar path deviation) (14). Also the subjects tended to keep the bar more directly over the shoulder during the maximal attempts (14), this tendency is confirmed by elite level lifters in a study by Madsen (26). This behavior reflects the finding that lifters will voluntarily modify their kinematics based upon the intensity of the effort (23).
**Force**

In the context of weight training, an increase in ability to produce force requires an increase in muscular strength. Strength increases due to adaptations in the nervous system (improved coordination and learning) and hypertrophy of the muscle (27, 30). These changes are brought about by the body’s adaptation to resistance exercises (25). These adaptations would include, but are not limited to, an increased number of capillaries, increased size of muscle fibers, increase in the amount of glycogen and an increase in the number of mitochondria (25). To develop strength, large amounts of tension must be applied to the muscle (25). There are three methods to elicit maximum muscular tensions as described by Zatsiorsky (38), which are:

1) Overcoming maximal and submaximal resistance that causes maximal or near-maximal muscle tension

2) Overcoming considerably less than maximal resistance that causes considerable less than maximal muscle tension until fatigue forces muscle tension to reach its maximum

3) Overcoming less than maximal resistance at maximal speed

**Power**

Power is defined as the ability to produce work over time. Power is related to force through the equation of $P = F \times V$ (power is equal to the product of force and velocity). The greater the power the more work is produced in a given amount of time or
the same amount of work is done in less time. Power has become one of the gold standards for measures of athleticism. Power production is a vital component in athletic performances that require explosive strength (31). Explosive strength is displayed in athletic movements where the contraction of musculature is preceded by a mechanical stretching (31). Therefore explosive strength is required in any countermovement jump, swing, or sprinting task. Hence the importance of explosive strength in sport as most every sport involves some sort of swing, jump or sprinting task.

In a study relating physical test measurements to sport performance, Davis et al found performance in the power clean (a power exercise) strongly correlated to performance in the shuttle run, sprint, and vertical jump (13). Performance measures such as these are commonly used to describe the physical abilities of athletes (8, 9, 20). Williford et al. (36) took a more direct route and conducted a study comparing individuals of various football abilities to results of power tests, finding high correlations between power and ability level. From these studies, it can be deduced that power is an essential component to athleticism and as such, is a focus of many strength and conditioning programs. However, questions regarding methods for improving power in an efficient manner remain as there are multiple methodologies to train power production currently espoused.

**Types of Loads and Variable Resistance Training (VRT)**

When designing an exercise routine, the type of load used is an important factor to be considered. Enoka describes four different types of loads that a limb can encounter,
including elastic, immovable, inertial and viscous (19). Table 1 gives an example of each type of resistance.

Table 1- Examples of different types of resistance

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<tr>
<td>Immovable</td>
<td>Pushing against a brick wall</td>
</tr>
<tr>
<td>Inertial</td>
<td>Lifting free weights</td>
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<tr>
<td>Viscous</td>
<td>Rowing a boat</td>
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These different types of loads can also be combined. For example, a combination of inertial and elastic loads would be a load consisting of free weights (FW) and elastic resistance (ER) loaded on the same barbell. This combination has been applied to strength and power movements in an effort to induce greater gains (32). In order to understand how these principles work one must understand the mechanics behind each individual aspect of the combination.

For movements with ER, the force of the elastic element is determined by the range of displacement (39). The formula for this ER is $F = k_1 D$, where $F$ is the force, $k_1$ is a coefficient of stiffness, and $D$ is the displacement of the elastic device (19, 39).

Although this formula is constrained to only linear regions of the force-strain curve. The force for the inertial load would be expressed using Newton’s second law, $F = ma$, where $F$ is the force applied to the system, $m$ represents the mass of the system, and $a$ is the
acceleration of the system (24). The combination of inertial and ERs is classified as variable resistance training (VRT). VRT is a method of training in which the total load changes throughout the range of motion as opposed to traditional resistance training in which the load remains constant.

A limitation of traditional resistance training is a deceleration of the bar which occurs towards the end of concentric movement (18). To counter this deceleration, a training method known as “ballistic training” was developed. Ballistic training requires the athlete to jump or throw the barbell at the end of the motion in order to continuously accelerate the bar (31). Therefore ballistic training is limited by the amount of weight that can be jumped with or thrown by the athlete. By increasing the resistance as the concentric motion is completed, VRT attempts to mimic the ballistic training without requiring the jump or release of the bar. This is done by forcing the person to continuously apply more force to the bar throughout the concentric motion in order to counter the increasing ER force. VRT may also allow for the accelerative benefits of ballistic training to be used with higher loads than normal ballistic training (35), which may allow for greater concentric power generation.

One method utilizing this style of training combines the use of elastic bands and free weight (32). Using elastic bands, researchers have observed increases in both peak force and peak power in both observational (35) and longitudinal (3) studies. It has also been suggested that VRT allows for the muscles to be optimally loaded throughout the range of motion by better fitting joint torque production capabilities of the muscles (4,
15). VRT should also decrease the dramatic deceleration resulting in an extended period of acceleration throughout the movement (31).

Increases in both strength and power have been observed both anecdotally and in the scientific community using this combination of ER and FW (3, 35). Scientists have used several apparatuses to achieve the ER. In some studies, bungee cords were used to provide the resistance (3, 12) while others have used elastic bands (35). Even though the principles are the same, elastic bands are far more popular in the strength and conditioning community. Most likely this is due to their versatility of practical applications in the weight room. Studies indicate that increases in force and power are dependent upon the amount of band resistance (12, 35).

Significant increases in strength, force, and power were not present in studies when a small percentage (less than 10%) of the overall load was achieved through the use of elastic bands (12, 15). Studies by Anderson and Wallace have used elastic band resistances of 20-35% of the load and have shown higher peak and average power and peak force (3, 35). Wallace compared peak and average power at band resistances of 20 and 35%, in the squat, finding 20% to result in higher peak and average power (35). However, Wallace used recreationally trained men and women as subjects and did not require any previous use of elastic bands. Wallace has suggested that there may be a point although he does not suggest at what load this point lies, at which increasing band resistance is not productive (35). Competitive powerlifters have been known to use much higher band resistance in a complex training scheme and witnessed positive results from this training. Though the effects of training with larger elastic loads (greater than 35%)

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cannot be isolated from complex training protocols these successes warrant a more formal investigation into the effects of these loads.

In another study, comparing powerlifters box squatting results while lifting a load of only FW versus lifting a combination of FW and ER, four notable differences were found (31). These differences were achieved with the combination of FW and ER:

1. A greater mean and peak concentric force were produced throughout the range of movement
2. The descent onto the box tended to be accelerated above the normal gravitational rate of 9.8 m/s², so greater eccentric force had to be generated to control the downward motion.
3. The stronger eccentric loading and the brief transition period involved while sitting before exploding upwards provided neuromuscular stimulation which approximates that usually encountered in popular plyometric training.
4. The force generated during the later stages increased, in strong contrast to the situation of normal squatting in which force production tends to decrease significantly.

From these findings it is suggested that similar combinations of free weight and ER may be applicable to other movements (31).

**Muscle Mechanics**

Neuromuscular adaptations are specific to the nature of the load imposed upon the system during chronic training (11, 29, 33). Therefore if a difference is observed between
the kinetics of free weight resistance and VRT then it can be concluded that the
neuromuscular adaptations will be different.

The eccentric portion of the lift plays a critical role in the concentric portion of
the lift, especially the portion just prior to the reversal of bar velocity. Just prior to bar
reversal is when the myotatic reflex can take place. The myotatic reflex is based upon the
activity of the muscle spindles. When the muscle is stretched the muscle spindles cause
an eventual discharge of alpha-motorneurons that in turn generate a reflex contraction of
the stretched muscle (28, 39). There is also the effect of the tendons being stretched and
causin a muscular contraction, which tends to happen more when the muscle is flexed
and a load is applied to the system quickly or with enough force to stretch the tendon
(28). The myotatic reflex and tendon reflex are combined with the effects the central
nervous system to achieve muscular action. The greater the load and the faster it is
applied to the system the greater effect the tendon reflex and thus the greater the
contraction of the affected muscle (28). The Golgi tendon lies in the muscle and inhibits
the muscle when force increases sharply (28, 39) although inhibition of the Golgi tendon
can be achieved through training (39).

Studies suggest that greater eccentric contractions, will cause greater
electromyography (EMG) activity (22). Cronin et al. found significantly greater eccentric
EMG activity when using a jump squat machine with elastic bands attached compared to
using the jump squat machine alone (12). Anderson et al. speculated that while using a
combination of ER and free weights (FW) that “greater muscle fiber recruitment and
stimulation during the eccentric portion of each repetition may bring about greater
neuromuscular adaptations and/or type IIx fiber recruitment” when compared to using only FW (3).

Behm stated that a key component to increasing strength is applying effort to accelerate a load (7). When lifting with sub-maximal FW typically the load is accelerated only as much as is needed to complete the lift, as is described in Figure 1 by Wilson (37). The force needed to move the bar then becomes less than that of the weight of the bar and the bar decelerates (18), whereas with VRT the bar decelerates less (3). Because of this Anderson et al. speculates that the acceleration remained constant longer while using the ER (3). By combining the findings of Bhem and Anderson one could conclude that by requiring the muscles to maintain a positive acceleration longer strength would increase at a greater rate than when training with FW alone.

It has been purposed that by using elastic bands a mechanical advantage is achieved (4, 15). The length-tension relationship of muscles is the main determinant of achieving a mechanical advantage (16, 31). Muscles can produce their peak force around their resting length, or in a bench press, around full extension (35). Therefore with the addition of elastic bands the muscles are receiving the greatest amount of resistance at the point where the greatest amount of force can be produced (35). This is different than with free weight exercises, as full extension when the least amount of force is produced and muscles are not optimally loaded (6).
Summary

A successful training regimen will consist of the best training methods to accomplish the goals of the trainee. Almost all sport requires high amounts of force and power to be generated, therefore high force and power exercises are valuable tools to coaches and athletes. Power and force production are among the most studied variables in all weight lifting related research. Although much research has been conducted on the force and power generated through traditional free weight exercises there has been little research on these variables produced in VRT methods. Some of the research that has investigated VRT may not be applicable due to mistakes in subject selection or set up of the variable resistance device. Also no research has been conducted on high loads of variable resistance, this may be due to the lack of experience the test subjects have with VRT. A solution to this issue would be to measure power and force outputs of trained individuals utilizing a familiar exercise with the variable resistance device setup as is common in the field.
CHAPTER 3

METHODS

INTRODUCTION

In the world of sports performance everyone is always looking for an edge. This has led to the development of many different training methods in order to induce greater gains. A promising method that has arisen is variable resistance training (VRT). There has been anecdotal evidence of VRT increasing strength and power (32, 34) VRT has been popular in powerlifting for more than a decade and more sports coaches are
beginning to accept it as a viable training method. The amount of research on VRT is limited. There has been no research investigating large percentages (over 35%) of the total load being supplied by variable resistance. The purpose of this study was to investigate the effects of three different loads (20%, 50% and 75% of the total load) provided by variable resistance and compare them to a press without variable resistance.

**Participants**

Seven experienced, healthy, male powerlifters and bodybuilders (aged 29.4 ± 5.8 years, body mass of 110.1 ± 14.5 kilograms) were recruited from a local powerlifting gym in Muncie, IN. The average maximal bench press of the subjects was 165.6 ± 20.2 kilograms. Participants were prescreened to ensure that there were no previous or present upper extremity injuries and no cardiovascular risk factors. Also, participants must meet the minimum requirement to be able to bench press a minimum of 136.4 kilograms and have had previous experience with ER bands in his training. After initial recruitment, the procedures, potential risks, and benefits associated with study participation were explained to the subjects. All participants signed informed consent forms approved by BSU Institutional Review Board (IRB) and filled out a health history document, medical history document, and a training history document.

**Calibration of the Elastic Bands**

All elastic bands used in this study were new and previously unused. The set was calibrated prior to the testing session using an Advanced Mechanical Technologies Incorporated (AMTI) force plate (Watertown, Massachusetts) set to collect at 2400 Hz and fifteen VICON F-series cameras set to collect at 120 Hz. The bands were attached to
a rack and bar in the same manner as they would in testing. The rack was then placed
over an AMTI force plate that was flush with the ground. A cinder block and a stack of
wooden blocks were placed on the force plate. The bar and attached bands were then
placed on the stack of blocks. The force exerted and the position of the bar was then
recorded. The height of the blocks was increased approximately every 3.8 centimeters (1 ½ inches) and the process was repeated. A total of twenty-two measurements were taken.
The force plate was tared each round so that the weight of the blocks equaled zero. Two
markers, one on each end of the bar were used to determine the positional data of the bar.
The range of the calibration exceeded the possible range of motion in the bench press. A
calibration force-displacement curve was generated for each band using a custom
MATLAB code. A best fit line (quadratic) was then applied to each force – displacement
curve using MATLAB’s curve fitting software. Using the equation generated by the best
fit line force outputs could be determined for each band at any distance within the
calibrated distance.

**Experimental Procedures**

The first testing session consisted of a one repetition maximal bench press and the
measuring of the full extension distance. All weights used for these procedures were
calibrated prior to subject testing. The testing procedure for the maximal effort bench
press followed ACSM guidelines on maximal effort strength testing (2). The subject was
allowed to eat and warm up (sub-maximal presses) as they would for their normal
training or contest, which includes no prior exercise before the session began. The
subject’s 1RM was determined within 4 trials with sufficient rest (4-5 minutes) between
attempts (39). The measure of full extension distance consisted of measuring the distance
from the center of the bar to the floor in the subject’s bench position with arms fully extended. Testing was performed in the athletic strength and conditioning facility in Worthen Arena at Ball State University.

Using the equations generated in MATLAB and the measured distance of each subject’s full bench press extension, the band combination for all conditions was determined. For each condition the load provided by FW was determined first using the appropriate percentage. The bar weight was then rounded to the nearest five pounds. The band resistance was then added to the bar to add up to the 85% of 1 repetition max load. The length of the bands was manipulated by adjusting the bench height and rack height in order to achieve the desired load. All loads provided by the bands deviated by no more than 1.5% of the desired amount.

The second testing session took place no earlier than one week after the first testing session. Participants were allowed to warm up as they would for normal training or contest. Two reflective markers were placed on each end of the bar and its position was recorded through fifteen F-Series VICON cameras. The information from the cameras was collected and reconstructed with VICON Workstation software. The collection rate was set at 120 Hz. The elastic bands were then set up using the “double looped” method (Figure 3).

Figure 3- Picture of Band Attachment
The participants then completed a single bench press with each of the four conditions (Table 2). The order of the conditions was determined by using a Latin Square (17). Participants were allowed sufficient rest (4-5 minutes) between attempts (39). The testing for the second session took place in the Biomechanics Laboratory at Ball State University.

Table 2- Testing condition loads for the experiment

<table>
<thead>
<tr>
<th>Condition</th>
<th>Load (% of Max)</th>
<th>% of Load provided by band</th>
<th>% of Load provided by weight</th>
</tr>
</thead>
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<tr>
<td>1</td>
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<td>3</td>
<td>85</td>
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<td>50</td>
</tr>
<tr>
<td>4</td>
<td>85</td>
<td>75</td>
<td>25</td>
</tr>
</tbody>
</table>

**Data Collected for Concurrent Studies**

During the second testing session participants had four EMG electrodes placed on them. One electrode each was placed on the medial tricep, short head of the biceps, anterior deltoide and pectoralis major each on the right side of the body. EMG data were collected for further study but were not analyzed in the current study.
Data Reduction and Analysis/Statistics

The position data was reconstructed, filtered, and gaps in the data were filled using a Woltering filter with predicted MSE of 20. Utilizing the position data from VICON Workstation, the known bar weight, and the force-displacement equations of the elastic bands, the velocity, force, and power were calculated utilizing a custom MATLAB code. The custom MATLAB code operated on the basis of Newton’s second law as is applied in the formulas in Figure 4 where F is force, m is mass and a is acceleration of the bar.

![Figure 4- Newton’s Second Law and how it was used in this study](image)

\[ F_{\text{Total}} = m \times a \]
\[ F_{\text{Person}} = F_{\text{Bar}} - F_{\text{Bands}} = m_{\text{Bar}} \times a \]
\[ F_{\text{Person}} = (m_{\text{Bar}} \times a) + F_{\text{Bar}} + F_{\text{Bands}} \]

Bar Force and bar mass were known. The positional data from the ends of the bar was averaged and filtered using a zero-lag second order Butterworth filter to account for any inconsistencies in the bar path and determine bar displacement. The first and second derivatives (velocity and acceleration) of bar displacement were then found and filtered with a second order Butterworth filter. The force from the bands was determined using the force-displacement curves created during the band calibrations. Knowing the force and velocity caused by the person, power generated was found through the equation \( P = F \times v \) (P is power, F is force and v is velocity).
SPSS v16 (SPSS Inc. Chicago, IL) was used to perform statistical analysis. One way ANOVAs were used to determine the differences in peak concentric power, peak concentric force and peak eccentric velocity among the four experimental conditions. Pairwise comparisons were made using the Least Significant Difference method. Significant level was set at 0.05.
Title: The Effects of Elastic Resistance Bands on the Bench Press

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The Effects of Elastic Resistance Bands on the Bench Press
ABSTRACT

Elastic bands are becoming more popular in strength and power training. Although increases in strength and power have been anecdotally reported with high loads of elastic resistance, there is no research on large band tensions and their effects on force and power variables. The purpose of this study was to quantify peak concentric force, peak concentric power and peak eccentric velocity produced by the subject when using differing levels of elastic resistance (0%, 20%, 50% and 75% of the total load being elastic resistance) in the bench press. Seven experienced male powerlifters and body builders participated in this study. Prior to subject testing all elastic bands were calibrated for force output throughout the bench press range of motion. Each subject performed a single repetition maximum press to determine the total correct testing load (85% of maximum press). The subjects then performed four presses with various elastic band resistances, each having the total equivalent weight of 85% of the subject’s maximal press weight at lockout. Dependent variables were peak concentric force, peak concentric power, and peak eccentric velocity as produced by the subject. A one-way ANOVA was used to determine the differences among the four levels of elastic resistance (ER) used in the study (α = 0.05). Compared to the baseline condition (2123.6 ± 499.9N), significantly lower average peak concentric force was observed with ER of 75% (1451.2 ± 151.0N, 31.9% decrease) (p = 0.01) and with an ER of 50% (1781.1 ± 174.3N, 16.4% decrease) (p = 0.05). When compared with baseline peak concentric power (702.6 ± 274.6W), higher peak power was observed in all band trials: 20% (895.2 ± 187.7W, 27.4% increase), 50% (972.5 ± 189.8W, 38.4% increase) and 75% (979.6 ± 171.0W, 39.4% increase) (p = 0.009; p = 0.007; p = 0.033, respectively). There was no significant difference in peak
concentric power in any ER trials. No significant differences (p = 0.08) were seen in peak eccentric velocity. Therefore ER loads of 20, 50 and 75% provide greater stimuli for producing peak concentric power than no ER, with only a 20% load of ER maintaining the same peak concentric force production as baseline. ER loads of 50 and 75% may not be as effective stimuli as free weights when the training objective is to increase force production.

Keywords: bench press, elastic resistance, variable resistance training
INTRODUCTION

The ability to produce high power output is vital in sport (15), but there is still much debate regarding how to best improve power output in athletes (4). Many methods have been experimented with during recent years. One method that has demonstrated success is variable resistance training (VRT). VRT alters resistance throughout the movement of the exercise. Almost all forms of VRT decrease the resistance throughout the eccentric portion and then subsequently increase resistance during the concentric portion of the exercise. VRT has become increasingly popular in the strength and conditioning community over the past few years. One of the more popular methods utilizing VRT is to combine elastic resistance (ER) with free weights FW. Increases in both strength and power have been reported using this method (2, 12). Scientists have used several apparatuses to achieve the ER. In some studies bungee cords were used to provide the resistance (2, 6) while others have used elastic bands (12). Even though the principles are the same, elastic bands are far more popular in the strength and conditioning community. As has been shown the success of achieving increased amounts of force and power is dependent upon the amount of band tension (6, 12).

Significant increases in strength, force, and power were not reported in studies wherein a small percentage (less than 10%) of the overall load is achieved through the use of elastic bands (6, 7). A study by Anderson and another by Wallace (both used ER consisting of 20-35% of the load) demonstrated higher peak and average power and force (2, 12). In the scientific community the 20-35% range is the highest amount of tension tested. Even though Wallace suggested that there may be a point at which increasing band tension is not productive (12), competitive powerlifters have been known to use
much higher band tensions in a complex training scheme and have witnessed positive results from this training (10). Although this has been observed in the field, no studies have compared elastic band tensions above 35%. Wallace compared peak and average power at band tensions of 20 and 35%, finding 20% to result in higher peak and average power than 35% ER (12). However, Wallace used recreationally trained men and women as subjects, and did not require any previous use of elastic bands. It may prove that Wallace’s results showed poor performances at higher band tensions because those individuals were not accustomed to the bands and higher tensions of ER.

The purpose of this study was to test different amounts of elastic tension ranging from smaller loads (20%) to larger loads (50 and 75%) that have not yet been observed scientifically. Individuals with experience using ER and a common band setup will be used in testing. It was hypothesized that 1) peak concentric power will increase with progressively larger amounts of ER; 2) peak concentric force will remain approximately the same throughout all conditions; and 3) peak eccentric velocity will increase with an increase in ER.

METHODS

Experimental Approach to the Problem

This investigation was intended to observe the differences in peak concentric power, peak concentric force, and peak eccentric velocity with different loads of ER. All testing used experienced subjects and common band setup methods.

Subjects
Seven experienced healthy male powerlifters and bodybuilders (aged 29.4 ± 5.8 years, body mass of 110.1 ± 14.5 kilograms, max bench press 165.6 ± 20.2 kilograms) were recruited from a local powerlifting gym in Muncie, IN. Participants were prescreened to ensure that there were no previous (within last two years) or present upper extremity injuries and no cardiovascular risk factors. Also, participants were able to bench press a minimum of 300 pounds and have had previous experience with ER bands in their training. After initial recruitment, participants were stepped through procedures, potential risks, and benefits associated with study participation. All participants signed informed consent forms approved by BSU Institutional Review Board (IRB), filled out a health history document, and a training history document.

Procedures

A new set of ER bands was used for the testing procedure. The set was calibrated prior to the testing session using an Advanced Mechanical Technologies Incorporated (AMTI) force plate (Watertown, Massachusetts) set to collect at 2400 Hz and 15 VICON F-series cameras set to collect at 120 Hz. The bands were attached to a rack in the same manner as they would in testing but over the AMTI force plate. The force plate was zeroed so that the bar and a predetermined height of blocks were equal to zero. The force exerted by the bands and the position of the bar was then recorded. The height of the blocks was increased approximately every 3.8 centimeters and the process repeated. The range of the calibration exceeded the possible range of motion in the bench press. A calibration force-displacement curve was generated for each band using a custom MATLAB code.
Subjects participated in two different testing sessions which took place at least one week apart. This session took place in the athletic weight room at Ball State University. The equipment used for both sessions was of the same manufacturer and model. The first session consisted of a single repetition max bench press test and a measurement of the height of the supine subject’s full elbow extension (full lockout). The measurement for the height of the full arm extension was defined as the distance between the center of the end of the bar and the floor. ACSM guidelines (1) were followed to find the maximum bench press for each individual, which includes no prior exercise that day. Each subject’s maximal bench press was found in no more than four attempts. Using the data from the band curves, the subject’s maximal bench press, and the measured distance of the subject’s full elbow extension, the appropriate band combinations were determined for each trial. The length of the bands were manipulated by adjusting the bench height and rack height in order to achieve the desired load. All loads provided by the bands deviated by no more than 1.5% of the desired amount.

The second testing session was performed in the Biomechanics Laboratory at Ball State University. Participants were allowed to warm up as they would for normal training or contest. Two reflective markers were placed on the ends of the bar and its position was recorded through fifteen MX -13 VICON cameras. The information from the cameras was collected and reconstructed with VICON Workstation software. The collection rate was set at 120 Hz. The elastic bands were set up using the “double looped” method (Figure 1).
The participants then completed a single repetition of the bench press with each of the four conditions (Table 1). The order of the conditions was determined by a Latin Square (8). Participants were allowed sufficient rest (4-5 minutes) between attempts (14).

Statistical Analysis

The point data was reconstructed, filtered, and gaps in the data were filled using a Woltering filter with predicted MSE of 20. Utilizing the position data from VICON Workstation, the known bar weight, and the force curves of the elastic bands generated through MATLAB (MathWorks, Boston, MA), each subject’s peak eccentric velocity, peak concentric force, and peak concentric power were calculated for each trial utilizing a custom MATLAB code.

SPSS v16 (SPSS Inc. Chicago, IL) was used to perform statistical analysis. One way ANOVAs were used to determine the differences between the baseline condition and conditions with various band resistances (20%, 50%, and 75%). The dependent variables were peak concentric power, peak concentric force and peak eccentric velocity. Significance was set at 0.05.
RESULTS

Significant changes were observed in two conditions for peak force $p \leq 0.001$ (Table 2), and all conditions for peak power $p = 0.002$, (Table 3). Follow-up pairwise comparisons indicated significant differences in both 50% ER ($1781.1 \pm 174.3N$), ($p = 0.05$) and 75% ER ($1451.2 \pm 151.0N$), ($p = .010$), which demonstrated a decrease in force when compared to the baseline trial ($2123.6 \pm 499.9N$). Significant differences in peak concentric force were seen between all ER conditions 20% and 50%, ($p = .001$); 20% and 75%, ($p \leq .001$); and 50% and 75% ($p = .001$).

When compared to the baseline ($702.6 \pm 274.6W$), differences in peak concentric power were significantly greater at all levels: 20% ($895.2 \pm 187.7W$), ($p = 0.009$); 50% ($972.5 \pm 189.8W$), ($p = 0.007$); and 75% ($979.6 \pm 171.0W$), ($p = 0.033$). Follow-up pairwise comparisons showed no significant differences between of ER conditions for peak concentric power. For peak eccentric velocity all comparisons were insignificant, ($p = .080$), (Table 4).

DISCUSSION

The purpose of this study was to determine how the kinetic properties of the bench press change with different loads of ER. It was also the intent of this study to be as applicable as possible to the strength and conditioning community. This determined how
the bands were set up, what bands were used, and the subject population selected. While the effects of smaller elastic loads have been observed in previous studies (2, 3, 6, 7, 12), no study to date has tested elastic tensions of 50 and 75%. Although greater tensions have been known to be used anecdotally, this is the first scientific study to observe the kinetics of such high elastic tensions at greater loads.

The results of this study support the hypothesis that combined loads of FW and ER result in greater peak concentric power than FW alone. These findings support using a combination of FW and ER as a training modality to increase power production. Furthermore the comparisons between ER conditions indicate peak concentric power does not change significantly between any of the ER conditions. Even though there is a 10% increase in peak concentric power between the 20% ER condition and the 50 or 75% ER conditions, a large standard deviation negates this change. The only differences observed between ER conditions were in peak concentric force.

Significant decreases in peak force were observed at the 75% and 50% ER levels with a 31.9% and 16.4% decrease in force from the FW baseline respectively. Such large decreases in peak force would provide poor stimuli to encourage strength gains.

Even though the subjects in this study were competitive bodybuilders and powerlifters there were still some large variations observed in the eccentric velocity (see standard deviations in Table 4). Although all subjects had experience with ER, not all of the subjects were accustomed to larger elastic loads. While all subjects performed well with the free weight and 20% elastic load, and most did well with 50% elastic tension, some had difficulty controlling the loads consisting of 75% ER. Therefore more
consistent results may be seen if subjects were accustomed to this resistance prior to the testing session.

The findings from this study contradict the findings of Wallace, who observed a greater peak power when ER was 20% of the load rather than 35% of the load, with the load being 85% of the subjects’ 1 RM (12). When comparing the methods of this study to those of Wallace (12), there are several important differences, the movement tested, band setup, and the amount of experience subjects had with the variable resistance. One main difference between this study and Wallace’s is the movement tested. This study tested the bench press while Wallace’s study was focused on the squat. When comparing the force profiles of the bench press (13) and the squat (15) they are very similar. This is especially true of the maximal effort bench press and sub-maximal effort squat force profiles. Both lift’s force profiles have; an acceleration phase (peak in force) to initiate the lift, a deceleration phase, and a second peak in force (associated with peak power in the squat). Zink also observed some sub-maximal bench presses with a similar force profile (15). In sub maximal bench press force profiles that did not resemble the two-peak curve, the force profile was simply an acceleration phase followed by a large deceleration phase (13). Even though there is some difference between the force profiles of the bench press and the squat, similar results have been reported when ER is applied. During his discussion Anderson made no distinction on how elastic tension affected the bench press or squat differently in any aspect (2). In fact Anderson described how the combined resistance (FW and ER) had the similar effects on strength in the bench press and the squat (2). Since performance effects are related to neuromuscular adaptations caused
specifically by the type of load over time (5, 9, 11), if similar effects are seen in the bench press and the squat than the kinetic properties (force and power production) behind those lifts should be similar.

Another key difference between this study and Wallace’s is the subject population that was tested. Wallace only required his subjects to have six months of experience with the back squat and none of the subjects had any prior experience with ER (12). This study tested individuals who were competitive in nature; bench pressed a minimum of three hundred pounds and had prior experience with ER. When looking at the subject populations from a practical sense, Wallace’s study examined the effects of ER on individuals as if it were their first training session, while this study examined the effects of ER on those who had been training with ER for some time. It would make sense that professionals in the field would want to know the effects of ER after an extended period of use, rather than the effects brought on by the first training session. Possibly the most important difference between this study and Wallace’s study is the method used to determine the testing load. In this study the total load at the top of the lift was always equal to 85% of the subject’s 1RM. Wallace’s main goal was to make the total work done equivalent between conditions, not to standardize the total load at the top of the lift. In fact in Wallace’s study the load at the top with 20% and 35% ER was actually equal to 95% and 100% of the subject’s 1RM respectively. Wallace’s method of loading essentially places a cap on the amount of ER that can be used and negates the actual kinetic properties of using ER. Also, Wallace’s loading method is not representative of
how ER is used in the strength and conditioning community and therefore has limited applicability.

Given the small sample size for this study, and some large variations in data it is recommended that future studies of variable resistance utilize larger subject pools. With such a small sample size it is possible that changes may be hidden by variability. Other limitations of this study include the results being specific to male powerlifters and bodybuilders who can bench press over three hundred pounds and that ER was provided only by double looped elastic bands. Recording subject experience with VRT and possibly making a distinction between those who have never used VRT methods, used VRT a little, and those who are proficient with it, may help control for variability. Future studies should focus on the mechanisms behind the training effects of variable resistance training, especially the effects of different intensities of loads.

PRACTICAL APPLICATIONS

From the findings in this study it is concluded that large amounts of elastic tension would provide experienced individuals with a great stimulus for developing power, but a poor stimulus for developing strength. The 20% elastic resistance condition showed no decrease in peak force, and a 27.4% increase in peak power. Therefore 20% elastic tension could be used as a middle ground as it would train both force and power production. The results of this study support using loads of 0 and 20% ER to increase muscular force and loads of 20, 50 and 75% ER to increase muscular power.
Table 1 - Testing condition loads for the experiment

<table>
<thead>
<tr>
<th>Condition</th>
<th>Load (% of Max)</th>
<th>% of Load provided by band</th>
<th>% of Load provided by weight</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>85</td>
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<td>100</td>
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<tr>
<td>4</td>
<td>85</td>
<td>75</td>
<td>25</td>
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</table>
Table 2- Change in peak concentric force

<table>
<thead>
<tr>
<th>Load Provided by Band</th>
<th>Peak Concentric Force (N) Mean ± SD</th>
<th>Percentage change from Baseline</th>
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</thead>
<tbody>
<tr>
<td>0%</td>
<td>2123.6 ± 499.9</td>
<td>--</td>
</tr>
<tr>
<td>20%</td>
<td>2185.4 ± 275.3‡</td>
<td>2.5</td>
</tr>
<tr>
<td>50%</td>
<td>1781.1 ± 174.3*†</td>
<td>-16.4</td>
</tr>
<tr>
<td>75%</td>
<td>1451.2 ± 151.0*†‡</td>
<td>-31.9</td>
</tr>
</tbody>
</table>

* significantly different than baseline, p<0.05
† significantly different than 20% trial, p<0.05
‡ significantly different than 50% trial, p<0.05
**Table 3- Change in peak concentric power**

<table>
<thead>
<tr>
<th>Load Provided by Band</th>
<th>Peak Concentric Power (W) Mean ± SD</th>
<th>Percentage change from Baseline</th>
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</thead>
<tbody>
<tr>
<td>0%</td>
<td>702.6 ± 274.6</td>
<td>--</td>
</tr>
<tr>
<td>20%</td>
<td>895.2 ± 187.7*</td>
<td>27.4</td>
</tr>
<tr>
<td>50%</td>
<td>972.5 ± 189.8*</td>
<td>38.4</td>
</tr>
<tr>
<td>75%</td>
<td>979.6 ± 171.0*</td>
<td>39.4</td>
</tr>
</tbody>
</table>

* >significantly different than baseline 0.05 level
Table 4- Change in peak eccentric velocity

<table>
<thead>
<tr>
<th>Load Provided by Band</th>
<th>Peak Eccentric Velocity (m/s) Mean ± SD</th>
<th>Percentage change from Baseline</th>
</tr>
</thead>
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<tr>
<td>0%</td>
<td>-0.493 ± 0.184</td>
<td>--</td>
</tr>
<tr>
<td>20%</td>
<td>-0.548 ± 0.114</td>
<td>11.2</td>
</tr>
<tr>
<td>50%</td>
<td>-0.640 ± 0.114</td>
<td>29.9</td>
</tr>
<tr>
<td>75%</td>
<td>-0.751 ± 0.271</td>
<td>52.5</td>
</tr>
</tbody>
</table>
Figure 1- Attachment of elastic bands to the bar
References


Summary

A variety of training methods has been investigated over the years, most investigations attempting to find a training method to develop an athlete’s power output. While these attempts are valid investigations the scientific community has not kept pace with that of the developments in the strength and conditioning world. Variable resistance training, specifically training with ER, has been used in the strength and conditioning field for some time with great success. While the few training studies using variable resistance training have shown positive results only a handful of studies have attempted to quantify the actual kinetic properties behind exercises using variable resistance, and
since the setup is not realistic for the gym, the results from these studies are not applicable.

The purpose of this study was to provide an insight to the kinetic effects elastic bands have on the bench press when set up in a typical training manner. All elastic bands were calibrated in the same manner as would be used in the testing process and force-displacement curves were generated prior to subject testing. Seven male experienced powerlifters and bodybuilders performed three presses with different levels of ER (20%, 50%, and 75%). The load at full arm extension was always 85% of the subject’s 1RM press. The peak concentric force, peak concentric power, and peak eccentric velocity from each of these presses was compared back to a baseline press of 85% of the subject’s 1RM. The baseline press consisted of only weighted resistance. Kinematics of the bar were captured and were used along with the force-displacement curves from the elastic bands to calculate the appropriate kinetics.

There were no significant differences between peak eccentric velocities. Only the trial with 75% band resistance showed a significant decrease (31.9%) in force when compared to the baseline trial (p=0.01). When compared to the baseline large increases in peak concentric power were observed at all levels of ER: 27.4% (20%), 38.4% (50%), 39.4% (75%). Differences between peak concentric power and baseline were significant at all levels: 20% (p=0.009), 50% (p=0.007), and 75% (p=0.033).

**Conclusions**

Not all subjects produced the highest amount of power in the same loading condition, this may be linked to the amount of experience with heavy elastic tensions.
This is supported by the results of Wallace, who showed that a group of inexperienced individuals produced higher power with 20% elastic tension rather than 35% (35). This could be because individuals who train often with variable resistance are likely to have different neuromuscular adaptations than those who train solely with FW, as neuromuscular adaptations are specific to the chronic training loads (11, 29, 33).

Peak force only significantly changes when the load is substantially different (from 0% to 75% of the load being ER). Thus loads consisting of small or medium amounts of elastic tension may have similar benefits, in terms of creating high forces, to training with FW. This study showed power output can be greatly increased when using elastic tension, as compared to FW, especially with higher amounts of tension (50-75%). Therefore smaller amounts of elastic tension, <20%, could be use to increase force production (strength) and larger amounts of tension, 50-75%, to train for higher power outputs. This conclusion is similar to that reached by Anderson, although Anderson suggested only 30% of the 1RM consist of elastic tension to increase power output (3). These differences in recommendations may be linked to Anderson’s subjects having no previous experience with variable resistance (3).

**Recommendations for Future Research**

Given the small sample size for this study, and some large variations in data it is recommended that future studies of variable resistance utilize larger subject pools. With such a small sample size it is possible differences between groups is hidden by variability within subjects. Also to help control for variability to record subjects experience with variable resistance training and possibly making a distinction between those who have
never used variable resistance training methods, used variable resistance training a little, and those who are proficient with it, especially when the study concerns high amounts of variable resistance. Studies should focus on the mechanisms behind the training effects of variable resistance training, especially the effects of different intensities of loads.
REFERENCES


34. Tate D. 2001.
Appendix A

Informed Consent

INFORMED CONSENT

Ball State University – Biomechanics Laboratory

Effect of elastic resistance bands on the bench press.

This is a scientific research study conducted by the personnel of the Biomechanics Laboratory at Ball State University. The principle investigator will be Michael Lawrence, a graduate assistant in the Ball State Biomechanics Laboratory. The purpose of this study is to examine the effects of small, medium, and large loads of elastic resistance compared to a baseline of weighted resistance in the bench press. The second
The purpose of this study is to examine the method of utilizing variable resistance training to overload the top portion of the bench press over the current max press.

You will be asked to complete a medical history questionnaire and prior to beginning the study. If you answer yes to any of the questions you will be not be able to participate in the study. You will also be asked to fill out a ‘AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire’ if you mark any one question in the first section (“History”) or any two in the second section (“Cardiovascular Risk Factors”) then you will be required to receive a doctor’s permission before participating in the study. Testing will be performed in the Athletic Weight room at Ball State University. You will be asked to fill out a form reporting if you have previous experience in using elastic resistance bands in your training. If you do not have previous experience using elastic resistance bands than you will be excluded from the study. If you cannot bench at least three hundred pounds during the first testing session, than you will be excluded from the study. The entirety of the study will require you to be present for a total of three hours. The time commitment for each visit is explained further in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Visit</th>
<th>Activity</th>
<th>Time Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Informal Meeting/Explanation of Study/Signing Informed Consent/ Filling out paperwork</td>
<td>30 minutes</td>
</tr>
<tr>
<td>2</td>
<td>One Repetition Maximal Effort Bench Press</td>
<td>30 minutes</td>
</tr>
<tr>
<td>3</td>
<td>One Press at each of 5 different Elastic Resistance Conditions</td>
<td>2 hours</td>
</tr>
</tbody>
</table>

During your first visit, you will sign the informed consent. The principle investigator will explain the study to you.

During your second visit, the first testing session will be conducted. You will perform a single repetition maximal bench press test. This testing session will take place in the athletic weight room in Worthen Arena at Ball State University. The testing procedure will follow ACSM guidelines on maximal effort strength testing (2). You will be allowed to
eat and warm up as you would for your normal training or contest, which includes no prior exercise that day. Your 1RM will be the last successful press. You will have sufficient rest (4-5 minutes) between attempts. Resistance will be progressed by 2.5 to 20 kilograms until you cannot complete the lift. After the testing is complete you will be free to leave the area. Your second testing session will be scheduled at least seven days after the first testing session.

During your third visit, the second testing session will be conducted. This testing session will be conducted in the Biomechanics Laboratory at Ball State University. You will have four EMG electrodes placed on your upper body. You may experience some minor discomfort during the preparation for application of the electrodes. The area where the electrodes are to be placed will be shaved, lightly abraded and swabbed with alcohol. One electrode will be placed on the tricep, bicep, anterior deltoid and pectoralis major each on the right side of the body. You will then complete a single bench press with each of the five conditions. You will be allowed sufficient rest (4-5 minutes) between each attempt. After the testing is complete you will be free to leave the area. You will be asked to refrain from strenuous exercise previous to testing as this may affect results.

The risk involved with maximal weight lifting includes, but is not limited to, muscle strains, muscle tears, and sprains. The possibility of a cardiovascular event including but not limited to myocardial infarction or stroke is also present due to required maximal exertion. However, every effort will be made to reduce the risk of injury by ensuring adequate warm-up, proper lifting technique, and close monitoring of all subjects' exercise form during testing. Participants may experience some muscle soreness after the testing session. Members of the research team, including spotters, will be present during the testing procedures. In the event of a medical emergency, care is available at Ball Memorial Hospital. You will be responsible for the costs of any care that is provided.

Your participation in this study is voluntary and you are free to withdraw at any time for any reason without penalty or prejudice on the part of the investigator. Your results will be treated with strict confidentiality and your name will not be used in any presentation of the results from this study. You will be given a number to identify your data and only the principal investigator will have access to these numbers. Your name will not be used in connection with any part of this study. The data from this study will be retained indefinitely. The paper data will be destroyed after 3 years. The electronic data will be stored on a secure storage computer in the Biomechanics Laboratory where the data will
be password protected only accessible by the research staff. The subject code will be kept in a separate and secure location. At the conclusion of this study, you will be supplied with all pertinent results as well as a brief interpretation of those results. The results will include maximal bench press, bar speed, force output and power calculations as well as EMG activity. These results will be provided on paper at which time the subject will have the opportunity to speak with any member of the research team about the results. This information is intended to give you some impression of the procedures, the stresses, and the risks associated with this study. If you have any questions, either now or in the future, feel free to ask the investigator.

For one’s rights as a research subject, the following person may be contacted: Coordinator of Research Compliance, Sponsored Programs Office, Ball State University, Muncie, IN 47306, (765) 285-5070.

It is understood that in the unlikely event of physical injury resulting from research procedures, Ball State University, its agents and employees, will assume whatever responsibility is required by law. Emergency medical treatment for injuries or illness is available where the injury or illness is incurred in the course of the study but compensation from BSU for medical treatment will not be available.
INFORMED CONSENT

Ball State University – Biomechanics Laboratory

I ____________________________ believe that I am in good physical condition and agree to participate in this research entitled “Effect of elastic resistance bands on the bench press.” I have had the study explained to me and my questions have been answered to my satisfaction. I have read the description of this study and give my consent to participate. I understand that I will receive a copy of this consent form to keep for future reference.

___________________________________________
Participant Name (Please Print) Date

___________________________________________
Participant Signature Date

___________________________________________
Investigator Signature Date

__________________________________________                      ________________
Principal Investigator: Faculty Advisor:

Michael Lawrence            Henry Wang, Ph.D.
Ball State University        Ball State University
Biomechanics Laboratory      Biomechanics Laboratory
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Muncie, IN 47306            Muncie, IN 47306
(765) 285-5178              (765) 285-5139
E-mail: malawrence@bsu.edu   E-mail: hwang2@bsu.edu
Medical History Questionnaire

Please answer the following questions to the best of your knowledge.

1. Have you in the last 2 years experienced any serious injury to any part of the wrist including the ligaments, cartilage, other soft tissue, or the joint itself? (i.e. broken wrist) Did recovery require surgery?

2. Have you in the last 2 years experienced any serious injury to any aspect of the elbow including the ligaments, cartilage, other soft tissue, or the joint itself? Did recovery require surgery?
3. Have you in the last 2 years experienced any serious injury to any aspect of the shoulder including the ligaments, cartilage, other soft tissue, or the joint itself? (i.e. shoulder dislocation, torn labrum, etc.) Did recovery involve surgery?

4. Have you recently experienced any injuries to the musculature of the upper body? (i.e. bicep strain or rupture)

5. Have you in the last 2 years broken your humerus, ulna, radius, clavicle or any part of the upper body?

6. Have you experienced any upper extremity injury within the past 4 weeks or is there any other upper extremity issue that may compromise your ability to perform a bench press?
Weightlifting History Form

For the study entitled: Effect of elastic resistance bands on the bench press.

1) Do you have experience bench pressing with elastic bands attached to the bar?
Appendix D

Health History Questionnaire
AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire

Assess your health status by marking all true statements

History

You have had:

- a heart attack
- heart surgery
- cardiac catheterization coronary
- angioplasty (PTCA)
- pacemaker/implantable cardiac defibrillator
- rhythm disturbance
- heart valve disease
- heart failure
- heart transplantation
- congenital heart disease

Symptoms:

- You experience chest discomfort with exertion.
- You experience unreasonable breathlessness
- You experience dizziness, fainting, or blackouts
- You take heart medications

Other health issues

- You have diabetes
- You have asthma or other lung disease
- You have burning or cramping sensation in your lower legs when walking short distances
- You have musculoskeletal problems that limit your physical activity.
- You have concerns about the safety of exercise
- You take prescription medication(s).
- You are pregnant.

If you marked any of these statements in this section, consult your physician or other appropriate health care provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

Cardiovascular risk factors

- You are a man older than 45 years.
- You are a woman older than 55 years, have had a hysterectomy, or are postmenopausal
- You smoke, or quit smoking within the previous 6 months.
- Your blood pressure is >140/90 mm Hg.
- You do not know your blood pressure.
- You take blood pressure medication.
- Your blood cholesterol level is >200 mg/dl.
- You do not know your cholesterol level.
You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister).

You are physically inactive (i.e., you get <30 minutes of physical activity on at least 3 days per week).

You are >20 pounds overweight

If you marked two or more of the statements in this section you should consult your physician or other appropriate health care provider before engaging in exercise. You might benefit from using a facility with a professionally qualified exercise staff to guide your exercise program.

None of the above

You should be able to exercise safely without consulting your physician or other appropriate health care provider in a self-guided program or almost any facility that meets your exercise program needs.