EFFECT OF PROGRESSIVE CALISTHENIC PUSH-UP TRAINING ON MUSCLE STRENGTH & THICKNESS

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Effect of progressive calisthenic push-up training on muscle strength & thickness

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ABSTRACT

Calisthenics, a form of resistance training, continue to increase in popularity; however, few studies have examined their effectiveness for muscle strength improvement. The purpose of this study was to compare progressive calisthenic push-up training (PUSH) to free weight bench press training (BENCH) as techniques to develop muscle strength and thickness. Twenty-three healthy, moderately trained males (mean ± SD: age 23 ± 6.8 years) were randomly assigned to PUSH (n=14) and BENCH (n=9), and trained three days per week for four weeks. Muscle thickness, seated medicine ball put, one repetition max bench press (1RM), and push-up progression (PUP) were measured pre- and post-training. Results revealed significant increases in 1RM ($p<0.001$) and PUP ($p<0.05$) for both groups post-training. The increase in PUP, however, was significantly greater for PUSH ($p<0.001$). This study is the first to demonstrate that calisthenics, using different progressive variations to maintain training principles, can improve upper body muscle strength.

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CHAPTER I. INTRODUCTION

Resistance training (RT) is a popular form of physical activity because it develops several neuromuscular and musculoskeletal characteristics: muscular power, muscular hypertrophy, muscular endurance, and muscular strength (Feigenbaum & Pollock, 1999; Kraemer & Ratamess, 2004; Ratamess et al., 2009). In order to improve one of these characteristics, and continue exercise progression, the demands of the exercise must be increased. To achieve exercise progression, a trainer manipulates RT variables. Among these variables are the external resistance used, number of sets and repetitions per exercise, rest interval length, and frequency of the activity (de Salles et al., 2009; Kraemer & Ratamess, 2004; Ratamess et al., 2009). Many studies have examined the effect of manipulating these training variables on muscle strength improvement (Berger, 1962; Campos et al., 2002; Capen, 1956; Ratamess et al., 2012).

Maximum muscular strength is defined as the amount of force a person's muscles can exert in a single maximal effort (Ratamess et al., 2009). According to previous studies, multiple-set programs, consisting of three to six sets, are ideal to increase muscle strength (Berger, 1962; Capen, 1956; Kraemer & Ratamess, 2004). The recommended number of repetitions for each exercise should be slightly less than or equal to six (Berger, 1962; Campos et al., 2002). Rest intervals from two to five minutes are necessary to maintain the prescribed number of repetitions per set because strength training is a very intense activity (de Salles et al., 2009). Training variables for maximal strength are not the same for muscle hypertrophy (muscle growth); thus, changes in muscle thickness are unlikely to occur. By applying these guidelines to a RT program increases in muscle strength should be achieved.

Calisthenic exercise (bodyweight training) is a form of RT that continues to increase in popularity over the last couple years. In fact, calisthenics was listed as the number two fitness trend for 2016, number one for 2015, by the American College of Sports Medicine (Thompson, 2014; Thompson, 2015). Although calisthenics are popular, other forms of RT are more commonly associated with muscle strength training. Traditional free weight and dumbbell exercises, such as the bench press and back squat, appear to be the most researched method of RT and the most used form of exercise to improve muscular strength (Berger, 1962; Capen, 1956; Kraemer & Ratamess, 2004; Stone et al., 2000). This may be due to the ease of manipulating some training variables, such as the external resistance, in order to maintain muscle strength development.

Studies on calisthenics are limited, with few available that test the effectiveness of calisthenics on improving muscle strength. These studies have concluded that calisthenic exercise does not result in strength improvement (Campney & Wehr, 1965; Shvartz & Tamir, 1971). Similarly, studies comparing the effectiveness of calisthenics on improving muscle strength to that of traditional weight training come to the same conclusions (Marcinik, Hodgdon, Mittleman, & O'Brien, 1985; Tsourlou, Gerodimos, Kellis, Stavropoulos, & Kellis, 2003). However, one major limitation with these conclusions is that these studies did not accurately apply the recommended strength training variables to the calisthenic exercises. In fact, the training variables used closely resembled those of a muscular endurance training program; given researchers focused on increasing the number of repetitions, rather than utilizing a more difficult variation for each exercise to keep the subjects' repetitions lower.

Even today, calisthenics appear to be utilized in more muscular endurance activities. These include high repetition exercises with minimal rest intervals between sets (Kraemer & Ratamess, 2004; Ratamess et al., 2009). Therefore, a critical need to apply current muscular strength training principles to calisthenic exercise exists. By utilizing advanced variations of each calisthenic exercise, strength training variables could be maintained. The use of these increasingly difficult variations could show that calisthenics are an effective method for improving muscle strength, and possibly a great alternative to traditional weight training. This is significant when considering that calisthenics require minimal to no equipment, making them both efficient and cost effective.

Purpose of the Study

The purpose of this study was to compare progressive calisthenic push-up training to standard free weight bench press training as techniques to develop muscle strength and thickness.

Research Questions

1. Can progressive push-up training increase upper body muscle strength or thickness?
2. Are progressive push-ups as effective as traditional weight training in developing upper body muscle strength or thickness?

Significance of the Study

Determining whether or not advanced variations of the push-up exercise can maintain strength training principles and continue muscle strength progression is significant when considering that calisthenics require minimal to no equipment, which makes them both an efficient and cost effective form of RT in comparison to traditional weight training.

Delimitations of the Study

1. Our research population only included moderately-resistance trained males between the ages of 18-45 years who were participating in RT at least twice a week for the last two to six months; therefore the results may not be transferrable to females, other age groups, or fitness levels.

2. This was the first known study to use a calisthenic exercise (push-up) progressively in order to maintain strength training variables, therefore the design of the push-up training was completely experimental with no similar studies to compare methods.

Limitations of the Study

1. Participants in the study completed the exercise routines to the best of their abilities.
2. Participants were not required to alter their diet or track hydration for the study which may affect results.
3. No known studies have used progressive calisthenic push-up training, so the exercises and progression levels used are completely experimental.
4. Some participants dropped out of the study for reasons beyond the researcher's control.

Definition of Terms

- Calisthenics – A form of RT that uses the body's own weight as a way of improving overall fitness.
- Exercise Progression – The act of moving forward or advancing toward a specific goal over time until the target goal has been achieved (Ratamess et al., 2009).
- Load – The amount of weight lifted or the resistance one exercises with and is highly dependent upon other training variables (Kraemer & Ratamess, 2004).
- Maximum Muscular Strength – The force a muscle or muscle group can exert in one maximal effort (Baechle & Earle, 2008).
- Muscular Endurance – The ability of certain muscles or muscle groups to perform repeated contractions against a sub-maximal resistance (Baechle & Earle, 2008).
- Muscular Hypertrophy – The increase in muscle thickness and cross-sectional area (Baechle & Earle, 2008).

- Muscular Power – The scalar product of force (strength) generation and movement velocity. Maximum muscular power is seen when a specific amount of work is completed in a faster duration of time, or when a greater amount of work is completed in the same amount of time (Ratamess et al., 2009).
- Muscular Strength – The ability of a muscle to generate force (Ratamess et al., 2009).
- Repetition – The number of times an exercise can be performed (Baechle & Earle, 2008).
- Repetition Maximum – The most weight lifted for a specified number of repetitions (Baechle & Earle, 2008).
- Resistance Training – A specialized method of conditioning that involves the progressive use of resistance to increase one's ability to exert or resist force (Baechle & Earle, 2008).
- Rest Interval – The time dedicated to recovery between sets and exercises (Baechle & Earle, 2008).
- Set – A group of repetitions sequentially performed before resting (Baechle & Earle, 2008).
- Training Variables – The specific exercise order, volume, frequency, muscle action, repetition speed, and rest interval length used in a RT program in order to improve a various muscular characteristics (Kraemer & Ratamess, 2004).
- Volume – The volume is estimated from the total number of sets and repetitions performed during a training session (Kraemer & Ratamess, 2004).

CHAPTER II. LITERATURE REVIEW

Resistance Training

Resistance training (RT) has become one of the most popular physical activities for improving various muscular characteristics such as power, hypertrophy, endurance, and strength (Feigenbaum & Pollock, 1999; Kraemer & Ratamess, 2004; Ratamess et al., 2009). In order to continuously improve these trainable characteristics, proper manipulation of program/training variables must be achieved. Common program variables of resistance training include choice of resistance, exercise selection and order, volume (number of sets and repetitions), frequency, and rest interval length (Baechle & Earle, 2008; de Salles et al., 2009; Kraemer & Ratamess, 2004; Ratamess et al., 2009). There are many different methods of resistance training. Traditional free weights and dumbbells are the most common, but weight machines, calisthenics (bodyweight), elastic tubing, and medicine balls are also tools that can be utilized in an effective RT program. The choice of which RT method used will vary between individuals due to current level of fitness, familiarization with exercises, and individual goals and/or preferences.

It is well known that the manipulation of the RT training variables mentioned above can stress the muscles in many different ways. The degree of effort an individual gives and specific structure of the training variables will ultimately determine which trainable characteristic will be achieved (Kraemer & Ratamess, 2004). In order to continuously improve a trainable characteristic, the demands of the RT program must be increased. This is known as exercise progression: the continued advancement towards a goal until the desired goal is reached (Ratamess et al., 2009). The most effective technique to achieve long-term progression in RT is through the organized manipulation of volume and intensity (Stone et al., 2000).

Muscular Power. Muscular power is the product of force (strength) generation and movement velocity (Ratamess et al., 2009). Maximum muscular power is seen when a specific amount of work is completed in a faster duration of time, or when a greater amount of work is completed in the same amount of time (Ratamess et al., 2009). Although muscular strength training may not optimally induce adaptations for power, strength is a component of power and has some influence in its development. It is because of this relationship that power training is usually integrated into a strength training program (Ratamess et al., 2009).

Exercise choice. Multiple-joint exercises are considered to be the most beneficial exercises when training for muscular power (Kawamori & Haff, 2004). Total-body exercises, such as the power clean and push press, are highly encouraged due to their rapid force production and efficiency for enhancing power (Baechle & Earle, 2008; Ratamess et al., 2009).

Training volume. High loads, 85-100% of one repetition maximum (1RM), are recommended to improve the force component of power. Low to moderate loads, 30-60% of 1RM for upper body and 0-60% of 1RM for lower body, performed at an explosive velocity are recommended to increase quick force production (Kawamori & Haff, 2004; Thomas et al., 2007). Multiple-set training, three to five, integrated into a strength training program is recommended to improve power (Ratamess et al., 2009; Thomas et al., 2007). Research has shown that using three to six repetitions per set is the ideal range for stimulating power adaptations (Kawamori & Haff, 2004; Thomas et al., 2007).

Rest intervals. Rest intervals for power training closely resemble strength training. In order to maintain form and the prescribed number of repetitions, longer rest is needed. Rest intervals of two to five minutes are the current recommendation (Baechle & Earle, 2008; Ratamess et al., 2009).

Training frequency. The frequency of power training is two to five days per week depending upon participant experience and exercise structure (Kraemer & Ratamess, 2004; Ratamess et al., 2009).

Muscular Hypertrophy. Muscular hypertrophy is the increase in muscle thickness as a result of RT training (Baechle & Earle, 2008). The most effective strategy for increasing muscle thickness is to perform three or more exercises per muscle group (Hedrick, 1995).

Exercise choice. Multiple-joint and single-joint exercises, free-weights and machines, have shown to be effective in eliciting muscular hypertrophy (Kraemer & Ratamess, 2004; Ratamess et al., 2009).

Training volume. Moderate to high volume RT programs, utilizing high loading (70-100% of 1RM) has shown to target muscle hypertrophy (Kraemer & Ratamess, 2004; Ratamess et al., 2009). The current recommendation for the number of sets per exercise is between three and six (Hedrick, 1995; Ratamess et al., 2009). Six to twelve repetitions for each set is ideal for stimulating muscle growth (Baechle & Earle, 2008; Hedrick, 1995; Ratamess et al., 2009).

Rest intervals. Rest interval length plays a major role in the performance of repetitions for multiple sets and the targeted training adaptations (Kraemer & Ratamess, 2004). Rest intervals are encouraged to be kept short to moderate in length, with specific times between 30 and 90 seconds (Baechle & Earle, 2008; Hedrick, 1995).

Training frequency. The frequency of muscular hypertrophy training is recommended at two to six days per week depending upon participant experience and exercise structure (Kraemer & Ratamess, 2004; Ratamess et al., 2009).

Muscular Endurance. Muscular endurance is the ability of a muscle to perform multiple contractions against a sub-maximal resistance (Baechle & Earle, 2008). Training for muscular endurance typically involves high repetitions and short rest, with the muscle experiencing greater amounts of time under tension (Ratamess et al., 2009).

Exercise choice. Unilateral and bilateral multiple- and single-joint exercises are strongly encouraged in training programs designed for muscular endurance (Stone & Coulter, 1994). Utilizing various sequences of exercises can help improve muscular endurance in persons of various fitness levels.

Training volume. High-volume programs have been shown to be superior for enhancing muscular endurance (Stone & Coulter, 1994). Multiple-set programs, two to three per exercise, are considered most effective (Baechle & Earle, 2008; Stone & Coulter, 1994). Light loads, consisting of 10-15 repetitions, have been most effective for improving endurance in novice and intermediate training participants (Stone & Coulter, 1994). Various loading strategies, using 10-20 repetitions, have been shown to improve endurance in advanced training participants (Ratamess et al., 2009).

Rest intervals. Rest intervals less than one minute are currently recommended to improve muscular endurance (Baechle & Earle, 2008; Ratamess et al., 2009). Shorter periods of rest are also typically associated with circuit training programs, which alternate exercise and limit rest time.

Training frequency. The frequency of muscular endurance training is between two to six days per week depending upon participant RT experience and exercise structure (Baechle & Earle, 2008; Graves et al., 1988; Ratamess et al., 2009).

Muscular Strength. Maximum muscular strength is the amount of force a person's muscles can exert in a single maximal effort (Ratamess et al., 2009). The magnitude of strength enhancement is dependent on the type of exercise program used and the structuring of the program variables.

Exercise choice. Single- and multiple-joint exercises are effective at increasing muscle strength. However, multiple-joint exercises such as the bench press and back squat are considered to be more effective. This is because multiple-joint exercises call for a greater magnitude of weight to be lifted (Stone et al., 1998). In addition, multiple-joint exercises recruit more motor units and larger muscles groups which invoke significantly greater hormonal and metabolic responses (Spiering et al., 2008). These hormonal responses provide positive responses and adaptations to the specified training.

Training volume. Muscular strength training programs typically utilize low-volumes (high load, low repetitions, moderate to high number of sets) to stimulate strength improvement. Studies have shown that using multiple-set programs, three sets, had larger increases in strength then single-set programs, one or even two sets (Berger, 1962; Capen, 1956). According to Kraemer (2004), three to six sets are most commonly used during resistance training to increase muscular strength. Strength increases have been shown to be greater when using heavy weights for three to five repetition max (RM) compared with nine to eleven RM and twenty to twenty-eight RM (Campos et al., 2002). Berger (1962) suggests that goal repetitions less than or equal to six RM is efficient to achieve the desired strength training stimulus. In order to continually improve muscular strength and maintain strength training repetition variables, it is recommended to increase the training load (weight lifted) when the individual can perform the current weight lifted for one to two repetitions over the desired number on two consecutive training sessions (Feigenbaum & Pollock, 1999).

Rest intervals. The length of rest periods between sets and exercises can significantly impact the bodies responses and adaptations to RT (Spiering et al., 2008). The amount of recovery time for multiple-joint exercises is recommended to be at least two to three minutes in length (Ratamess et al., 2009). Ratamess (2012) support these recommendations, concluding individuals with higher levels of maximal strength may require more rest time between sets to improve maximal strength levels. A similar study has shown that when training with loads smaller than 90% of 1RM for multiple sets, two to five minute rest intervals are necessary to maintain prescribed number of repetitions performed per set (de Salles et al., 2009).

Training frequency. The frequency of muscular strength training is recommended between two to seven days per week depending upon participant RT experience and exercise structure (Baechle & Earle, 2008; Graves et al., 1988; Ratamess et al., 2009).

Calisthenic Effects on Muscle Strength

Calisthenics are a form of RT that manipulates the body's own weight to improve overall fitness. In today's society, many people engage in these types of exercises (push-ups, pull-ups, sit-ups) for the purpose of improving their physical fitness. Unfortunately, modern calisthenics are not typically associated with standard strength training principles. If you mention calisthenics today, most individuals would likely think of performing muscular endurance activities, such as push-ups and crunches for high repetitions, or less taxing exercises like Jumping-Jacks or jogging. Wade (2012) suggests that calisthenics have become more of a secondary option in exercise, such as circuit training or other endurance-like activities.

In the past, few studies have attempted to measure the effects of calisthenics on various training variables. Specifically looking at muscular strength, these studies found that calisthenic exercises do not result in any muscular strength improvements (Campney & Wehr, 1965; Shvartz

& Tamir, 1971). In fact, Campney (1965) stated that the exercises and the number of repetitions used in the training routine seriously questioned the relation of the program to a strength-development objective. Campney (1965) elaborated on the repetition range when explaining how participants in higher levels of the training program were able to perform more repetitions for each exercise, making it very unlikely that strength development was occurring.

Campney (1965) specifically tested a program originally recommended by the President's Council on Physical Fitness for developing muscular strength. Exercises in the program included toe touches, sprinters, sitting stretches, knee push-ups, sit-ups, leg raises, and flutter kicks. These exercises were performed three times a week with little to no rest time (Campney & Wehr, 1965). Shvartz (1971) tested an experimental group with 10 minute periods of calisthenic exercise. The exercises utilized in the program were Jumping-Jacks, arm circling, the burpee, side bending, toe touching, and trunk twisting. The exercises were performed in a 10 minute period, three times a week for a total of eight weeks. The study did not mention the use of any rest time, but did state that the heart rate of the subjects was monitored for 10 seconds immediately following each calisthenic exercise. This suggests that each exercise was performed back-to-back with minimal rest for the full 10 minute period.

In addition to the high number of repetitions performed in both studies, the limited rest time of the programs closely resembles the variables of muscular endurance training rather than strength training. Muscular endurance training is associated with a higher number of repetitions and shorter rest periods between exercises and sets (Kraemer & Ratamess, 2004; Ratamess et al., 2009). As mentioned previously, goal repetitions less than or equal to six RM are ideal to achieve the desired strength training stimulus (Berger, 1962). To improve maximal strength, longer rest intervals, two to three minutes, should be used between sets to maintain the training stimulus (de Salles et al., 2009; Ratamess et al., 2009; Ratamess et al., 2012). In order to train at the desired work load needed to achieve this lower repetition range, a progressive increase in the difficulty of calisthenic exercises through variation is required. As a subject adapted to the demands of the calisthenic exercises, the researches would be able to apply these progressions/variations in order to increase the training loads. By doing this, the subjects' strength may have continued to improve over time.

Calisthenics vs. Weight Training for Muscle Strength

Limited information is available on the effects calisthenic exercise has on muscular strength. In addition, strength changes elicited by calisthenics, compared to those following a weight training program, have not been widely investigated. In the past, calisthenic exercises were used as the standard physical conditioning program for the Navy (Marcinik et al., 1985). The Navy, however, identified upper torso muscular strength as a critical limiting factor in performance from observing the demands of lifting and carrying heavy loads on board Navy vessels (Marcinik et al., 1985). The discovery of this information prompted the Navy to evaluate current calisthenic training regimes to those of weight training.

Participants in the study were selected to participate in either the standard Navy recruit calisthenic conditioning program or an experimental circuit weight training program. The calisthenic conditioning program consisted of five exercises: sit-ups, push-ups, flutter kicks, 8-count body builders, and Jumping-Jacks, performed for 10 minutes total. The circuit weight training program performed two circuits each session consisting of 15s work/15s rest. Specific exercises utilized in the program included the bench press, shoulder press, hip flexion, knee extension, pull-up, arm-curl, lat-pulldown, leg press, arm dips, incline sit-ups, and all calisthenic conditioning exercises. This is pretty significant difference in training routines when considering that the calisthenic group was performing five exercises and the weight training group was performing fifteen.

The circuit weight training program participants also utilized weight at 70% of their 1RM (Marcinik et al., 1985). According to Baechle & Earle (2008), 70% of 1RM equates to about 10 repetitions. Although less than or equal to six repetitions is the goal when training for improvements in muscular strength, one study has shown that loads corresponding to eight to twelve RM have resulted in significant strength increases in novice lifters (Campos et al., 2002). This is important to note because the circuit weight training group were training at a specific repetition range, whereas the calisthenic conditioning group was not. The calisthenic conditioning group worked to complete as many repetitions as possible within the given amount of time. The circuit weight training group implemented an ongoing load progression, or increase, in order to maintain a 10 RM for the exercises.

In another study, researching the effects of a calisthenics and a weight training program on lower leg muscle strength in women, a similar procedure for their calisthenic training group and weight training group was utilized (Tsourlou et al., 2003). The weight training group used weights that allowed for 10-12 repetitions per set, increasing the resistance by approximately 20% when subjects could perform more than the desired number of repetitions, 12, for three consecutive sets. The calisthenic training group, however, only added repetitions to their exercises in order to increase training intensity. Once repetitions reach numbers greater than the strength training stimulus, muscular strength improvements are no longer the training variable being impacted (Kraemer & Ratamess, 2004; Ratamess et al., 2009).

The results of these studies found that weight training was more beneficial at producing improvements in muscular strength than calisthenics (Marcinik et al., 1985; Tsourlou et al., 2003). In fact, the researchers found that calisthenic training failed to supply a training stimulus of sufficient magnitude to improve strength in the participants. These findings are not surprising considering that the calisthenic group in both studies did not correctly manipulate training variables to apply the necessary training stimulus to improve muscular strength. These methods are a common theme among the few studies found, resulting in the same conclusions when comparing calisthenics to weight training exercises.

Push-ups as a Measure of Muscle Strength

The push-up exercise may be one of the most recognizable calisthenic exercises today. The push-up is used to improve specific musculoskeletal characteristics in the chest, shoulders, arms, and trunk. The primary muscles utilized during the push-up are the pectoralis major and triceps brachii. Unfortunately, most push-up routines today do not contain the variation needed to continually increase muscular strength gains. The most common form of progression prescribed to trainees is to increase the number of repetitions of the exercise. This type of progression has little to do with muscular strength, but has established the push-up as a very popular method for improving and assessing a person's muscular endurance (Invergo, Ball, & Looney, 1991).

Studies have attempted to discover if the "classic" push-up can be used as a possible method to measure upper body muscular strength (Invergo et al., 1991; Mayhew, Ball, Arnold, & Bowen, 1991). The main purpose of this was to determine the feasibility of using the push-up as an alternative to the 1RM bench press test to predict maximal strength. The bench press exercise is one of the most traditional methods for improving and measuring muscular strength (Invergo et al., 1991; Ratamess et al., 2012). In these studies, the 1RM bench press test was the primary method used for predicting maximal strength. For the push-up exercise, a one minute maximum test, also known as a muscular endurance test, was used for comparison (Invergo et al., 1991; Mayhew et al., 1991).

Mayhew (1991) and Invergo (1991) both concluded that there was a low correlation between maximal bench press and push-up performance. Invergo (1991) stated that the low correlation may be due to the fact that push-up performance was more a measure of relative muscular endurance than muscular strength. Mayhew (1991) suggested that the differences in procedures for executing the push-up and the bench press may be the major cause for the low correlation. The two exercises appear to be similar, but the specificity of their mechanics and muscular involvement may significantly widen their relation to one another. This widening may lead to too much variability in push-up performance to make it an accurate predicator of bench press lifting capacity (Mayhew et al., 1991). Mayhew (1991) also theorized that hand placement during the push-up exercise could cause considerable variation when assessing an individual's upper body strength.

In relation, one study tested literature suggesting the isolation of different muscles with various hand placements during performance of a push-up (Cogley et al., 2005). The main focus of the study was to use electromyography (EMG) to examine muscle activation of the pectoralis major and triceps brachii during performance of the push-up exercise with three different hand positions. The three hand positions in the study were classified as shoulder width, wide base, and narrow base position. The shoulder width hand position was determined by using the edge of the deltoid muscle. The wide base hand position was set at 20 cm laterally from the shoulder width hand position. The narrow base position required subjects to place their hands together in the shape of a diamond, directly under the sternum. A cadence of three seconds was used, along with two to three minutes of rest between tests to minimize the possibility of fatigue (Cogley et al., 2005). Push-ups performed from the narrow hand position showed greater EMG activity in the pectoralis major and triceps brachii muscles than the wide base hand position. This result suggests that the number of repetitions performed from the narrow base hand position would be less than the repetitions performed from the wide base hand position. If an individual uses the push-up as a muscular strengthening exercise, the narrow base hand position is a recommended variation due to its increased demands on the upper body muscles (Cogley et al., 2005).

Another study measured the effect of push-up training on stable and unstable surfaces on muscular strength and muscular endurance (Chulvi-Medrano, Martinez-Ballester, & Masia-Tortosa, 2012). The study randomly assigned subjects to three different training groups: a "classic" push-up group, a BOSU® group, or a T-Bow® group. The 1RM bench press was used to measure muscular strength before and after an eight week intervention, with a frequency of two days per week. All training groups performed three sets of ten repetitions at a cadence of two seconds on both the eccentric and concentric phases. Additional weight, via weight plates, was added to the subjects back if more than ten repetitions could be performed for each set. No rest time information was provided (Chulvi-Medrano et al., 2012). The results of this study found that none of the intervention groups improved muscular strength or endurance significantly. Chulvi-Medrano (2012) suggested that the push-up training may have needed to implement different training phases. These stages would be designed specifically for improving maximum strength (six repetitions) and then muscle endurance (12-15 repetitions). This would be more beneficial because the current procedure used a repetition range (10 repetitions) that was in between the two training zones.

Push-ups vs. Bench Press for Muscle Strength

A recent study has supported the idea that the push-up exercise can be used to induce muscular strength gains similar to the bench press exercise (Calatayud et al., 2015). The purpose of the study was to evaluate strength gains after a five week training period with either the bench press or push-up exercise, with the same loads and variables. As mentioned, the previous studies that have measured the effectiveness of calisthenic exercises on muscular strength did not apply the necessary strength training loads and variables. Calatayud et al. (2015) recognized the possible limitations of the "classic" push-up exercise, mentioning that performing the push-up exercise with bodyweight only (true calisthenic exercise) was not likely to provide the training stimulus needed to induce muscular strength gains. This is due to the fact that the intensity of the "classic" push-up exercise can only be increased through adding additional repetitions. In order to provide the necessary training stimulus for muscular strength, elastic bands were used as additional resistance with the push-up exercise (Calatayud et al., 2015).

Subjects of the study participated in their training program for five weeks. The frequency of training was two sessions each week. Each training session successfully applied the recommended strength training variables by utilizing five sets of six repetitions. In addition, Calatayud et al. (2015) controlled for exercise movement speed and kept the rest intervals between sets to four minutes. According to de Salles (2009), this would provide sufficient recovery time to maintain strength training loads. Surface EMG signals were also used in each training group to help evaluate any differences in muscle activation in the anterior deltoid and the pectoralis major (Calatayud et al., 2015).

The results of the study showed significant strength gains in both the bench press group and push-up group, with no significant differences between them. In addition, when looking at the EMG results, similar high levels of muscle activity were observed in both exercises. From these results, Calatayud et al. (2015) was able to conclude that when EMG values are comparable and the same conditions are reproduced (training variables), the bench press and push-up exercise can provide similar muscle strength gains. The study supports the idea that the push-up exercise can be used to effectively improve muscular strength. It is important to note that elastic bands were used during the push-up exercise to provide the resistance needed to maintain muscular strength training variables. If, however, progressive variations of the push-up exercise can help an individual maintain the desired training variables, muscular strength gains could be observed.

Summary

RT is an important aspect of physical activity, developing several neuromuscular and musculoskeletal characteristics: muscular power, muscular hypertrophy, muscular endurance, and muscular strength (Feigenbaum & Pollock, 1999; Kraemer & Ratamess, 2004; Ratamess et al., 2009). In order to continually improve one of these specific musculoskeletal characteristics the manipulation of RT variables must occur, known as exercise progression. Among these variables are the external resistance used, number of sets and repetitions per exercise, rest interval length, and frequency of the activity (de Salles et al., 2009; Kraemer & Ratamess, 2004; Ratamess et al., 2009).

Muscular power is the product of force (strength) generation and movement velocity (Ratamess et al., 2009). Multiple-joint, total-body exercises are considered to be the most beneficial when training for muscular power (Kawamori & Haff, 2004). Multiple-set training (three to five sets), utilizing three to six repetitions per set, is recommended for improving muscular power (Kawamori & Haff, 2004; Ratamess et al., 2009; Thomas et al., 2007). Rest intervals of two to five minutes are currently recommended to maintain the prescribed number of repetitions (Baechle & Earle, 2008; Ratamess et al., 2009).

Muscular hypertrophy is the increase in muscle thickness as a result of RT training (Baechle & Earle, 2008). Multiple-joint and single-joint exercises have both been shown to be effective at inducing muscle growth. Moderate to high volume RT programs, utilizing high loading (70-100% of 1RM) has shown to target hypertrophy (Kraemer & Ratamess, 2004; Ratamess et al., 2009). Three to six sets of six to twelve repetitions are ideal for stimulating muscle growth (Baechle & Earle, 2008; Hedrick, 1995; Ratamess et al., 2009). Rest intervals are recommended between 30 and 90 seconds in length (Baechle & Earle, 2008; Hedrick, 1995).

Muscular endurance is the ability of a muscle to perform multiple contractions against a sub-maximal resistance (Baechle & Earle, 2008). Unilateral and bilateral multiple- and single-joint exercises are primarily used in muscular endurance programming (Stone & Coulter, 1994). High-volume programs, utilizing two to three sets per exercise, have been shown to be most effective for enhancing muscular endurance (Baechle & Earle, 2008; Stone & Coulter, 1994). Loads allowing for 10-15 repetitions and 10-20 repetitions have successfully been used to improve muscular endurance in people with novice to intermediate and advanced training experience (Ratamess et al., 2009; Stone & Coulter, 1994). Rest intervals less than one minute are recommended to improve muscular endurance (Baechle & Earle, 2008; Ratamess et al., 2009).

Muscular strength, specifically maximum strength, is the amount of force a person's muscles can exert in a single maximal effort (Ratamess et al., 2009). According to previous studies, multiple-set programs, consisting of three to six sets, are the preferred method to increase muscular strength (Berger, 1962; Capen, 1956; Kraemer & Ratamess, 2004). The recommended number of repetitions for each exercise should be slightly less than or equal to six (Berger, 1962; Campos et al., 2002). Since training for maximal strength is an intense exercise, rest intervals from two to five minutes are necessary to maintain the prescribed number of repetitions per set (de Salles et al., 2009). Training variables for maximal strength are different than muscular hypertrophy (muscle growth); thus, changes in muscle thickness are unlikely to occur during strength training. By applying these guidelines to a RT program, increases in muscular strength should be achieved.

Calisthenic exercise (bodyweight training) is a form of RT that has continued to increase in popularity over the last couple years. Although calisthenics are popular, traditional free weight and dumbbell exercises, such as the bench press and back squat, appear to be the most researched method of RT and the most used form of exercise to improve muscular strength (Berger, 1962; Capen, 1956; Kraemer & Ratamess, 2004; Stone et al., 2000). Calisthenics appear to be utilized in more muscular endurance activities: high repetition exercises with minimal rest intervals between sets (Kraemer & Ratamess, 2004; Ratamess et al., 2009). Although research has measured the effectiveness of calisthenic training on improving muscular strength, these studies are limited and have not applied the recommended training variables in order to continue strength progression (Campney & Wehr, 1965; Marcinik et al., 1985; Shvartz & Tamir, 1971; Tsourlou et al., 2003). Therefore, the need to apply current muscular strength training principles to calisthenic exercise exists.

The push-up exercise is a very common calisthenic exercise due to its convenience and functionality. It is also a very adaptable exercise, allowing an individual to alter its difficulty by applying many different variations, such as hand placement and the altering of stability (Chulvi-Medrano et al., 2012; Cogley et al., 2005). By utilizing advanced variations of the push-up exercise, strength training principles could be maintained. The use of these increasingly difficult variations could show that calisthenics are an effective method for improving muscular strength, and possibly a great alternative to traditional weight training. This is significant when considering that calisthenics require minimal equipment and are cost effective.

Table 1

Summary of Calisthenic Studies

Publication	N (Gender)	Duration (Days)	Training Type	Exercise Prescription	Highlighted Outcome
Campney et al. (1964)	19 (9M, 10F)	30	Calisthenic	6 warm-up exercise, 7 conditioning exercises (toe touch, sprinter, sitting stretch, knee push-up, sit-up, leg raiser, & flutter kicks), & 1 aerobic exercise. Multiple repetitions, ↑ as subjects adapted. No sets or repetitions mentioned. Rest periods discouraged.	No significant strength improvement.
Marcinik, et al. (1985)	87 (M)	24	***Study II*** Calisthenic	5 exercises (sit-ups, push-ups, flutter kicks, body builders, & jumping jacks) performed for 10 minutes. No sets, repetitions, or rest time given. Assumed multiple repetitions with little rest.	Calisthenics fail to supply training stimulus. Subjects show significant ↓ in strength for several measures, with a 12.3% ↓ in bench press.
			Study II Weight Training	15 exercises for 2 circuits at 15 seconds work & 15 seconds rest. Work on the weight machine performed at 70% of 1RM. As many repetitions as possible in 15 second interval.	Weight training shows significant ↑ in muscular strength for all measures, with a 12.3% ↑ in the bench press.
Tsourlou, et al. (2003)	35 (F)	30	Calisthenic	3 lower body exercises (squats, stationary lunges, & lunges) Subjects performed 2-3 sets of 12-15 repetitions. Rest periods were 60 seconds between sets.	Calisthenics not shown to provide the necessary stimulus to improve muscular fitness or body composition.
			Weight Training	3 lower body exercises (leg extensions, leg curls, & hip extensions) performed on machines. 3 sets of 10-12 repetitions, ↑ resistance by 20% once subjects could perform 3 sets of 12 repetitions comfortably. Rest periods were 60 seconds.	Light-weight training shown to increase muscular strength and decrease body fat.
Chulvi-Medrano, et al. (2012)	30 (M)	16	Calisthenic with weight plates (Push-ups)	3 groups on unstable surfaces. 5lb plates, on subjects' back, to help subjects obtain a seven on OMNI-Res scale. 3 sets of 10 repetitions performed. No rest period provided. A cadence of 2:2 (2 seconds eccentric: 2 seconds concentric) used with metronome.	Strength, measure through one repetition maximum did not improve significantly for any intervention.
Calatayud, et al. (2014)	30 (22M, 8F)	16 (10 training)	Calisthenic with Elastic Bands (Push-ups) Weight Training (Bench press)	Each session was 5 sets of 6 repetitions with the same load/resistance used to reach the 6RM during the EMG session. Rest periods were set at 4 minutes. Same load/resistance, rest time, speed of movement technique & grip width was maintained for all training session.	Significant ↑ in 1RM & 6RM tests with similar gains. When EMG values are comparable & same conditions are reproduced, similar strength gains can be achieved.

Note. Number (N), Male (M), Female (F), Electromyography (EMG), Repetition Max (RM), Increase (↑), Decrease (↓)

CHAPTER III. METHODS

The purpose of this study was to compare progressive calisthenic push-up training to standard free weight bench press training as techniques to develop muscle strength and thickness.

Research Questions

1. Can progressive push-up training increase upper body muscle strength or thickness?
2. Are progressive push-ups as effective as traditional weight training in developing upper body muscle strength or thickness?

Subjects

Twenty-seven healthy, moderately trained males 18-45 years of age were recruited, of which 23 (mean ± SD: age 23 ± 6.8 years, height 180.8 ± 5.7 cm, body mass 81.9 ± 14.1 kgs, body fat 10.4 ± 3.7 %) completed the study. A moderately-resistance trained subject was someone who was currently performing resistance exercise at least twice a week for the last two to six months (Baechle & Earle, 2008). Prior to inclusion in the study, subjects provided written informed consent, a self-reported health history, and a Physical Activity Readiness Questionnaire (PARQ). Additional exclusion criteria included: individuals with any history of joint pain, shoulder impingement syndrome, musculoskeletal disorders, such as rheumatoid arthritis, and/or specific injuries to the hands or shoulders. Each subject completed 15 sessions in the following order: one familiarization session, a pre-training fitness assessment, 12 training sessions, and a post-training fitness assessment. Subjects were trained three days per week, separated by 48 hours, and randomly assigned to a Push-up Progression Group (PUSH, n=14; mean ± SD: age 24 ± 8.5 years, height 180.7 ± 5.7 cm, body mass 79.6 ± 14.4 kgs, body fat 9.9 ± 1.1 %) or a Bench Press Group (BENCH, n=9; mean ± SD: age 21 ± 2.3 years, height 180.9 ± 6.1 cm, body mass 85.6 ± 13.7 kgs, body fat 11.3 ± 1.0 %). Descriptive measures were recorded prior to starting the training sessions.

Procedures

All procedures were approved in advance by the North Dakota State University Institutional Review Board, and written consent was obtained.

Familiarization Session. During the familiarization session, participants learned about the purpose of the study, the different exercises, including proper form/body position, the specific training variables that were to be used during training sessions, and the cadence that was to be followed while performing each exercise. Participants also had the opportunity to ask questions about the study until they fully understood what was required of them.

Pre- and Post-Training Fitness Assessment Sessions. During the pre- and post-training fitness assessment sessions each subject underwent a series of tests to determine baseline and final measurements. Baseline measurements were conducted during the Pre-Training Fitness Assessment Session at least 48 hours before the first training session. Final measurements where conducted during the Post-Training Fitness Assessment Session at least 48 hours after the last training session. The order of the assessments was the ultrasound measurement, seated medicine ball put test, one repetition max bench press test, and push-up progression estimation. Each subject's age, height, body mass, and body fat percentage were recorded prior to the ultrasound measurement. Weight was recorded using an eye level scale (Detecto, Webb City, MO) and height was measured using a stadiometer (Seca, Chino, CA). A body composition analyzer (model TBF-300A; Tanita, Arlington Heights, IL) was used to determine participant body fat percentage. All data was collected on workout sheets created by the researcher.

Muscle thickness. Thickness of the left pectoralis major muscle was measured using B-mode on an ultrasound system (model HD11 XE; Philips Ultrasound, Bothell, WA) with a L12-5 50 mm linear array probe. The protocol for the ultrasound and method for measuring muscle thickness was conducted according to Yasuda, Fujita, Ogasawara, Sato, & Abe (2010). A one image technique was used to compare muscle thickness between baseline and final measurements. The site of ultrasound measurement was at 60% of the measured distance from the left clavicle to the left nipple, with the ultrasound head placed directly under the 60% indicator mark. The images were captured at a frequency of 37 hertz with a depth of 7 centimeters and gain of 100. Muscle thickness for each image was determined by averaging four evenly spaced measurements. Test-retest reliability of this one image technique was 2.5% using coefficient of variation and 0.953 using interclass correlation coefficient.

Seated medicine ball put test. The medicine ball put test was used to measure power of the upper body muscles. Although this study was designed for muscle strength improvement, strength is a factor of power. Any post-training improvements were likely due to increases in subject upper body muscle strength. The test was meant to be an alternative measure of muscle performance because it was not a specific exercise used in the PUSH or BENCH training. The protocol for the seated medicine ball put was conducted according to Clemons, Campbell, and Jeansonne (2010). A 12 pound medicine ball (Power Systems, Knoxville, TN) was used for testing.

One repetition max (1RM) bench press test. The purpose of the 1RM bench press test was to measure the maximum strength of the chest muscle group. The measurement of the 1RM during the bench press was conducted according to the NSCA's protocol (Baechle & Earle, 2008). A standard adjustable flat bench and weight clips, and a standard 45 pound Olympic barbell with weight plates ranging from 2.5 pounds to 45 pounds were used to complete the 1RM test.

Push-up progression estimation test (experimental approach). Starting push-up progression was determined by the researcher, taking into account the subjective estimation of which progression level from Table 2 each subject felt they could complete. At the estimated progression level, each subject attempted to complete three sets of six repetitions (6/6/6) for double arm progressions or three sets of three repetitions (3/3/3) per side for single arm progressions. A two minute rest was given between sets. If subject successfully completed the prescribed number of sets and repetitions for the progression, with good form, the subject moved on to the next push-up progression level. This process continued until the subject failed to complete the prescribed number of sets and repetitions, or proper form was compromised, for the current push-up progression level. The previous push-progression the subject completed with proper form was considered the baseline progression. Subjects randomly assigned to the PUSH used the baseline progression level they completed during testing as their starting point during the first training session.

Table 2

Push-up Progressions

Progression (Level)	Variation	Beginning Repetitions	Total Volume
1	Wall Push-up	3 sets of 6 reps	3 sets of 6 reps
2	Incline Push-up	3 sets of 6 reps	3 sets of 6 reps
3	Kneeling Push-up	3 sets of 6 reps	3 sets of 6 reps
4	Half Push-up	3 sets of 6 reps	3 sets of 6 reps
5	Full Push-up	3 sets of 6 reps	3 sets of 6 reps
6	Close Push-up	3 sets of 6 reps	3 sets of 6 reps
7	Uneven Push-up	3 sets of 3 reps per side	3 sets of 6 reps
8	½ One-Arm Push-up	3 sets of 3 reps per side	3 sets of 6 reps
9	Archer Push-up	3 sets of 3 reps per side	3 sets of 6 reps
10	One-Arm Push-up	3 sets of 3 reps per side	3 sets of 6 reps

Note. Repetitions (reps)

Training Sessions. All subjects completed a dynamic warm-up consisting of jogging in place (one minute), jumping jacks (one minute), jogging in place (one minute), shoulders rolls (20x), arm circles (20x), chest openers (20x), followed by a subsequent warm-up specific to their training group. Correct form for the BENCH and PUSH were monitored by trained staff. Push-up form was changed for each push-up progression level in Table 2. Research staff thoroughly monitored form in both groups to ensure conditions were the same for all subjects. A verbal cadence of two seconds on eccentric phase and two seconds on concentric phase was used to avoid any discrepancies in the subjects' velocity in both training groups. The cadence was voiced by the same researcher, for each subject, each session, to ensure consistency between subjects.

BENCH. Following the dynamic warm-up, subjects began a lift specific warm-up with the bench press exercise by performing eight repetitions at 40% of their estimated 1RM, followed by one minute of rest (NSCA, 2012). The subjects then completed a second warm-up set of six repetitions at 60% of their estimated 1RM, followed by a two minute rest. After the rest interval, subjects began their training sequence at 75% of their estimated 1RM. Training sequence began at three sets of six repetitions, utilizing a three minute rest between sets. Each training session, subjects attempted to complete one additional repetition for each set. Once subjects were able to perform three sets of eight repetitions, on two consecutive training sessions, intensity was increased by adding weight in 10 pound increments. After adding additional weight, subjects went back to performing three sets of six repetitions. The increase in weight ensured subjects maintained appropriate strength training progression in order to elicit the desired training response.

PUSH. Following the dynamic warm-up, subjects performed two warm-up sets of a push-up progression that was two levels below their baseline progression. For the first warm-up set, subjects performed eight repetitions for double arm progressions or four repetitions per side for single arm progressions followed by one minute of rest. For the second warm-up set, subjects performed six repetitions for double arm progressions or three repetitions per side for single arm progressions followed by two minutes of rest. After the warm-up sets were completed, subjects completed the actual training sequence. Training sequence began at three sets of six repetitions for double arm progressions or three sets of three repetitions per side for single arm progressions, utilizing a three minute rest interval between sets. Subjects attempted to complete one additional repetition per set each training session. Once subjects were able to complete three sets of eight repetitions for double arm progressions or three sets of four repetitions per side for single arm progressions, on two consecutive training sessions, intensity was increased by progressing to the next push-up variation in Table 2. After progressing to a more difficult variation, subjects went back to performing the three sets of six repetitions for double arm progressions or the three sets of three repetitions per side for single arm progressions for the new progression level.

Example: a subject at the Close Push-up progression (level 6) began the first training session attempting to complete three sets of six repetitions (6/6/6). If the subject achieved three sets of six repetitions (6/6/6) during the first session, the subject then attempted to complete three sets of seven repetitions (7/7/7) during the second training session. If, during the second session, the subject completed one set of seven repetitions (7/6/6) or two sets of seven repetitions (7/7/6), the subject remained at three sets of seven repetitions (7/7/7) until they were achieved in a single training session. Once three sets of seven (7/7/7) was achieved, the subject then worked to complete three sets of eight repetitions (8/8/8). This process continued each training session until the subject successfully completed three sets of eight repetitions (8/8/8) for his current push-up level on two consecutive training session. Once subject achieved three sets of eight repetitions

(8/8/8) on two consecutive sessions, the subject progressed to the next level in the push-up variation in Table 2. Example: Close Push-up (level 6) subject completed two consecutive training sessions of three sets of eight repetitions (8/8/8), so he began the next training session with Uneven Push-ups (level 7). Training sessions for this progression began by attempting to complete three sets of three repetitions (3/3/3) for each side, a total training volume of three sets of six repetitions (6/6/6) because the Uneven Push-up is a single arm progression. Once subject achieved three sets of four repetitions (4/4/4) for each side, a total training volume of three sets of eight repetitions (8/8/8), on two consecutive training sessions, he progressed to the next push-up variation in Table 2. This process continued for each push-up progression.

Push-up Progressions

The push-up progression levels, and their order, were inspired by Wade (2012), and were selected for this study for their ability to stress the body and elicit the desired training response for individuals at any fitness level. Since subjects in the study were moderately trained, baseline progressions were between levels five and seven. Although baseline progressions were not lower than level five, the progressions and their directions were still included in the study. The purpose of including all levels in the study was to demonstrate how an individual at any fitness level could utilize the progressions as a method for continued muscle strength improvement. The 10 push-up progression levels, in order, are shown in Table 2.

A few of the push-up progressions used in the study alternated the stress of the exercise on a single side of the body and required the use of an 8 pound medicine ball (Power Systems, Knoxville, TN). For single arm push-up exercises, subjects began with their non-dominant arm first. When performing single arm push-up exercises with their dominant arm, subjects completed the exact number of repetitions achieved with their non-dominant arm. This was to help subjects overcome any muscle imbalances. Subjects completed one half of the desired repetitions per set on each side, before three minute rest was given. The total number of repetitions per set was split to more accurately maintain the training volumes between the PUSH and BENCH groups. Emphasis was made during each single arm set to maintain a consistent pressing force on the side without the medicine ball support. Once a subject was unable to maintain the same amount of force, by utilizing more force on the side with the medicine ball to assist with the pressing movement, the set was stopped. This process was to ensure that each side of the body was stressed with the same amount of force for each repetition. The quality, not the quantity, of each repetition was important.

Wall Push-up (Level 1). The distance subjects stood away from the wall was determined by measuring their arm length from shoulder to wrist. After arm length was obtained, subjects stood one and half of their measured arm length away from the wall. With feet and hands shoulder-width apart, subjects raised arms perpendicular to body and leaned forward until their palms were flat against the wall. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of the body, until their forehead gently touched the wall. This was the finish position. The subjects then pressed back up to the start position.

Incline Push-up (Level 2). Feet and hand position were shoulder-width apart. Hands were placed on a two foot, inclined surface at a 45° angle. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of the body, until their upper arms were parallel to the inclined surface. This was the finish position. The subjects then pressed back up to the start position.

Kneeling Push-up (Level 3). The subjects placed their hands on the floor shoulder-width apart. Knees were kept together, bent at 90°, while shifting the weight off the knees and onto the lower thigh directly above the knee. This position kept the body in alignment and tension off the knees. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of body, until their upper arms were parallel to the ground. This was the finish position. The subjects then pressed back up to the start position.

Half Push-up (Level 4). The subjects placed their hands and feet shoulder-width apart on the ground, with the body and elbows in a straight line. An 8 pound medicine ball was then placed directly under their hips. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of the body, until their hips made contact with the medicine ball. This was the finish position. Subjects then pressed back up to the start position.

Full Push-up (Level 5). The subjects placed their hands and feet shoulder-width apart on the ground, with the body and elbows in a straight line. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pinching against the sides of the body, until their upper arms were parallel to the ground. This was the finish position. The subjects then pressed back up to the start position.

Close Push-up (Level 6). The subjects placed their feet shoulder-width apart on the ground. Hands were placed directly under the chest with the thumbs of each hand touching and the index fingers no more than three inches apart. The body and elbows remained straight. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of the body, until their chest made contact with their hands or their upper arms were parallel to the ground. This was the finish position. The subjects then pressed back up to the start position.

Uneven Push-up (Level 7). This was the first single arm exercise. The subjects placed their hands and feet shoulder-width apart on the ground, with the body and elbows in a straight line. The dominant hand was placed directly on top of an 8 pound medicine ball. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of the body, until their chest made contact with the medicine ball. This was the finish position. The subjects then pressed back up to the start position. One half of the desired repetitions for each set were completed with the non-dominant arm first before switching to the other side.

½ One-arm Push-up (Level 8). The subjects placed their hands shoulder-width apart on the ground, with the body and elbows in a straight line. Feet were placed one foot length wider than the shoulder-width position. Extra stability was required for the ½ One-arm Push-ups, so the foot adjustment helped the subjects maintain balance during the lowering phase. An 8 pound medicine ball was placed directly under each subjects hips. After body was in proper alignment, subjects lifted one arm off the floor and placed it on their lower back. This was the starting position. The subjects then lowered their body, initiating the movement at the elbow, upper arm pressing against the side of the body, until their hips made contact with the medicine ball. This was the finish position. The subjects then pressed back up to the start position. Emphasis was made to keep the body as straight as possible during the movement by instructing subjects to initiate the movement at the elbow and move straight up and down. If too much twisting of the torso and hips (lateral flexion) occurred, the set was stopped. One half of the desired repetitions for each set were completed with the non-dominant arm first before switching to the other side.

Archer Push-up (Level 9). The subjects placed their hands and feet shoulder-width apart on the ground, with the body and elbows in a straight line. After body was in proper alignment, the subjects extended their dominant arm out perpendicular to their body and placed their finger tips on an 8 pound medicine ball. This was the starting position. The subjects then lowered their body, initiating the movement at the elbow, upper arm pressing against the side of the body, until their upper arm was parallel to the ground. This was the finish position. While lowering, the medicine ball under the extended arm was allowed to roll from the subjects' finger tips to the palm of their hand. This allowed the medicine ball to act as a moveable kickstand so subjects could maintain balance and increase the demands on each side of the body. The subjects then pressed back up to the start position, letting the medicine ball roll back to the finger tips. One half of the desired repetitions for each set were completed with the non-dominant arm first before switching to the other side.

One-arm Push-up (Level 10). The subjects placed their hands shoulder-width apart on the ground, with the body and elbows in a straight line. Feet were placed one foot length wider than the shoulder-width position. Extra stability was required during the One-arm Push-up, so the foot adjustment helped the subjects maintain balance during the lowering phase. After body was in proper alignment, subjects lifted one arm off the floor and placed it on their lower back. This was the starting position. The subjects then lowered their body, initiating the movement at the elbow, upper arm pressing against the side of the body, until their upper arm was parallel to the ground. This was the finish position. The subjects then pressed back up to the start position. Emphasis was made to keep the body as straight as possible during the movement by instructing the subjects to initiate the movement at the elbow and move straight up and down. If too much twisting of the torso and hips (lateral flexion) occurred, the set was stopped. One half of the desired repetitions for each set were completed with the non-dominant arm first before switching to the other side.

Statistical Analysis

For age, height, body mass, and body composition, descriptive statistics were used. For dependent variables (muscle thickness, medicine ball put test, one repetition max, and push up progression), separate 2 (Training: PUSH and BENCH) x 2 (Time: pre and post) ANOVAs with repeated measures were used. An alpha level of $p < 0.05$ was used to determine differences. If a significant interaction was found, independent and paired t-tests with Bonferroni corrections were used to compare the post-training adaptations.

CHAPTER IV. ARTICLE

Introduction

Resistance training (RT) is a popular form of physical activity because it develops several neuromuscular and musculoskeletal characteristics: muscular power, muscular hypertrophy, muscular endurance, and muscular strength (Feigenbaum & Pollock, 1999; Kraemer & Ratamess, 2004; Ratamess et al., 2009). In order to continuously improve one of these characteristics, manipulation of RT variables, such as the external resistance used, number of sets and repetitions per exercise, rest interval length, and frequency of the activity, needs to occur (de Salles et al., 2009; Kraemer & Ratamess, 2004; Ratamess et al., 2009). Many studies have examined the effect of manipulating these training variables on muscle strength improvement (Berger, 1962; Campos et al., 2002; Capen, 1956; Ratamess et al., 2012). According to these studies, programs consisting of three to six sets, less than or equal to six repetitions, with two to five minute rest intervals between sets, are ideal to increase muscular strength (Berger, 1962; Campos et al., 2002; Capen, 1956; de Salles et al., 2009; Kraemer & Ratamess, 2004). By applying these guidelines to a RT program increases in muscular strength should be achieved.

Calisthenic exercise (bodyweight training) is a form of RT that continues to increase in popularity over the last couple years. In fact, calisthenics was listed as the number two fitness trend for 2016, number one for 2015, by the American College of Sports Medicine (Thompson, 2014; Thompson, 2015). Although calisthenics are popular, other forms of RT are more commonly associated with muscular strength training. Traditional free weight and dumbbell exercises, such as the bench press and back squat, appear to be the most researched method of RT and the most used form of exercise to improve muscular strength (Berger, 1962; Capen, 1956; Kraemer & Ratamess, 2004; Stone et al., 2000). This may be due to the ease of manipulating some training variables, such as the external resistance, in order to maintain muscular strength development.

Studies on calisthenics are limited, with few available that have tested the effectiveness of calisthenics on improving muscle strength. These studies have concluded that calisthenic exercise does not result in muscle strength improvement (Campney & Wehr, 1965; Marcinik et al., 1985; Shvartz & Tamir, 1971; Tsourlou et al., 2003). However, one major limitation with these conclusions is that the studies did not accurately apply the recommended strength training variables to the calisthenic exercises. In fact, the training variables used closely resembled those of a muscular endurance training program; given researchers focused on increasing the number of repetitions, rather than utilizing a more difficult variation for each exercise to keep the subjects' repetitions lower.

Even today, calisthenics appear to be utilized in more muscular endurance activities. These include high repetition exercises with minimal rest intervals between sets (Kraemer & Ratamess, 2004; Ratamess et al., 2009). Therefore, a critical need to apply current muscular strength training principles to calisthenic exercise exists. By utilizing advanced variations of each calisthenic exercise, strength training variables could be maintained. The use of these increasingly difficult variations could show that calisthenics are an effective method for improving muscle strength, and possibly a great alternative to traditional weight training. This is significant when considering that calisthenics require minimal to no equipment, making them both efficient and cost effective. The purpose of this study was to compare progressive calisthenic push-up training to standard free weight bench press training as techniques to develop muscle strength and thickness.

Methods

Subjects. Twenty-seven healthy, moderately trained males 18-45 years of age were recruited, of which 23 (mean ± SD: age 23 ± 6.8 years, height 180.8 ± 5.7 cm, body mass 81.9 ± 14.1 kgs, body fat 10.4 ± 3.7 %) completed the study. A moderately-resistance trained subject was someone who was currently performing resistance exercise at least twice a week for the last two to six months (Baechle & Earle, 2008). Prior to inclusion in the study, subjects provided written informed consent, a self-reported health history, and a Physical Activity Readiness Questionnaire (PARQ). Additional exclusion criteria included: individuals with any history of joint pain, shoulder impingement syndrome, musculoskeletal disorders, such as rheumatoid arthritis, and/or specific injuries to the hands or shoulders. Each subject completed 15 sessions in the following order: one familiarization session, a pre-training fitness assessment, 12 training sessions, and a post-training fitness assessment. Subjects were trained three days per week, separated by 48 hours, and randomly assigned to a Push-up Progression Group (PUSH, n=14; mean ± SD: age 24 ± 8.5 years, height 180.7 ± 5.7 cm, body mass 79.6 ± 14.4 kgs, body fat 9.9 ± 1.1 %) or a Bench Press Group (BENCH, n=9; mean ± SD: age 21 ± 2.3 years, height 180.9 ± 6.1 cm, body mass 85.6 ± 13.7 kgs, body fat 11.3 ± 1.0 %). Descriptive measures were recorded prior to starting the training sessions.

Procedures. All procedures were approved in advance by the North Dakota State University Institutional Review Board, and written consent was obtained.

Familiarization session. During the familiarization session, participants learned about the purpose of the study, the different exercises, including proper form/body position, the specific training variables that were to be used during training sessions, and the cadence that was to be followed while performing each exercise. Participants also had the opportunity to ask questions about the study until they fully understood what was required of them.

Pre- and post-training fitness assessment sessions. During the pre- and post-training fitness assessment sessions, each subject underwent a series of tests to determine baseline and final measurements. Baseline measurements were conducted during the Pre-Training Fitness Assessment Session at least 48 hours before the first training session. Final measurements where conducted during the Post-Training Fitness Assessment Session at least 48 hours after the last training session. The order of the assessments was the ultrasound measurement, seated medicine ball put test, one repetition max bench press test, and push-up progression estimation. Each subject's age, height, body mass, and body fat percentage were recorded prior to the ultrasound measurement. Weight was recorded using an eye level scale (Detecto, Webb City, MO) and height was measured using a stadiometer (Seca, Chino, CA). A body composition analyzer (model TBF-300A; Tanita, Arlington Heights, IL) was used to determine participant body fat percentage. All data was collected on workout sheets created by the researcher.

Muscle thickness. Thickness of the left pectoralis major muscle was measured using B-mode on an ultrasound system (model HD11 XE; Philips Ultrasound, Bothell, WA) with a L12-5 50 mm linear array probe. The protocol for the ultrasound and method for measuring muscle thickness was conducted according to Yasuda, Fujita, Ogasawara, Sato, & Abe (2010). A one image technique was used to compare muscle thickness between baseline and final measurements. The site of ultrasound measurement was at 60% of the measured distance from the left clavicle to the left nipple, with the ultrasound head placed directly under the 60% indicator mark. The images were captured at a frequency of 37 hertz with a depth of 7 centimeters and gain of 100. Muscle thickness for each image was determined by averaging four evenly spaced measurements. Test-retest reliability of this one image technique was 2.5% using coefficient of variation and 0.953 using interclass correlation coefficient.

Seated medicine ball put test. The medicine ball put test was used to measure power of the upper body muscles. Although this study was designed for muscle strength improvement, strength is a factor of power. Any post-training improvements were likely due to increases in subject upper body muscle strength. The test was meant to be an alternative measure of muscle performance because it was not a specific exercise used in the PUSH or BENCH training. The protocol for the seated medicine ball put was conducted according to Clemons, Campbell, and Jeansonne (2010). A 12 pound medicine ball (Power Systems, Knoxville, TN) was used for testing.

One repetition max (1RM) bench press test. The purpose of the 1RM bench press test was to measure the maximum strength of the chest muscle group. The measurement of the 1RM during the bench press was conducted according to the NSCA's protocol (Baechle & Earle, 2008). A standard adjustable flat bench and weight clips, and a standard 45 pound Olympic barbell with weight plates ranging from 2.5 pounds to 45 pounds were used to complete the 1RM test.

Push-up progression estimation test (experimental approach). Starting push-up progression was determined by the researcher, taking into account the subjective estimation of which progression level from Table 2 each subject felt they could complete. At the estimated progression level, each subject attempted to complete three sets of six repetitions (6/6/6) for double arm progressions or three sets of three repetitions (3/3/3) per side for single arm progressions. A two minute rest was given between sets. If subject successfully completed the prescribed number of sets and repetitions for the progression, with good form, the subject moved on to the next push-up progression level. This process continued until the subject failed to complete the prescribed number of sets and repetitions, or proper form was compromised, for the current push-up progression level. The previous push-progression the subject completed with proper form was considered the baseline progression. Subjects randomly assigned to the PUSH used the baseline progression level they completed during testing as their starting point during the first training session.

Training sessions. All subjects completed a dynamic warm-up consisting of jogging in place (one minute), jumping jacks (one minute), jogging in place (one minute), shoulders rolls (20x), arm circles (20x), chest openers (20x), followed by a subsequent warm-up specific to their training group. Correct form for the BENCH and PUSH were monitored by trained staff. Push-up form was changed for each push-up progression level in Table 2. Research staff thoroughly monitored form in both groups to ensure conditions were the same for all subjects. A verbal cadence of two seconds on eccentric phase and two seconds on concentric phase was used to avoid any discrepancies in the subjects' velocity in both training groups. The cadence was voiced by the same researcher, for each subject, each session, to ensure consistency between subjects.

BENCH. Following the dynamic warm-up, subjects began a lift specific warm-up with the bench press exercise by performing eight repetitions at 40% of their estimated 1RM, followed by one minute of rest (NSCA, 2012). The subjects then completed a second warm-up set of six repetitions at 60% of their estimated 1RM, followed by a two minute rest. After the rest interval, subjects began their training sequence at 75% of their estimated 1RM. Training sequence began at three sets of six repetitions, utilizing a three minute rest between sets. Each training session, subjects attempted to complete one additional repetition for each set. Once subjects were able to perform three sets of eight repetitions, on two consecutive training sessions, intensity was increased by adding weight in 10 pound increments. After adding additional weight, subjects went back to performing three sets of six repetitions. The increase in weight ensured subjects maintained appropriate strength training progression in order to elicit the desired training response.

PUSH. Following the dynamic warm-up, subjects performed two warm-up sets of a push-up progression that was two levels below their baseline progression. For the first warm-up set, subjects performed eight repetitions for double arm progressions or four repetitions per side for single arm progressions followed by one minute of rest. For the second warm-up set, subjects performed six repetitions for double arm progressions or three repetitions per side for single arm progressions followed by two minutes of rest. After the warm-up sets were completed, subjects completed the actual training sequence. Training sequence began at three sets of six repetitions for double arm progressions or three sets of three repetitions per side for single arm progressions, utilizing a three minute rest interval between sets. Subjects attempted to complete one additional repetition per set each training session. Once subjects were able to complete three sets of eight repetitions for double arm progressions or three sets of four repetitions per side for single arm progressions, on two consecutive training sessions, intensity was increased by progressing to the next push-up variation in Table 2. After progressing to a more difficult variation, subjects went back to performing the three sets of six repetitions for double arm progressions or the three sets of three repetitions per side for single arm progressions for the new progression level.

Example: a subject at the Close Push-up progression (level 6) began the first training session attempting to complete three sets of six repetitions (6/6/6). If the subject achieved three sets of six repetitions (6/6/6) during the first session, the subject then attempted to complete three sets of seven repetitions (7/7/7) during the second training session. If, during the second session, the subject completed one set of seven repetitions (7/6/6) or two sets of seven repetitions (7/7/6), the subject remained at three sets of seven repetitions (7/7/7) until they were achieved in a single training session. Once three sets of seven (7/7/7) was achieved, the subject then worked to complete three sets of eight repetitions (8/8/8). This process continued each training session until the subject successfully completed three sets of eight repetitions (8/8/8) for his current push-up level on two consecutive training session. Once subject achieved three sets of eight repetitions (8/8/8) on two consecutive sessions, the subject progressed to the next level in the push-up variation in Table 2. Example: Close Push-up (level 6) subject completed two consecutive training sessions of three sets of eight repetitions (8/8/8), so he began the next training session with Uneven Push-ups (level 7). Training sessions for this progression began by attempting to complete three sets of three repetitions (3/3/3) for each side, a total training volume of three sets of six repetitions (6/6/6) because the Uneven Push-up is a single arm progression. Once subject achieved three sets of four repetitions (4/4/4) for each side, a total training volume of three sets of eight repetitions (8/8/8), on two consecutive training sessions, he progressed to the next push-up variation in Table 2. This process continued for each push-up progression.

Push-up Progressions. The push-up progression levels, and their order, were inspired by Wade (2012), and were selected for this study for their ability to stress the body and elicit the desired training response for individuals at any fitness level. Since subjects in the study were moderately trained, baseline progressions were between levels five and seven. Although baseline progressions were not lower than level five, the progressions and their directions were still included in the study. The purpose of including all levels in the study was to demonstrate how an individual at any fitness level could utilize the progressions as a method for continued muscle strength improvement. The 10 push-up progression levels, in order, are shown in Table 2.

A few of the push-up progressions used in the study alternated the stress of the exercise on a single side of the body and required the use of an 8 pound medicine ball (Power Systems, Knoxville, TN). For single arm push-up exercises, subjects began with their non-dominant arm first. When performing single arm push-up exercises with their dominant arm, subjects completed the exact number of repetitions achieved with their non-dominant arm. This was to help subjects overcome any muscle imbalances. Subjects completed one half of the desired repetitions per set on each side, before three minute rest was given. The total number of repetitions per set was split to more accurately maintain the training volumes between the PUSH and BENCH groups. Emphasis was made during each single arm set to maintain a consistent pressing force on the side without the medicine ball support. Once a subject was unable to maintain the same amount of force, by utilizing more force on the side with the medicine ball to assist with the pressing movement, the set was stopped. This process was to ensure that each side of the body was stressed with the same amount of force for each repetition. The quality, not the quantity, of each repetition was important.

Wall push-up (level 1). The distance subjects stood away from the wall was determined by measuring their arm length from shoulder to wrist. After arm length was obtained, subjects stood one and half of their measured arm length away from the wall. With feet and hands shoulder-width apart, subjects raised arms perpendicular to body and leaned forward until their palms were flat against the wall. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of the body, until their forehead gently touched the wall. This was the finish position. The subjects then pressed back up to the start position.

Incline push-up (level 2). Feet and hand position were shoulder-width apart. Hands were placed on a two foot, inclined surface at a 45° angle. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of the body, until their upper arms were parallel to the inclined surface. This was the finish position. The subjects then pressed back up to the start position.

Kneeling push-up (level 3). The subjects placed their hands on the floor shoulder-width apart. Knees were kept together, bent at 90°, while shifting the weight off the knees and onto the lower thigh directly above the knee. This position kept the body in alignment and tension off the knees. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of body, until their upper arms were parallel to the ground. This was the finish position. The subjects then pressed back up to the start position.

Half push-up (level 4). The subjects placed their hands and feet shoulder-width apart on the ground, with the body and elbows in a straight line. An 8 pound medicine ball was then placed directly under their hips. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of the body, until their hips made contact with the medicine ball. This was the finish position. Subjects then pressed back up to the start position.

Full push-up (level 5). The subjects placed their hands and feet shoulder-width apart on the ground, with the body and elbows in a straight line. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pinching against the sides of the body, until their upper arms were parallel to the ground. This was the finish position. The subjects then pressed back up to the start position.

Close push-up (level 6). The subjects placed their feet shoulder-width apart on the ground. Hands were placed directly under the chest with the thumbs of each hand touching and the index fingers no more than three inches apart. The body and elbows remained straight. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of the body, until their chest made contact with their hands or their upper arms were parallel to the ground. This was the finish position. The subjects then pressed back up to the start position.

Uneven push-up (level 7). This was the first single arm exercise. The subjects placed their hands and feet shoulder-width apart on the ground, with the body and elbows in a straight line. The dominant hand was placed directly on top of an 8 pound medicine ball. This was the starting position. The subjects then lowered their body, initiating the movement at the elbows, upper arms pressing against the sides of the body, until their chest made contact with the medicine ball. This was the finish position. The subjects then pressed back up to the start position. One half of the desired repetitions for each set were completed with the non-dominant arm first before switching to the other side.

½ One-arm push-up (level 8). The subjects placed their hands shoulder-width apart on the ground, with the body and elbows in a straight line. Feet were placed one foot length wider than the shoulder-width position. Extra stability was required for the ½ One-arm Push-ups, so the foot adjustment helped the subjects maintain balance during the lowering phase. An 8 pound medicine ball was placed directly under each subjects hips. After body was in proper alignment, subjects lifted one arm off the floor and placed it on their lower back. This was the starting position. The subjects then lowered their body, initiating the movement at the elbow, upper arm pressing against the side of the body, until their hips made contact with the medicine ball. This was the finish position. The subjects then pressed back up to the start position. Emphasis was made to keep the body as straight as possible during the movement by instructing subjects to initiate the movement at the elbow and move straight up and down. If too much twisting of the torso and hips (lateral flexion) occurred, the set was stopped. One half of the desired repetitions for each set were completed with the non-dominant arm first before switching to the other side.

Archer push-up (level 9). The subjects placed their hands and feet shoulder-width apart on the ground, with the body and elbows in a straight line. After body was in proper alignment, the subjects extended their dominant arm out perpendicular to their body and placed their finger tips on an 8 pound medicine ball. This was the starting position. The subjects then lowered their body, initiating the movement at the elbow, upper arm pressing against the side of the body, until their upper arm was parallel to the ground. This was the finish position. While lowering, the medicine ball under the extended arm was allowed to roll from the subjects' finger tips to the palm of their hand. This allowed the medicine ball to act as a moveable kickstand so subjects could maintain balance and increase the demands on each side of the body. The subjects then pressed back up to the start position, letting the medicine ball roll back to the finger tips. One half of the desired repetitions for each set were completed with the non-dominant arm first before switching to the other side.

One-arm push-up (level 10). The subjects placed their hands shoulder-width apart on the ground, with the body and elbows in a straight line. Feet were placed one foot length wider than the shoulder-width position. Extra stability was required during the One-arm Push-up, so the foot adjustment helped the subjects maintain balance during the lowering phase. After body was in proper alignment, subjects lifted one arm off the floor and placed it on their lower back. This was the starting position. The subjects then lowered their body, initiating the movement at the elbow, upper arm pressing against the side of the body, until their upper arm was parallel to the ground. This was the finish position. The subjects then pressed back up to the start position. Emphasis was made to keep the body as straight as possible during the movement by instructing the subjects to initiate the movement at the elbow and move straight up and down. If too much twisting of the torso and hips (lateral flexion) occurred, the set was stopped. One half of the desired repetitions for each set were completed with the non-dominant arm first before switching to the other side.

Statistical Analysis. For age, height, body mass, and body composition, descriptive statistics were used. For dependent variables (muscle thickness, medicine ball put test, one repetition max, and push up progression), separate 2 (Training: PUSH and BENCH) x 2 (Time: pre and post) ANOVAs with repeated measures were used. An alpha level of $p < 0.05$ was used to determine differences. If a significant interaction was found, independent and paired t-tests with Bonferroni corrections were used to compare the post-training adaptations.

Results

The PUSH and BENCH significantly increased 1RM compared to baseline [$F(1,21) = 22.604$, $p < 0.001$] with no significant differences between groups (Figure 1). A significant interaction effect was found for the push-up progression estimation [$F(1,21) = 52.994$, $p < 0.001$]. Post-hoc tests for push-up progression estimation showed a significant increase pre- to post-training for the PUSH [$t(13) = -18.735$, $p < 0.001$] and BENCH [$t(8) = -3.500 = p < 0.01$], and the change in the PUSH was significantly greater than the BENCH [$t(21) = 4.380$, $p < 0.001$] at the post-training time point (Figure 2). The training volume (sets x repetitions) between groups was not significantly different [$t(21) = 2.073$, $p = 0.051$], but appeared to be slightly larger in the PUSH (mean ± SE: 258.64 ± 1.15) compared to the BENCH (mean ± SE: 254.33 ±

1.89) (Figure 3). No significant differences were found within or between groups for the change in medicine ball put distance [$F(1,21) = 2.937$, $p = 0.101$] for the PUSH pre- (mean ± SE: distance 4.1 ± 0.12 m) to post- (mean ± SE: distance 4.1 ± 0.14 m) training and the BENCH pre- (mean ± SE: distance 4.2 ± 0.15 m) to post- (mean ± SE: distance 4.1 ± 0.18 m) training. No significant differences were found within or between groups for change in muscle thickness [$F(1,21) = 1.105$, $p = 0.305$] for the PUSH pre- (mean ± SE: thickness 3.01 ± 0.12 cm) to post- (mean ± SE: thickness 3.13 ± 0.14 cm) training and the BENCH pre- (mean ± SE: thickness 3.38 ± 0.25 cm) to post- (mean ± SE: thickness 3.42 ± 0.25 cm) training.

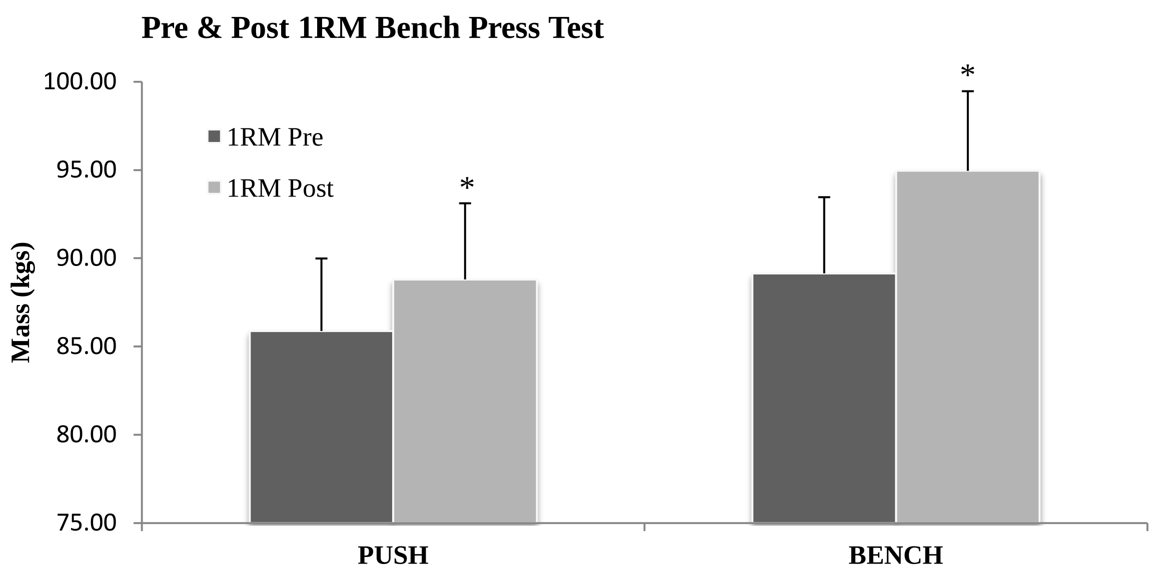

Figure 1. A comparison of one repetition maximum (1RM) strength values (mean ± SE) for the push-up progression group (PUSH) and the bench press group (BENCH) pre- and post-training. *****Significantly greater than corresponding pre-training value.

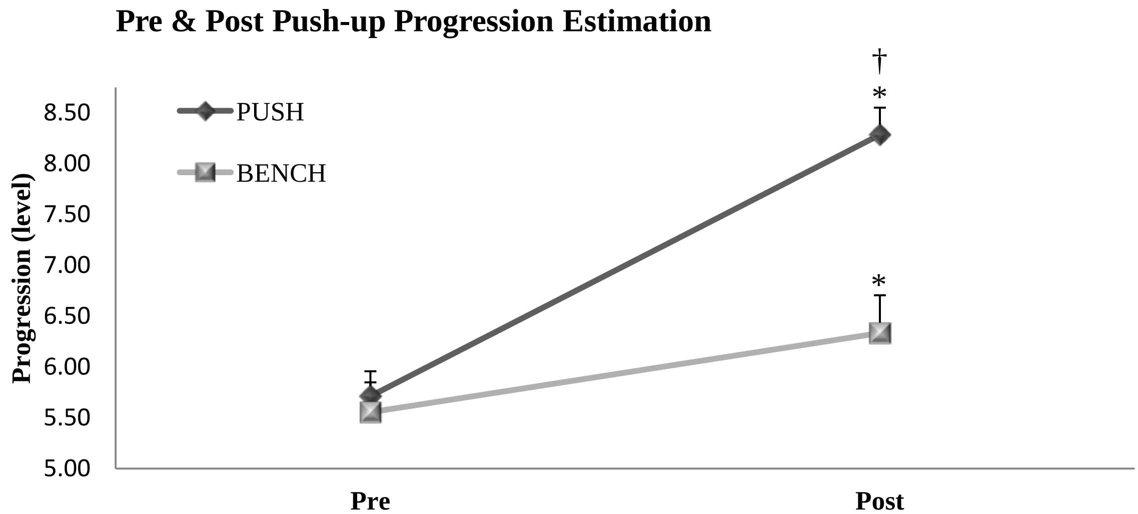

Figure 2. A comparison of push-up progression estimation (mean ± SE) for the push-up progression group (PUSH) and the bench press group (BENCH) pre- and post-training. *****Significantly greater than corresponding pre-training value. †Significantly greater than BENCH post-training values.

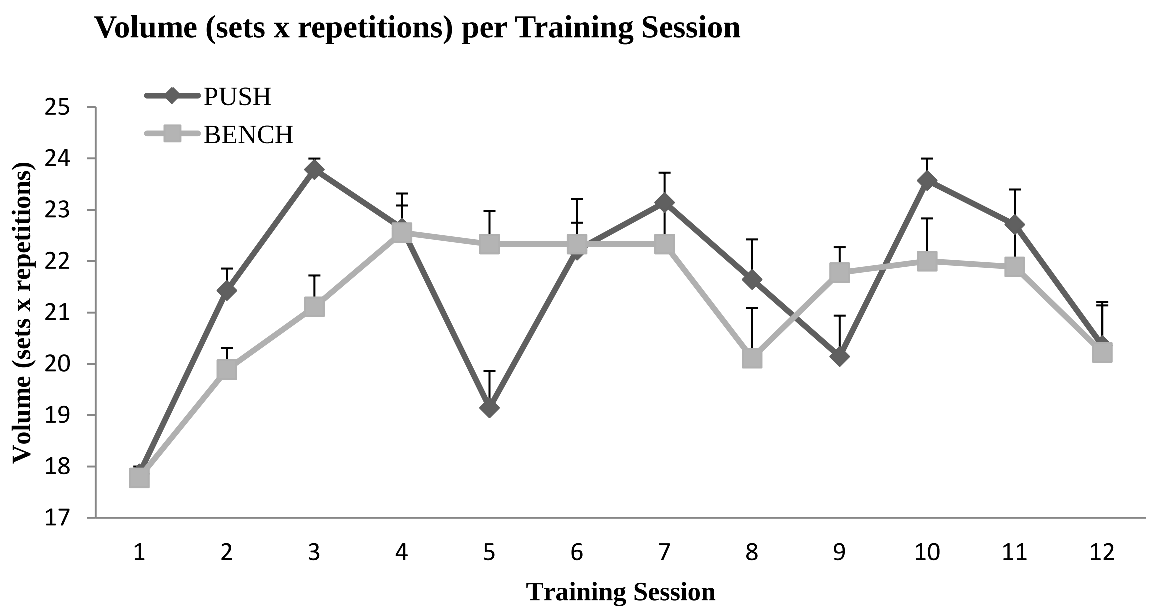

Figure 3. A comparison of volume (sets x repetitions) between the push-up progression group (PUSH) and the bench press group (BENCH) for each training session (mean ± SE).

Discussion

This was the first study to compare progressive variations of the push-up (calisthenic training) to the bench press (standard free weight training) as techniques to develop upper body muscle strength and thickness. The main finding of the investigations is that progressive push-up exercise can provide the necessary training stimulus to improve muscle strength similar to the traditional barbell bench press exercise when muscle strength training progressive variables, such as intensity, sets, repetitions, and rest time, are maintained.

Previous studies have failed to report improvements in muscle strength when utilizing calisthenic exercises (Campney & Wehr, 1965; Marcinik et al., 1985; Shvartz & Tamir, 1971; Tsourlou et al., 2003). These studies chose to increase the training intensity of the calisthenic exercises by adding repetitions, rather than varying the exercise to keep repetitions low, leading to a training intensity that was likely not high enough to stimulate strength adaptations. This type of training is commonly used for improving muscle endurance, and not muscle strength. The calisthenic training implemented in our study shows how the push-up, through the manipulation of body and hand position, can produce an adequate training intensity to increase muscle strength.

In support of our findings, Calatayud et al. (2015) found that push-ups with elastic bands, for added resistance, induced similar muscle activation levels and strength gains as the bench press exercise. The study demonstrated how biomechanically similar exercises, specifically the push-up, can improve upper body muscle strength when training variables are maintained. Although no statistical differences were observed between the PUSH and BENCH 1RM, we do acknowledge that the BENCH appeared to have a larger mean increase post-training (6.52%) than the PUSH (3.4%). This increase in the BENCH may have occurred due to improvements in form, technique, and overload while training with the specific bench press exercise used for the 1RM test. Another explanation for the difference may be the experimental and subjective selection of baseline push-up progressions for the PUSH. Essentially, subjects in the PUSH may not have started their training at a push-up variation that was challenging (intense) enough to provide the necessary stimulus to begin strength adaptations during the first week of training. This may have put the PUSH group at a slight disadvantage over the four week training period. Nevertheless, the ability of the PUSH to improve 1RM strength with only bodyweight progressions is novel.

The study also shows improvement in each group's push-up progression estimation from baseline; further indicating how these biomechanically similar exercises may have cross over benefits when training variables are kept the same. With that said, these data also showed that the PUSH improved push-up progression level to a significantly greater extent than the BENCH. This may be due to the BENCH training on a more stable surface, rather than in a more unstable position like the PUSH. While the PUSH specifically trained with push-ups and likely improved technique with each progression, each variation did incorporate a different body position. This suggests that additional factors, such as core strength and shoulder stability, may have played the larger role in the BENCH being unable to perform the more demanding push-up variations. It is also important to note that the mean improvement in BENCH (0.78 levels), compared to the PUSH (2.57 levels), while statistically significant, is not actually a full progression level. This shows that while 1RM strength improvement is transferable between the two exercises, push-ups may strengthen a wider range of muscles to effectively perform advanced progressions, especially single arm variations.

Based on these results, it is important to discuss the capability of progressive calisthenic push-up training to prolong strength improvement after reaching the level 10 variation used in this study. Although it will require a lot of training to successfully perform the One-arm Push-up variation with great form for several repetitions, additional variations will eventually be needed to continue progression in the strength repetition range and avoid ceiling effects. It is true that calisthenic exercise may not be as convenient as standard free weights in their ability to add external resistance to intensify the demands of the exercise. However, one positive about calisthenic exercise is that they can easily be manipulated to meet the needs of the trainee with little to no equipment. Many variations, including planche push-ups, and techniques, such as leg raising, foot distance apart, and declined surfaces, can intensify and extend the calisthenic push-up variations used in this study to continue increases in muscle strength. In addition, the possibility of combining external resistance (elastic bands and weighted vests) to calisthenic variations exists. These exercises would no longer be considered true calisthenics, but the variations could continue strength improvements beyond the initial ceiling. With that said, more research is needed to discover and support the benefits of calisthenic exercise, especially in longer training studies.

The training volume (sets x repetitions) between groups was not significantly different, but appeared to be slightly larger in the PUSH (mean ± SE: 258.64 ± 1.15) compared to the BENCH (mean ± SE: 254.33 ± 1.89). The increase is likely due to the inability of the PUSH to split three sets of seven repetitions for each side during the single arm push-up variations. Instead of progressing from three sets of six repetitions to three sets of seven repetitions like the BENCH or during double arm push-up variations, the PUSH progressed directly from three sets of six repetitions to three sets of eight repetitions during single arm variations, splitting the repetitions for each side. This means the PUSH may have completed more training sessions at three sets of eight repetitions. Load based volume (sets x repetitions x load) was not compared because of the difficultly to accurately estimate the specific load an individual in the PUSH would be moving during any push-up variation, especially single arm variations.

No significant differences in medicine ball put distance pre- and post-training were discovered for the PUSH or BENCH. Although upper body muscle strength did improve both groups 1RM, and strength is a factor of power, the slower training velocity and higher volume may have reduced the subjects' ability to quickly generate the force needed to propel the medicine ball greater distances (Kraemer & Ratamess, 2004). There were no significant differences in muscles thickness pre- and post-training in either group. The training variables used for this study were designed to improve maximal muscle strength, which differs from the variables that would be implemented for muscle hypertrophy (muscle growth). However, we wanted to explore the time course of the potential change in muscle thickness further in order to see if subtle changes could be detected in the short time frame. These findings support current literature on the recommended training variables for inducing muscle hypertrophy, and suggest that neuromuscular adaptations may have also influenced the improvement in muscle strength (Hedrick, 1995; Kraemer & Ratamess, 2004; Ratamess et al., 2009).

This is the first known study to apply current strength training variables to the calisthenic push-up exercise through the use of different variations. Therefore, the design of the push-up training is completely experimental with no similar studies to compare techniques or methods. The study was successful at improving upper body muscle strength, in both groups, after four weeks of training, however, the data from this study may not be transferrable to other populations, or other calisthenic exercises involving different muscles, variations, or training procedures. Further research is needed to compare the effectiveness of progressive calisthenic push-up variations, and different calisthenic exercises, in longer training studies, and determine their effects on core strength and stability, and other musculoskeletal characteristics. In addition, there is opportunity to explore the benefits calisthenic exercise may have on joint health and injury prevention. Calisthenics use a resistance that is never heavier than the lifters own mass and incorporates movements requiring multiple muscles for stabilization that may help develop these muscles in proportion to one another, rather than isolating muscles and lifting progressively heavier external loads. This study is the first to validate that the push-up, a calisthenic exercise, can be used to improve upper body muscle strength similar to the bench press by using different variations to maintain the recommended strength training variables in moderately trained males.

Practical Application

Progressive calisthenic push-up training increases upper body muscle strength similar to standard free weight bench press training when progressive variables for each group are kept the same. The push-up is easily adaptable to any fitness level through the use of variations and not only works the muscles of the chest and arms, but also incorporates many more muscles, including the stabilizing muscles of the shoulder and core. Strength and conditioning specialists, physical therapists, and trainers may use the information from this study to design or include one or more of these progressive variations into a resistance training program. By utilizing these unique variations, the push-up exercise would provide an efficient and cost effective alternative to the standard bench press exercise as a technique to increase upper body muscle strength. This is important when considering that push-ups are a functional exercise that requires minimal to no equipment, meaning it can be performed just about anywhere.

CHAPTER V. SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to compare progressive calisthenic push-up training to standard free weight bench press training as techniques to develop muscle strength and thickness. The main finding of the investigations is that progressive push-up exercise can provide the necessary training stimulus to improve muscle strength similar to the traditional barbell bench press exercise when muscle strength training progressive variables, such as intensity, sets, repetitions, and rest time, are maintained. The PUSH and BENCH significantly increased 1RM compared to baseline [$F(1,21) = 22.604$, $p < 0.001$] with no significant differences between groups. Although no statistical differences were observed between the PUSH and BENCH 1RM, we do acknowledge that the BENCH appeared to have a larger mean increase post-training (6.52%) than the PUSH (3.4%). This increase in the BENCH may have occurred due to improvements in form, technique, and overload while training with the specific bench press exercise used for the 1RM test. Another explanation for the difference may be the experimental and subjective selection of baseline push-up progressions for the PUSH. Essentially, subjects in the PUSH may not have started their training at a push-up variation that was challenging (intense) enough to provide the necessary stimulus to begin strength adaptations during the first week of training. This may have put the PUSH group at a slight disadvantage over the four week training period. Nevertheless, the ability of the PUSH to improve 1RM strength with only bodyweight progressions is novel.

A significant interaction effect was found for the push-up progression estimation [$F(1,21) = 52.994$, $p < 0.001$]. Post-hoc tests for push-up progression estimation showed a significant increase pre- to post-training for the PUSH [$t(13) = -18.735$, $p < 0.001$] and BENCH [$t(8) = -$

3.500 = $p < 0.01$]. This further indicates how these biomechanically similar exercises may have cross over benefits when training variables are kept the same. With that said, the change in the PUSH was significantly greater than the BENCH [$t(21) = 4.380$, $p < 0.001$] at the post-training time point. This may be due to the BENCH training on a more stable surface, rather than in a more unstable position like the PUSH. While the PUSH specifically trained with push-ups and likely improved technique with each progression, each variation did incorporate a different body position. This suggests that additional factors, such as core strength and shoulder stability, may have played the larger role in the BENCH being unable to perform the more demanding push-up variations. It is also important to note that the mean improvement in BENCH (0.78 levels), compared to the PUSH (2.57 levels), while statistically significant, is not actually a full progression level. This shows that while 1RM strength improvement is transferable between the two exercises, push-ups may strengthen a wider range of muscles to effectively perform advanced progressions, especially single arm variations.

Based on these results, it is important to discuss the capability of progressive calisthenic push-up training to prolong strength improvement after reaching the level 10 variation used in this study. Although it will require a lot of training to successfully perform the One-arm Push-up variation with great form for several repetitions, additional variations will eventually be needed to continue progression in the strength repetition range and avoid ceiling effects. It is true that calisthenic exercise may not be as convenient as standard free weights in their ability to add external resistance to intensify the demands of the exercise. However, one positive about calisthenic exercise is that they can easily be manipulated to meet the needs of the trainee with little to no equipment. Many variations, including planche push-ups, and techniques, such as leg raising, foot distance apart, and declined surfaces, can intensify and extend the calisthenic push-up variations used in this study to continue increases in muscle strength. In addition, the possibility of combining external resistance (elastic bands and weighted vests) to calisthenic variations exists. These exercises would no longer be considered true calisthenics, but the variations could continue strength improvements beyond the initial ceiling. With that said, more research is needed to discover and support the benefits of calisthenic exercise, especially in longer training studies.

The training volume (sets x repetitions) between groups was not significantly different [$t(21) = 2.073$, $p = 0.051$], but appeared to be slightly larger in the PUSH (mean ± SE: 258.64 ± 1.15) compared to the BENCH (mean ± SE: 254.33 ± 1.89). The increase is likely due to the inability of the PUSH to split three sets of seven repetitions for each side during the single arm push-up variations. Instead of progressing from three sets of six repetitions to three sets of seven repetitions like the BENCH or during double arm push-up variations, the PUSH progressed directly from three sets of six repetitions to three sets of eight repetitions during single arm variations, splitting the repetitions for each side. This means the PUSH may have completed more training sessions at three sets of eight repetitions. Load based volume (sets x repetitions x load) was not compared because of the difficultly to accurately estimate the specific load an individual in the PUSH would be moving during any push-up variation, especially single arm variations.

No significant differences were found within or between groups for the change in medicine ball put distance [$F(1,21) = 2.937$, $p = 0.101$] for the PUSH pre- (mean ± SE: distance 4.1 ± 0.12 m) to post- (mean ± SE: distance 4.1 ± 0.14 m) training and the BENCH pre- (mean ± SE: distance 4.2 ± 0.15 m) to post- (mean ± SE: distance 4.1 ± 0.18 m) training. Although increases in upper body muscle strength improved both groups 1RM, and strength is a factor of power, the slower training velocity and higher volume may have reduced the subjects' ability to quickly generate the force needed to propel the medicine ball greater distances (Kraemer & Ratamess, 2004). No significant differences were found within or between groups for the change in muscle thickness [$F(1,21) = 1.105$, $p = 0.305$] for the PUSH pre- (mean ± SE: thickness 3.01 ± 0.12 cm) to post- (mean ± SE: thickness 3.13 ± 0.14 cm) training and the BENCH pre- (mean ± SE: thickness 3.38 ± 0.25 cm) to post- (mean ± SE: thickness 3.42 ± 0.25 cm) training. The training variables used for this study were designed for maximal muscle strength improvement, which differs from the variables that would be implemented for muscle hypertrophy (muscle growth). However, we wanted to explore the time course of the potential change in muscle thickness further in order to see if subtle changes could be detected in the short time frame. These findings support current literature on the recommended training variables for inducing muscle hypertrophy, and suggest that neuromuscular adaptations may have also influenced the improvement in muscle strength (Hedrick, 1995; Kraemer & Ratamess, 2004; Ratamess et al., 2009).

Conclusions

This is the first known study to apply current strength training variables to the calisthenic push-up exercise through the use of different variations. Therefore, the design of the push-up training is completely experimental with no similar studies to compare techniques or methods. The study was successful at improving upper body muscle strength, in both groups, after four weeks of training, however, the data from this study may not be transferrable to other populations, or other calisthenic exercises involving different muscles, variations, or training procedures. Further research is needed to compare the effectiveness of progressive calisthenic push-up variations, and different calisthenic exercises, in longer training studies, and determine their effects on core strength and stability, and other musculoskeletal characteristics. In addition, there is opportunity to explore the benefits calisthenic exercise may have on joint health and injury prevention. Calisthenics use a resistance that is never heavier than the lifters own mass and incorporates movements requiring multiple muscles for stabilization that may help develop these muscles in proportion to one another, rather than isolating muscles and lifting progressively heavier external loads. This study is the first to validate that the push-up, a calisthenic exercise, can be used to improve upper body muscle strength similar to the bench press by using different variations to maintain the recommended strength training variables in moderately trained males.

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APPENDIX A. IRB APPROVAL LETTER

NDSU NORTH DAKOTA STATE UNIVERSITY

August 18, 2015

Dr. Kyle Hackney
Department of Health, Nutrition & Exercise Sciences

IRB Approval of Protocol #HE16013, "Effect of Progressive Calisthenic Push-up Training on Muscular Strength & Quality"
Co-investigator(s) and research team: Christopher Kotarsky, Sean Mahoney, Kara Stone

Approval period: 8/18/2015 to 8/17/2016
Continuing Review Report Due: 7/1/2016

Research site(s): NDSU Funding Agency: n/a
Review Type: Expedited category # 4
IRB approval is based on the original protocol submission, with revised: protocol and consent form (received 8/13/2015).

Additional approval is required:
o prior to implementation of any changes to the protocol (Protocol Amendment Request Form).
o for continuation of the project beyond the approval period (Continuing Review/Completion Report Form). A reminder is typically sent 4-6 weeks prior to the expiration date; timely submission of the report is your responsibility. To avoid a lapse in approval, suspension of recruitment, and/or data collection, a report must be received, and the protocol reviewed and approved prior to the expiration date.

A report is required for:
o any research-related injuries, adverse events, or other unanticipated problems involving risks to participants or others within 72 hours of known occurrence (Report of Unanticipated Problem or Serious Adverse Event Form).
o any significant new findings that may affect risks to participants.
o closure of the project (Continuing Review/Completion Report Form).

Research records are subject to random or directed audits at any time to verify compliance with IRB regulations and NDSU policies.

Thank you for cooperating with NDSU IRB procedures, and best wishes for a successful study.

Sincerely,
Kristy Shirley
Digitally signed by Kristy Shirley
DN: cn=Kristy Shirley, o=NDSU, ou=Institutional Review Board, email=kristy.shirley@ndsu.edu, c=US
Date: 2015.08.18 14:11:09 -05'00'
Kristy Shirley, CIP, Research Compliance Administrator

For more information regarding IRB Office submissions and guidelines, please consult www.ndsu.edu/irb. This Institution has an approved FederalWide Assurance with the Department of Health and Human Services: FWA00002439.

INSTITUTIONAL REVIEW BOARD
NDSU Dept 4000 | PO Box 6050 | Fargo ND 58108-6050 | 701.231.8995 | Fax 701.231.8098 | ndsu.edu/irb

Shipping address: Research 1, 1735 NDSU Research Park Drive, Fargo ND 58102

APPENDIX B. INFORMED CONSENT FORM

NDSU **North Dakota State University**
Health, Nutrition, and Exercise Sciences
Department # 2620, PO Box 6050
Fargo, ND 58108-6050
701-231-6706

Title of Research Study:
Effect of Progressive Calisthenic Push-up Training on Muscular Strength & Quality

This study is being conducted by:
Principal Investigator -Kyle Hackney, PhD, CSCS, kyle.hackney@ndsu.edu, 701-231-6706.
Co-investigator - Chris Kotarsky, christopher.kotarsky@ndsu.edu, 216-956-5412.

Where is the study taking place?
The study will take place in the Bentson-Bunker Fieldhouse, rooms 14 and/or 15.

Why am I being asked to take part in this research study?
We are looking to recruit 30 participants for this study.

You are being asked to participate in this study because you:

- Are a male between 18-45 years of age.
- Are apparently healthy as identified by the Physical Activity Readiness Questionnaire and Health History Forms.
- Have participated in resistance exercise, weightlifting, or weight training for a minimum of 2 days per week for the past 2-6 months.

You should not participate in this study if you:

- Answered "Yes" to any questions on the Physical Activity Readiness Questionnaire.
- Are current tobacco-user / e-cigarette users, or have quit within last 6 months.
- Are currently taking anabolic steroids.
- Have a BMI > 29 or have blood pressure ≥ 140/90 mm HG.
- Have a pacemaker.
- Consumed other dietary supplements (other than vitamins) within the past 30 days.
- Have any current or previous cardiovascular, musculoskeletal, or neurological medical problems.
- Have any other health condition that may put you at risk during the study. (Such as diabetes, asthma, cardiovascular disease, etc.)

What is the reason for doing the study? By determining if advanced variations of the push-up exercise can maintain strength training principles and continue muscular strength progression, the study could show that calisthenics are an effective method for improving muscular strength. Muscle size is not expected to increase with strength training, but strength adaptations could illicit changes in muscle quality (amount of strength per muscle area). This is significant when considering that calisthenics require minimal equipment and are a very cost effective form of resistance training in comparison with traditional free weight training.

What will I be asked to do? You will take part in 15 sessions in the following order: one familiarization session, a pre-training fitness assessment, 12 training sessions, and a post-training fitness assessment. You will be trained three days per week, separated by 48hrs, in one of two randomly assigned groups: a Push-up Progression Group (PUSH), or a Bench Press Group (BENCH). The familiarization session and two training fitness assessments will last 35 minutes and the training sessions will last 40 minutes. The familiarization session can be scheduled at any time that works for you and the research team. The purpose of the session is to inform you of the specific exercises and techniques that will be used during the training sessions.

Pre- and post-training fitness assessments will be scheduled two days before and two days after training sessions. You will undergo a series of tests to determine baseline and final fitness measurements. At this visit we will measure your height, weight and body fat percentage. The research team will then measure the thickness of your left pectoralis major muscle using ultrasound. Next, you will perform a seated medicine ball put test to measure the power of your upper body muscles. A one repetition max bench press test will be used to measure the maximum strength of your chest muscle group. Lastly, you will undergo a push-up progression estimation test to determine which push-up variation matches your current level of upper body muscular strength.

Training sessions will need to be scheduled at three days per week with at least 24-48hrs of rest in between sessions. Depending on group assignment, you will be training with either the bench press or a variation of the push-up exercise. A brief warm-up will be provided prior to training. If you are in the bench press group, you will be asked to perform 3 sets of 6 repetitions with 3 minutes of rest between each set during your first training session. The initial weight lifted will be determined by your fitness assessment results. Progression will be maintained by increasing the resistance used once you can perform 3 sets of 8 repetitions for the current weight lifted. If you are in the push-up progression group, you will be asked to perform 3 sets of 6 repetitions with 3 minutes of rest between each set during your first training session. The initial push-up variation used will be determined by your fitness assessment results. Each subsequent training session you will be asked to complete one additional repetition for each set until you complete 3 sets of 8 repetitions for your initial push-up variation. Once you achieve 3 sets of 8 repetitions, you will begin a more difficult push-up variation at 3 sets of 6 repetitions.

Where is the study going to take place, and how long will it take? This study will take place in room 15 of Bentson-Bunker Fieldhouse. The estimated time for each session is as follows:

Familiarization Session	= 35 minutes
Pre-Training Fitness Assessment	= 35 minutes
Training Session (12 total: 3 weeks)	= 40 minutes each
Post-Training Fitness Assessment	= 35 minutes

It is estimated that the total time for this study will be ~585 minutes (9.75 hours).

What are the risks and discomforts? It is not possible to identify all potential risks in research procedures, but the researchers have taken reasonable safeguards to minimize any known risks to you. If new findings develop during the course of this research which may change your willingness to participate, we will tell you about these findings. Below are examples of known risks for this study.

Physical- Muscle Strength Testing and Resistance Exercise

1. Muscle soreness following testing & training: Exercising with a greater resistances, performing new exercises, or maximal exercises (risk: moderate).
2. Muscle cramping: Inadequate warm-up or stretching, not enough water intake before training (risk: low).
3. Musculoskeletal injury: Improper warm-up, muscle overloading or improper performance of exercises can cause muscle, ligament, tendon, or bone injury (risk: low).
4. Adverse cardiovascular responses: Abnormal heart rate or blood pressure responses from adapting to the demands of the exercise or holding breath to help generate force (risk: low).
5. Lightheadedness: Quickly standing after completing exercises or the strain of exercises (risk: low).
6. General personal injury: Inadvertently walking into test stations, having contact with sharp edges, or hardware failure (equipment breaks, etc.) could cause injury (risk: low).

Ultrasound Measurements

1. Rash or skin irritation: At the site of application of the ultrasound gel (risk: low).

Privacy

1. We will be collecting health information via questionnaires to determine if participants are eligible for the study. We will keep this information confidential and store it under lock and key. (risk: low)

Risk Minimization

The study team has minimised the known risks by studying healthy participants that are moderately trained in resistance exercise. By being physically healthy and familiar with resistance exercise, all exercise testing risks are lowered. In addition, staff will ensure you are adequetly hydrated before training. Previously tested protocols will be included in the study, and staff have had training in proper resistance exercise techniques. Non-allergenic ultrasound gel will be used to reduce the risk of rash or skin irritation. If redness, swelling, or bruising occurs at any sites during this study please contact Kyle Hackney, NDSU: 701-231-6706 or cell: 616-886-0226 or call Student Health Services directly at 701-231-7331. If you feel it’s a medical emergency call 911.

What are the benefits to me? You may increase your upper body muscle strength by performing the exercise routine in this research study.

What are the benefits to other people? By determining if advanced variations of the push-up exercise can maintain strength training principles and continue muscular strength progression, the study could show that calisthenics are an effective method for improving muscular strength.

This is significant when considering that calisthenics require minimal equipment and are a very cost effective form of resistance training in comparison with traditional free weight training.

Do I have to take part in the study? Your participation in this research is your choice. If you decide to participate in the study, you may change your mind and stop participating at any time without penalty or loss of benefits to which you are already entitled.

What will it cost me to participate? There are no direct costs for participation in the study.

What are the alternatives to being in this research study? Instead of participating in this research study, you can choose not to participate.

Who will see the information that I give? We will keep private all research records that identify you. Your information will be combined with information from other people taking part in the study. When we write about the study, we will write about the combined information that we have gathered. We may publish the results of the study; however, we will keep your name and other identifying information private. We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from your research records and these two things will be stored in different places under lock and key. If you withdraw before the research is over, your information will be retained in the research record and we will not collect additional information about you.

Can my taking part in the study end early? You can choose to not be in the study at any time; however, we ask that you please contact the researchers if you choose to do so. If you fail to show up to sessions or fail to comply with the study guidelines you may be removed from the study.

Will I receive any compensation for taking part in this study? By becoming a participant and completing the study, you will be entered into a drawing to win $50 dollars. Ten of the thirty total participants in this study will win the $50 prize.

What happens if I am injured because of this research? If you receive an injury in the course of taking part in the research, you should contact Chris Kotarsky at 216-956-5412 or Dr. Kyle Hackney at the following phone number NDSU 701-231-6706 or cell 616-886-0226. If an injury should occur, first aid will be administered as well as contact of emergency services (911) if needed. Payment for this treatment must be provided by you and your third party payer (such as health insurance). This does not mean that you are releasing or waiving any legal right you might have against the researcher or NDSU as a result of your participation in this research.

What if I have questions? Before you decide whether to accept this invitation to take part in the research study, please ask any questions that might come to mind now. Later, if you have any questions about the study, you can contact the researcher Chris Kotarsky, christopher.kotarsky@ndsu.edu, cell 216-956-5412.

What are my rights as a research participant?

You have rights as a participant in research. If you have questions about your rights, or complaints about this research you may talk to the researcher or contact the NDSU Human Research Protection Program by:

- Telephone: 701.231.8995 or toll-free 1-855-800-6717
- Email: ndsu.irb@ndsu.edu
- Mail: NDSU HRPP Office, NDSU Dept. 4000, PO Box 6050, Fargo, ND 58108-6050.

The role of the Human Research Protection Program is to see that your rights are protected in this research; more information about your rights can be found at: www.ndsu.edu/irb .

Documentation of Informed Consent:

You are freely making a decision whether to be in this research study. Signing this form means that

1. you have read and understood this consent form
2. you have had your questions answered, and
3. you have decided to be in the study.

You will be given a copy of this consent form to keep.

____ _________________
Your signature Date

____
Your printed name

____ _________________
Signature of researcher explaining study Date

____
Printed name of researcher explaining study

APPENDIX C. PARTICPANT RECRUITMENT LETTER

Effect of Progressive Calisthenic Push-up Training on Muscle Strength & Thickness

Principal Investigator: Kyle Hackney, PhD, kyle.hackney@ndsu.edu, 701-231-6706.
Co-investigator: Chris Kotarsky, christopher.kotarsky@ndsu.edu, 216-956-5412.

This study will test if advanced variations of the push-up exercise can increase muscle strength. Muscle size is not expected to increase with strength training, but strength adaptations could illicit changes in muscle quality (amount of strength per muscle area). This is significant when considering that calisthenics require minimal equipment and are a very cost effective form of resistance training in comparison with traditional free weight training.

We are looking to recruit 30 total participants for this study. To participate you should be a male between 18-45 years of age, apparently healthy with no previous or current cardiovascular, musculoskeletal, or neurological medical problems, have participated in resistance exercise, weightlifting, or weight training for a minimum of 2 days per week for the past 2-6 months.

We are asking you to complete one familiarization session/meeting, two training fitness assessments (before and after training) and twelve training sessions over 4 consecutive weeks. For training, you will be randomly assigned to a bench press training group or a push-up training group. During training fitness assessments we will measure the size of your muscles (using ultrasound), your upper body muscular power with a seated medicine ball put test, your maximum upper body muscular strength with the one repetition max bench press test, and determine which push-up variation matches your current level of upper body muscular strength using a push-up progression level estimation test. Each training session will last only 20 minutes and will include training with either the bench press or a variation of the push-up exercise depending on group assignment.

First group Pre-Fitness Assessments are this week! Still plenty of time to get into the schedule. **Second group Pre-Fitness Assessments begin the week of October 18th**.

If interested or for more information please contact Chris Kotarsky at e-mail: christopher.kotarsky@ndsu.edu, Phone: 216-956-5412.

This research has been approved by the North Dakota State University Institutional Review Board (Protocol # HE16103).

APPENDIX D. SUBJECT TRAINING FORM

Subject #: ______________________ Age: __________________ Date: _________________

Fitness Assessment Pre-Date: __________________ Post-Date: ______________________

	Height (in)	Weight (lbs)	Body Fat %	Ultrasound (cm)				Put Test (in)			1RM (lbs)	Push-up
Pre												
Post												

AVERAGES: **Ultrasound** Pre: _____ Post: ______ **BEST:** **Put Test** Pre:_____Post: _____

Training Sessions **PUSH Progression**: _________ **BENCH** (**75% 1RM**): ___________

Session #1			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			

Session #2			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			

Session #3			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			

Session #4			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			

Session #5			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			

Session #6			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			

Session #7			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			

Session #8			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			

Session #9			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			

Session #10			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			

Session #11			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			

Session #12			
Date:			
Weight:			
Push-up:			
Sets:	**#1**	**#2**	**#3**
Reps:			