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The Hypertrophic Effects of Practical Vascular Blood Flow Restriction Training

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by

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ABSTRACT

Practical blood flow restriction training is a new training technique that has the potential to increase muscular hypertrophy and muscular strength while allowing practitioners to train with lighter loads (20-30% of 1-RM). Through the use of elastic knee wraps, the limbs can be restricted using a perceived pressure scale. The comparison of practical blood flow resistance training with traditional, non-blood flow restricted resistance training and its effects on muscular hypertrophy and strength has not been investigated.

Twenty-one resistance-trained males participated in a 4-week training program and were randomly assigned to one of two groups: Practical BFR training (BFR; $n = 10$) and Resistance training (RT; $n = 11$). The primary difference between the groups was the BFR group performed approximately 62% of all sets blood flow restricted at 20-30% of 1-RM while the RT group performed all sets at an intensity of > 70% 1-RM in a traditional manner (non-blood flow restricted). Perceived pressure for blood flow restriction in the BFR group for the arms and legs was 7 out of 10. Workouts for both groups were similar and consisted of whole body routines ~3 days/week. A 2x2 repeated measures ANOVA was used to assess group, time, and group by time interactions. Statistical significance was set to $p \leq 0.05$.

There was a no difference in total lifting volume with the BFR group achieving a total lifting volume that was 11% less than the RT group. There was a main effect for time for biceps cross-sectional area ($p = 0.004$), thigh girth ($p = 0.002$), bench press 1RM ($p = 0.001$) and leg press 1RM ($p < 0.001$). Specifically, BFR improved from 220.5 ± 65.1 to 235.0 ± 50.6 pounds and from 822 ± 135.9 to 952.5 ± 168.9 pounds in the bench press and leg press, respectively.

The RT improved from 245.9 ± 60.9 to 257.7 ± 53.5 pounds and from 780.5 ± 192.4 to 957.3 ± 213.4 pounds in the bench press and leg press, respectively. No interaction effects were observed for all hypertrophy and strength variables.

4-weeks of practical blood flow restriction training is as effective for inducing maximal bench press and leg press strength, as well as biceps muscle size and thigh muscle size, as compared to traditional resistance training, despite training at low percentages of subjects 1-RM.

CHAPTER ONE:

INTRODUCTION

Rationale/Intro

1.1 Skeletal Muscle Hypertrophy

It is well known that muscular hypertrophy is stimulated by resistance training through metabolic, mechanical, and hormonal processes (McCall et al., 1996; Staron et al., 1994). Skeletal muscle hypertrophy is a process that synthesizes contractile proteins, specifically myosin and actin, and other structural proteins, resulting in the increase of the cross-sectional area of the muscle fibers. Synthesis of these new proteins must exceed the breakdown of proteins for hypertrophy to occur. The status of protein synthesis exceeding protein breakdown is known as positive net protein balance. Exercise and nutritional interventions are required to maximize the potential of skeletal muscle hypertrophy. Maximizing this process as much as possible is important for gaining muscular size.

Skeletal muscle hypertrophy is realized in part via metabolic, mechanical, translational, and hormonal processes that occur at the cellular level. The first involves proliferation of myogenic progenitor cells, also known as satellite cells. Mechanical damage to the muscle fibers (via resistance exercise) stimulates this process and is regulated by myogenic regulatory transcription factors, specifically myogenic differentiation (MyoD) and myogenin (MyoG) transcription factors (Coffey & Hawley, 2007). Satellite cell activity is required for skeletal muscle to add new sarcomeres. The myonuclear domain theory explains the activity of satellite cells and will be addressed later. The next process is muscle protein synthesis, a complex process stimulated by exercise and nutrition interventions leading to the synthesis of new muscle proteins. The responsible signaling pathway for IFG-1 mediated muscle protein synthesis is the PI(3)K-Akt-mTOR pathway (Glass, 2003).

1.2 Vascular Blood Flow Restriction Training

To achieve muscular hypertrophy under normal conditions, loads of at least 70% of 1RM must be lifted (ACSM, 2009). In some conditions or with certain individuals, the high mechanical stress of this load placed on the joints may not be withstood. KAATSU training, or blood flow restriction training, was developed to provide low intensity lifting alternatives that may stimulate muscular hypertrophy gains. KAATSU training was developed by Dr. Yoshiaki Sato, M.D., Ph. D, in the late 1960's in Japan. The idea first came to Dr. Sato at a Buddhist memorial; just from the way Dr. Sato was kneeling, he noticed numbness and a swelling sensation similar to that he felt during resistance training. This inspired Dr. Sato to investigate the effects restricting blood flow has on muscle while training. (Sato, 2005)

Blood flow restriction training involves using a wrapping device, such as a blood pressure cuff, and decreasing blood flow to a muscle. Recently, practical applications of vascular blood flow restriction training involve using elastic knee wraps as a wrapping device. Data has shown, verified by ultrasound, that practical vascular blood flow restriction training using knee wraps resulted in venous, but not arterial constriction (Wilson et al., 2013). The results of the study suggest practical vascular blood flow restriction training increases motor unit recruitment leading to an acute increase in skeletal muscle cross-sectional area. This would allow for the use of practical vascular blood flow restriction training in a research setting without using costly research equipment. The purpose of vascular blood flow restriction training is to provide an alternative to traditional resistance training to achieve muscular hypertrophy. In a study by Sumide et al. (2009), muscular hypertrophy was shown to occur using vascular blood flow restriction training with intensities as low as 20% 1RM with moderate vascular blood flow restriction (~100mmHg). Vascular blood flow restriction training can cause skeletal muscle hypertrophy gains in little as one week while showing no indicators of skeletal muscle damage or elevated inflammation (Abe et al., 2005a).

At the present time, only a few studies have investigated, in trained populations, the benefits of practical vascular blood flow restriction training. Practical vascular blood flow restriction training involves using a vascular blood flow restriction device such as knee wraps or elastic bands to occlude the limbs instead of the expensive research KAATSU apparatus that uses a pressure cuff controlled by a computer. One recent study by Yamanaka, Farley, and Caputo (2012) used trained, division 1A athletes and performed four weeks of training involving occluded bench press and squats. The researchers used elastic bands with Velcro as their practical vascular blood flow restriction device. After the four weeks of training with a frequency of three days per week they found significant increases in 1-RM bench press and squat strength (7.0% and 8.0%) and upper and lower chest girth (3%). The study is one of the first to use practical methods of vascular blood flow restriction and show increases in both strength and muscle size.

1.2.1 Physiological Mechanisms to Vascular Blood Flow Restriction Training

There are many proposed mechanisms as to how vascular blood flow restriction training can stimulate muscular adaptations. These mechanisms include: metabolic accumulation, fast-twitch fiber recruitment, and increased protein synthesis via the PI(3)K-Akt-mTOR pathway. Secondary mechanisms thought to also have an effect via vascular blood flow restriction stimulus are heat shock proteins, nitric oxide synthase-1 (NOS-1), and myostatin (Loenneke et al., 2010). To date the research is incomplete on what mechanism influences muscle hypertrophy the most or what metabolite is primarily responsible for increases in GH with vascular blood flow restriction (Loenneke et al., 2010). A further understanding on the mechanisms of vascular blood flow restriction training may lead to more optimal protocols for use of the training technique.

Professionals recommend vascular blood flow restriction training be used by specific populations such as athletes, rehabilitation patients with ACL and cardiac problems, elderly, and astronauts (Loenneke & Pujol 2009). Many of the research studies have investigated the benefits of use in a clinical setting (Abe et al., 2005b). Athletes and recreational bodybuilders should not overlook the proposed benefits to vascular blood flow restriction training. The future focus of the research needs to inspect the potential benefits of vascular blood flow restriction training in a practical setting so non-rehabilitating populations may utilize the benefits.

Problem Statement/Purpose

The purpose of this study was to investigate the effects of vascular blood flow restriction training as a training technique within a normal resistance training bout over a four week period in trained college-age males. The use of vascular blood flow restriction training has been used in rehabilitation (Abe et al., 2005b), training periods of recovery, and compared against normal resistance training bouts as a standalone training session (Abe et al., 2005c). No research to date has compared two training groups where one group completes a training period with the majority of training blood flow restricted, while the other performs a traditional resistance training period. Specifically, the present study aimed to investigate the hypertrophic effects and strength effects over a four week training period between these two groups.

Study Variables

The independent variable, or treatment variable, was the amount vascular blood flow restriction exercise used in the resistance-training program. The second independent variable is time. All assessments of the dependent variables occurred pre and post training. The first dependent variable was skeletal muscle hypertrophy measured in two ways, first through the cross-sectional area changes via a BodyMetrix™ Pro ultrasound, second by the assessment of body circumferences at specific sites via a Power Systems spring-loaded tape measure. The next dependent variable was upper and lower body strength measures. Upper body muscular strength was measured with 1-RM bench press. Lower body muscular strength was measured with 1-RM leg press.

Hypotheses

Ho_1: There will be no difference between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in biceps skeletal muscle hypertrophy (cross-sectional area) as measured by ultrasound following four weeks of resistance training.

Ho_2: There will be no difference between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in vastus lateralis skeletal muscle hypertrophy (cross-sectional area) as measured by ultrasound following four weeks of resistance training.

Ho_3: There will be no difference between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in upper arm circumference following four weeks of resistance training.

Ho_4: There will be no difference between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in thigh circumference following four weeks of resistance training.

Ho_5: There will be no difference between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in bench press strength following four weeks of resistance training.

Ho_6: There will be no difference between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in leg press strength following four weeks of resistance training.

Conceptual Model

Under normal conditions, resistance training can stimulate muscle protein synthesis through S6K1 phosphorylation downstream of mTOR. Increased levels of muscle protein synthesis can lead to muscular hypertrophy of the myofibrils. Under the recommendations of the ACSM (2009), resistance training with a load of at least 70% of 1-RM for multiple sets, periodized with 6-12 repetitions performed per set is optimal for stimulating muscle hypertrophy. The reason why a load of at least 70% of 1-RM is recommended is to recruit fast-twitch muscle fibers, which have a greater capacity to hypertrophy and greater amounts of S6K1 (McCall et al., 1996; Loenneke et al., 2011).

Practical vascular blood flow restriction training has been shown to increase motor unit recruitment and muscle thickness at low intensities (30% of 1-RM) (Wilson et al., 2013). If fast-twitch muscle fibers are recruited during vascular blood flow restriction training at low intensities then muscle protein synthesis and subsequent muscle hypertrophy can occur. The metabolite/volume threshold theory states that recruitment of fast-twitch fibers would lead to the hypertrophic signaling at an overall lower volume of work than regular exercise to volitional fatigue (Loenneke et al., 2011). The present study theorizes that if practical vascular blood flow restriction training is performed in addition to regular resistance training, there is the potential for greater hypertrophy and maximal strength increases than those performing traditional resistance training over a 4 week period.

Operational Definitions

Trained college-aged males: Males ages 18-25 who have participated in recreational resistance training for one year.

Practical vascular blood flow restriction training: Resistance training with blood flow restriction to the muscle using a wrapping apparatus such as a knee wrap that occludes the veins, but not the arteries serving the muscles.

Skeletal muscle hypertrophy: Increase in the cross-sectional area of the muscle via growth of the myofibrils.

Body composition: The measurement of the amount of fat mass and fat free mass via skinfold thickness.

Maximal Muscular strength (1-RM): The maximum amount of resistance that can be moved for one repetition in a given resistance exercise.

Traditional resistance training bout: One session of exercise using free weights, machines, barbell, and cables in an organized routine based off of up-to-date, practical knowledge of exercise physiology.

Traditional resistance training program: An organized exercise regimen following principles of progression and periodization using weighted and resistance modalities.

Traditional resistance training bout with vascular blood flow restriction training: A normal resistance training bout with vascular blood flow restriction training technique added at the end of the training bout.

Volitional fatigue: A resistance training set performed to a level of exhaustion where the participant cannot perform another repetition without cheating in exercise form.

Assumptions

The first assumption of the study was that the participants are truthful in their exercise history. The study requires trained males that have resistance trained at least two times per week over the past year. The next assumption was that the participants are capable of following and understanding instructions given to them on proper exercise technique as they are led through the training program. It was assumed the all participants respond normally to exercise and are not taking exogenous anabolic steroids that could affect the response to resistance training. The last assumption was that all participants maintain a normal, healthy diet that would support the effects of the training performed in the study.

Limitations

A limitation of this study was the lack of research with the specific topic. Vascular blood flow restriction training is a new topic in exercise physiology research. Much of the data on practical vascular blood flow restriction training is in press. Though the research is limited, this provides the opportunity to expand the knowledge on the effects of vascular blood flow restriction training in specific populations.

Delimitations

The delimitations imposed on this training study was the inclusion criteria of the participants: age, gender, and training status. The study included males aged 18 – 25 with at least a year of resistance training. Previous research related to this study also used a similar population (Yamanaka et al., 2012). A female population of similar age was not used because females have a more difficult time achieving significant muscle hypertrophy in the amount of training time this study used.   For practical reasons, the population included in the study would be the population actually employing the technique used in the study in a practical setting.

Another delimitation includes the control for dietary intake. All participants were given 25g of whey protein after each workout. This practice was the most practical attempt to control the participants' dietary intake given the time constraints the primary investigator had with the participants.

Significance

Vascular blood flow restriction training is an uncommon technique of training not seen outside of laboratories and clinical settings. Much is unknown on the mechanisms of how hypertrophy gains occur with vascular blood flow restriction training, but the data shows low intensity vascular blood flow restriction training can cause hypertrophy gain in little as one week (Abe et al., 2005c). This result is opposite of the normal time course it takes for humans to see hypertrophy gains with normal resistance training. The problem with vascular blood flow restriction training is that most studies use pressure cuff devices that are research tools and very expensive (Wilson et al., 2013). Athletes and strength training practitioners need a practical way to utilize the technique to gain the potential benefits. Practical vascular blood flow restriction training was developed for this reason. Practical vascular blood flow restriction training involves the use of elastic knee wraps to occlude the veins, but not the arteries, as desired in the vascular blood flow restriction training protocol (Wilson et al., 2013).

More research is needed with practical vascular blood flow restriction training. The use of practical vascular blood flow restriction training is to provide a low intensity alternative to training. This can be used to taper down from a training cycle to prevent detraining or prevent physical stress on the joints. No study has investigated vascular blood flow restriction training as a technique incorporated in a workout to produce greater fatigue, while also equating for volume. Combining the practical vascular blood flow restriction technique with a standard periodized workout regimen could lead to new uses for vascular blood flow restriction training. The results of this study may justify practical vascular blood flow restriction trainings use in a practical setting for athletes and strength practitioners.

CHAPTER TWO:

REVIEW OF LITERATURE

1.1 Training for Muscular Hypertrophy

The ACSM position stand (2009) on resistance exercise for healthy adults provides program design recommendations for muscle hypertrophy. Muscle actions that are concentric, eccentric, and isometric are required for resistance training adults at all levels of progression. Multiple-set training is recommended over single-set training. The most effective programming that optimizes hypertrophy in trained individuals involves high loads, short rest intervals, and moderate to high volume. A review of the literature by the ACSM (2009) also states that with high volume, short rest, and moderate to high loads results in greater acute increases in growth hormone and testosterone. The base numbers that are recommended are a loading range from 70-100% of 1 RM for 1-12 repetitions. Using the recommended loading range, three to six sets are periodized so that more sets are performed at the 6-12 RM load more than the 1-6 RM load

Exercise selection for hypertrophy training involves single- and multi-joint exercises. The common recommendation says to perform multi-joint exercise before single joint, but the ACSM recognizes exceptions to this rule to induce greater fatigue. For advanced training programs, rest periods should be 1 to 2 minutes in length for exercises of moderate to moderate-high intensity, while rest periods of 2 to 3 minutes can be used for heavy core loading exercises such as barbell squats or deadlifts. When performing the exercise through the concentric and eccentric movements, the ACSM (2009) recommends slow-to-moderate velocities for novice trainees and slow to fast repetition velocities depending on the exercise.

Lastly, the position stand of the ACSM (2009) states that to cause muscular hypertrophy novices should train the total body at least 2 to 3 days per week. Intermediate training can increase to 4 days per week using a split routine. For the most advanced training, the frequency recommended is 4-6 days per week using a split routine with higher volumes.

1.2 Hypertrophic Mechanisms of Skeletal Muscle

After understanding how to train for skeletal muscle hypertrophy, a closer look at the physiology behind the process could explain the reason for the recommendations. Skeletal muscle hypertrophy is a process that results in the increase in the cross-sectional area of the muscle fibers. Type II or fast-twitch muscle fibers show a greater capacity for hypertrophy as compared to type I or slow-twitch muscle fibers (McCall et al., 1996). Due to this capacity for fast-twitch muscle fibers to hypertrophy, resistance training should be performed with a load or intensity that recruits all motor units as stated by the size principle (Henneman & Mendell, 1981; Cope & Pinter, 1995). It should be noted that hypertrophic mechanisms are responsible for the increase in cross-sectional area of the muscle fiber; and that hyperplasia, the growth of new muscle fibers, has not been found to occur in human skeletal muscle. (McCall et al., 1996).

1.2.1 Satellite Cells

There are major processes that occur at the cellular level that are responsible for muscular hypertrophy. The mechanical stress of resistance training can lead to the creation of new sarcomeres through satellite cell activation. Satellite cells, also known as myogenic progenitor cells, are located between the basal lamina and sarcolemma of the muscle fiber. These cells are thought to proliferate, differentiate, and then fuse with existing myofibers during the process of load induced muscle hypertrophy (Petrella et al., 2006). The myonuclear domain theory provides the explanation of how this occurs. The myonuclear domain theory suggests that, within a certain volume of cytoplasm, the myonucleus controls production of mRNA and other proteins. With increases in myofiber size, a proportional increase of myonuclei occurs. The satellite cells are the contributors of the new myonuclei (Petrella et al., 2006).

A study by Petrella et al. (2006) hypothesized that advanced muscular hypertrophy in young men is facilitated by myonuclear addition due to satellite cell activation. Participants consisted of 26 young (27± 1 yr., 50% women) and 26 older (63.7 ± 1 yr., 50% women) adults who completed 16 weeks of knee extensor resistance training. Vastus lateralis biopsies were taken at baseline, 24 h after one bout, and after 16 weeks. Satellite cells were identified through immunohistochemistry with anti-neural cell adhesion molecule (NCAM+). The results found myofiber hypertrophy was twofold greater in young men vs. others, only young men increased in NCAM+ cells per 100 myofibers, and myonuclei per fiber. The results suggest myonuclear addition was effectively accomplished in young men. (Petrella et al., 2006)

1.2.2 Muscle Protein Synthesis

Nutritional status and resistance training stimulate muscle protein synthesis leading to skeletal muscle hypertrophy. Muscle protein synthesis is mediated by IGF-1 through translation initiation leading to gene expression (Coffey & Hawley, 2007). The binding of IGF-1 cascades to activate of PI(3)K (Glass, 2003). PI(3)K activation leads to opportunity for Akt to bind and become phosphorylated by kinase Pdk-1, resulting in activation of the mammalian target of rapamycin (mTOR). Activation of mammalian target of rapamycin (mTOR) results in two actions that are essential for translation initiation to occur. The two actions of mTOR are phosphorylation the positive regulator of protein translation $p70^{S6}$ kinase ($p70^{S6}K$) and inhibits the activity of 4E-BP1, a negative regulator of protein initiation factor eIF-4E (Glass, 2003). Once mTOR acts, this pathway completes the creation of new proteins for skeletal muscle hypertrophy.

To confirm that resistance exercise can stimulate muscle protein synthesis and cause muscle hypertrophy, research was performed with twelve healthy males who were assessed for rates of muscle protein synthesis at 4 hours post-exercise or 24 hours post exercise (Chelsey et al., 1992). The researchers in this study wanted to confirm that protein synthesis remains elevated post exercise and to create a time course for the process. Six subjects in the 4-hour post exercise group performed resistance training the same day leucine, a branch chain amino acid known to stimulate muscle protein synthesis, was infused. Six subjects in the 24-hour post exercise group exercised the day before leucine infusion. Measurements were made after 3 days of rest where no other exercise was performed. The subjects performed 4 sets of 6-12 repetitions of the biceps curl, preacher curl, and concentration curl with a load of 80% of 1RM. All sets were performed to volitional fatigue and rest time between sets was 3 minutes. The data showed that protein synthesis was elevated in the biceps at both the 4 and 24-hour post exercise mark after a single bout of heavy resistance training (Chelsey et al., 1992). A later study examining the time course of protein synthesis was performed after the previous study. The nutritional intervention of this study was the primed constant infusion technique of L-[$1,2^{-13}C_2$] leucine into both arms over 11 hours. One arm performed 12 sets of 6-12-RM elbow flexion while the other served as a control. MPS was calculated from the in vivo rate of incorporation of L-[$1,2^{-13}C_2$] leucine. This study found that muscle protein synthesis increases after one bout of resistance training and peaks 24-hours post-exercise and remains elevated post-exercise for 36-48 hours (MacDougall et al., 1995). The methodology in both experiments was similar. The important aspect of these studies is that they reported increases in muscle protein synthesis and that resistance training and nutritional interventions (specifically ingestion of L-leucine) stimulate the process.

2.1 Vascular Blood Flow Restriction Training

Vascular blood flow restriction training, also known as KAATSU or blood flow restriction training, provides an alternative to normal resistance training that can stimulate muscle hypertrophy. Blood flow restriction is applied at the veins in the arms and thigh by a KAATSU apparatus or practically through elastic knee wraps (Loenneke & Pujol, 2009). As discussed earlier, the ACSM recommends training at least 70% of 1 RM for 6-12 repetitions to produce skeletal muscle hypertrophy gains. With similar training frequency and volume as high intensity training, vascular blood flow restriction training can produce the same changes in muscle hypertrophy (Abe et al., 2005c). Abe et al. (2005c) investigated the effects of twice daily low intensity resistance training (20% of 1-RM) with venous blood flow restriction on IGF-1 and skeletal muscle size. The low intensity vascular blood flow restriction training group was compared with a low intensity (20% of 1-RM) with no vascular blood flow restriction group. There was a significant increase in circulating IGF-1 and muscle cross-sectional area in the low intensity vascular blood flow restriction group, but not the low intensity group. Two other important aspects of this study is that hypertrophy gains were seen in two weeks and markers for muscle damage (myoglobin, CPK, and lipid peroxide) were not elevated. The data suggests that vascular blood flow restriction training can produce muscle hypertrophy in a short period of time, produces hypertrophy similar to high intensity training, and does not elevate markers of muscle damage. Vascular blood flow restriction training could be an effective method of training without inducing orthopedic stress to the joints.

2.1.1 Clinical Vascular Blood Flow Restriction Training

There is great potential for vascular blood flow restriction training's use in injured athletes and other rehabilitation settings. When dealing with ACL injuries vascular blood flow restriction training may be the optimal modality to use to prevent muscle atrophy. Rehabilitating athletes with ACL injuries would be restricted in their activities while recovering from their injury. Vascular blood flow restriction training combined with daily activity walk training has been investigated to see if hypertrophy gains occur. Abe et al. (2005b) conducted a study where nine young men (21.2 ± 2.7 years) performed walk training with occluded legs and nine young men (21.5 ± 2.9 years) performed regular walk training. Training was conducted twice a day, six days per week for three weeks using five sets of 2-minute bouts with one minute rest between bouts at 50 meters/minute on the treadmill. Subjects in the occluded walking group showed significant elevations in growth hormone and significant increase of thigh muscle cross-sectional area and muscle volume (4-7% increase). The group that performed walk training without vascular blood flow restriction showed no change in muscle size and no elevations in growth hormone. The data suggested by this study show that occluded walk training may be a useful method for promoting muscle hypertrophy, especially in rehabilitation and younger populations (Abe et al. 2005b).

2.1.2 Time Course for Hypertrophic Effects of Vascular Blood Flow Restriction Training

One interesting aspect of vascular blood flow restriction training is that researchers see hypertrophy gains in little as one week of training. A study by Abe et al. (2005a) examined the day to day change in muscular strength and muscle size during 7 days of vascular blood flow restriction training. The focus was on one subject, 47 years old and male with resistance training experience, but the subject did not train the previous three months. Low intensity resistance training with leg muscle blood flow restriction was conducted twice a day for 7 consecutive days. The training volume and load was performing 3 sets of 15 repetitions with 30 seconds rest. Intensity was performed at 20% of 1-RM. Pressures used during blood flow restriction ranged from 160-220 mmHg, starting at 160 mmHg on the first day increasing by 20 mmHg each day. Whole muscle imaging was done by a MRI in the quadriceps muscle and isometric absolute strength was measured by an isokinetic dynamometer. After one week the subject gained absolute strength (303 Nm from 257 Nm baseline) and increased muscle size (3.5% from baseline) after one week of low intensity vascular blood flow restriction training. Similar results found by this study have been shown to occur in 8-12 weeks of training (Abe et al., 2005). This study also examined markers for muscle damage and inflammation and found no elevation throughout the week. The results suggest vascular blood flow restriction training can cause significant hypertrophy in a very short period of time, unlike traditional training methods.

2.1.3 Pressure and Training Recommendations

To properly use vascular blood flow restriction training, the correct pressures must be utilized to gain beneficial effects. A study by Sumide et al. (2009) sought to investigate the optimal pressure to be used in vascular blood flow restriction training. The study was conducted with twenty-one subjects randomly divided into four groups based on the pressure applied through vascular blood flow restriction. There was a no pressure group (0 mmHg), a 50-pressure group (50 mmHg), 150-pressure group (150 mmHg), and 250-pressure group (250 mmHg). Each group trained 3 times a week for 8 weeks at 20% of 1-RM performing straight leg raising, hip joint adduction, and maximum force abduction training. The study used isokinetic contraction at 180 degrees per second to determine muscle work (Nm). The results showed significant increase in muscle work in the 50 mmHg pressure and 150 mmHg pressure group, suggesting that the optimal pressure to use for vascular blood flow restriction training is between 50-150 mmHg (Sumide et al., 2009) to realize improvements in isokinetic contraction performance.

A review by Loenneke & Pujol (2009) discusses the use of vascular blood flow restriction to produce muscle hypertrophy gains. The recommended exercise prescription summarized by the literature calls for low-intensities of 20-50% of 1RM with performing the concentric and eccentric movements for 2 seconds each. Three to five sets are recommended and should be completed to near-volitional fatigue, resting 30 to 60 seconds while vascular blood flow restriction remains on the limbs (Loenneke & Pujol, 2009).

2.2 Mechanisms of Vascular Blood Flow Restriction Training

So far vascular blood flow restriction training studies have shown hypertrophic effects in short amount of time, opposite of normal time course for hypertrophy gains (Abe et al., 2005a). How vascular blood flow restriction training operates is still in question. There are reviews of the literature that propose the mechanisms of how vascular blood flow restriction training works. Loenneke, Wilson, and Wilson (2010) have proposed several primary and secondary mechanisms on how vascular blood flow restriction training operates. The first proposed mechanism involves metabolic accumulation and elevations in growth hormone. Though growth hormone has not been shown to enhance muscle protein synthesis in humans when combined with resistance training, vascular blood flow restriction training may be different due to the levels of growth hormone elevation seen in vascular blood flow restriction training (Loenneke et al., 2010). One such study compared vascular blood flow restriction training to non-occluded training measuring growth hormone levels 15 minutes post exercise. Both groups performed bilateral leg extension of the same intensity (20% of 1-RM for 14 repetitions x 5 sets). The vascular blood flow restriction group showed concentration of growth hormone ~290 times as high 15 minutes post-exercise as compared to baseline levels. The non-occluded group did not increase much above resting levels pre-exercise (Takarada et al., 2000). Loenneke et al. (2010) suggest that highly increased growth hormone levels seen during vascular blood flow restriction training may play a greater role in collagen synthesis, providing a protective effect in transferring force from skeletal muscle. Such high levels of growth hormone may also have an effect on IGF-1 activity, but more research is needed on its response to vascular blood flow restriction training.

It was noted above that increases in muscle protein synthesis could increase skeletal muscle hypertrophy (Glass, 2003). A study by Fujita et al. (2007) examined muscle protein synthesis and phosphorylation of ribosomal S6 kinase 1 (S6K1), a downstream target of mTOR in subjects performing leg extension exercise (20% of 1-RM) while occluded (200 mmHg). Subjects were six young male subjects not currently on an exercise program, but healthy and physically active. There was also a control group that performed the resistance training with no restriction of blood flow. The results showed significant increases in plasma lactate immediately after and 40 minutes after exercise in the vascular blood flow restriction group. Increases in plasma lactate were also found in the control group, but the levels were significantly lower than the vascular blood flow restriction group. The most important discovery in the study was that S6K1 became phosphorylated and muscle protein synthesis was significantly stimulated in the vascular blood flow restriction group ($P < .05$) while MPS and S6K1 remained unchanged from baseline in the control (Fujita et al., 2007). If one acute bout of vascular blood flow restriction at a low intensity of 20% of 1-RM is able to signal mTOR and increase protein synthesis, it must be included in the possible mechanisms of how vascular blood flow restriction training induces muscle hypertrophy.

The next proposed mechanism of how vascular blood flow restriction stimulates hypertrophy gains in skeletal muscle is fiber type recruitment. Under normal conditions slow twitch muscle fibers are recruited first until the intensity demands the use of fast twitch muscle fibers. As seen in vascular blood flow restriction training studies, vascular blood flow restriction training recruits fast twitch fibers during training even though intensities are low (Loenneke et al., 2010). A more recent review of the research has suggested a new theory related to fiber type recruitment and the mechanism of vascular blood flow restriction training. Loenneke et al. (2011) has suggested blood flow restriction training works by the metabolite/volume threshold theory. The theory dismisses acute elevations of growth hormone as a mechanism for hypertrophy as new evidence shows that mechanism may not be true with regular resistance training. Fiber type recruitment is stated as possibly the most important factor in vascular blood flow restriction training and muscle hypertrophy. Muscle protein synthesis responses have been seen regardless of intensity in resistance training and are activated via signaling proteins S6K1. Signaling proteins such as S6K1 are 3-4 fold higher in fast twitch fibers as compared to slow twitch fibers. Fast twitch fibers must be recruited for this to occur. Vascular blood flow restriction training with low intensity has shown higher threshold motor unit recruitment (Loenneke et al., 2011). The separating factor for vascular blood flow restriction training at low intensities and regular low intensity training is that vascular blood flow restriction training at low intensities can cause muscular volitional fatigue sooner than non-occluded low intensity training. The theory states that vascular blood flow restriction training should be performed to volitional fatigue to see hypertrophic gains from vascular blood flow restriction training (Loenneke et al., 2011).

The mechanisms of vascular blood flow restriction training need further investigation. It may be possible that that all of the aforementioned mechanisms play a role in muscular hypertrophy. More research on which mechanism exerts the greatest influence is needed. The current study is based on the data reporting that vascular blood flow restriction training recruits fast-twitch fibers at low intensities and can produce substantial muscular volitional fatigue needed to stimulate muscle protein synthesis.

2.2.1 Practical Vascular Blood Flow Restriction Training

A recent shift in the focus of research on vascular blood flow restriction, or blood flow restriction training, is on the practicality of the trainings use in a commercial fitness setting. The previously reviewed literature above focuses performs vascular blood flow restriction training with expensive, less practical KAATSU training devices. It would be difficult and impractical for recreational fitness enthusiasts, athletes, and strength practitioners to acquire expensive research equipment just to utilize blood flow restriction training. There is new data to support the use of practical vascular blood flow restriction methods. In a study by Wilson et al. (2013), twelve resistance-trained males (21 ± 3 years) were recruited to perform five sessions of exercise, of practical vascular blood flow restriction leg training. The aim of the study was to investigate the acute effects of practical vascular blood flow restriction training on muscle activation and muscle thickness. The second aim was to validate practical vascular blood flow restriction training as effective as traditional vascular blood flow restriction training. For practical vascular blood flow restriction training to be quantified, ultrasonography was used at 3 perceived pressures to confirm the venous, arterial, both, or no vascular blood flow restriction.

The 3 perceived pressures were 0 out of 10 (control), 7 out of 10 (moderate), and 10 out of 10 (tight). Knee wraps (Harbinger Red- Line, Fairfield, CA, USA; 76 mm wide) were used to occlude the upper thigh of both legs. The first session was used to test 1-RM and confirm venous, but not arterial vascular blood flow restriction at moderate pressure for each subject. At tight perceived pressure complete arterial and venous vascular blood flow restriction was found and subjects were not assigned to a tight wrap group. The second session measured baseline muscle thickness, vertical power, blood lactate, and muscle activation of the vastus lateralis during 15 repetitions of 30% of 1RM with no wraps. In the same session after being assigned to experimental groups, subjects performed 4 sets of leg press at 30% of 1-RM. In the first set, subjects performed 30 repetitions followed by 3 sets of 15 repetitions. There was 30 seconds rest between all sets. Blood lactate was measures at 3 time points post exercise (1, 5, 10 minutes) and subjects would return 24 hours later for measures of muscle thickness, vertical power, and soreness. The training session was repeated on visit 4 (minimum 96 hours post visit 3) and visit 5 consisted of the same measures as visit 3 (24 hours post visit 4).This study is the first to quantify and confirm venous, but not arterial vascular blood flow restriction using knee wraps at a perceived 7 out of 10 pressure. The study found, via ultrasonography that at the tight pressure (10 out of 10 perceived) that 67% of subjects has complete arterial restriction. The results found that blood lactate was higher in the moderate pressure group (6.2 ± 2.8 mMOLs) vs control (4.7 ± 1.8 mMOLs), suggesting vascular blood flow restriction training at moderate pressures could provide a greater metabolic stimulus while training at the same intensity. Muscle thickness significantly increased from baseline in the moderate pressure group at time points 0, 1, and 5 minutes post exercise (4.8 ± .25 cm to 5.4 ±.26 cm), but not 24 hours post exercise. The authors suggest this indicates no muscle damage occurred from this training session. The control group showed no significant increases from baseline in muscle thickness. No differences were found between groups on perceived soreness or peak power. Using a perceived pressure scale and confirming venous, but not arterial vascular blood flow restriction using knee wraps to practically occlude muscle groups is the most significant finding of the study and would allow further investigation of the effects of practical vascular blood flow restriction training using similar methods.

Another recent study by Yamanaka et al. (2012) suggested practical vascular blood flow restriction training could increase strength and muscle girth in trained division 1A football players. The study used elastic bands with Velcro straps to occlude upper and lower limbs and trained 3 times a week performing bench press and squat exercises for 4 weeks of training. It is important to note that the training for this study was in addition to regular resistance training, but all subjects performed the same amount of training. The exercise protocol for both groups involved the first set being performed at 20% of the predetermined 1-RM for 30 repetitions followed by 3 sets of 20 repetitions at the same intensity. Subjects rested 45-seconds between sets regardless of being in the occluded group or the non-occluded group. The results showed that there was a significant increase in 1-RM bench and squat strength (7% and 8% respectively) and significant increases in upper and lower chest girth (3% for both girths) for only the vascular blood flow restriction group. The study suggests that strength and hypertrophy outcomes can occur in trained collegiate males when using practical vascular blood flow restriction training. The study is one of the first to use practical vascular blood flow restriction methodology in trained collegiate males and measure both strength and hypertrophy.

2.3 Safety Concerns of Vascular Blood Flow Restriction Training

With much of the research focusing on vascular blood flow restriction training's effect on muscular hypertrophy and the mechanism of action, many are now concerned with the safety of vascular blood flow restriction training. A review by Loenneke et al. (2011) summarizes the current literature examining potential safety issues with vascular blood flow restriction training. The potential concerns for risk are in cardiovascular responses, oxidative stress, muscle damage, nerve conduction velocity, and pressure cuff pressures and widths. The review included what was known about vascular blood flow restriction training compared to normal high intensity resistance training. Loenneke et al. (2011) concluded that blood flow restriction training provides a safe training alternative regardless of age and training status. One case study has been reported by Iversen & Rostad (2010) of low-load ischemic exercise-induced rhabdomyolysis. Rhabdomyolysis is characterized by injury to the muscle cell causing their contents, including creatine kinase (CK), to leak into the vascular component. The one subject performed one treatment of one-leg knee extension exercise, while occluded, at 1 set of 30 repetitions followed by 4 sets of 15 repetitions using 12 kg resistance. The 31 year old athlete was receiving treatment for persisting quadriceps atrophy and weakness following knee articular cartilage resection and micro fracture. After 11 months of detraining, he trained for two months prior to participation of treatment. Two days after the initial treatment, the participant reported severe muscle soreness, not consistent with the vascular blood flow restriction literature. The participant had a history of deep vein thrombosis after knee surgery, which was prior to the bout of occlusion training. After hospital treatment for rhabdomyolysis, the participant continued the treatment of low-load blood flow restriction training 2 times a week, in addition to training with the ice hockey team for 4 days a week. No other incidents of rhabdomyolysis were reported after this case.

In summary, traditional resistance training at higher percentages of 1-RM is well established as a primary way to induce muscle hypertrophy. Along with proper nutritional interventions, hypertrophy is shown to occur after multiple weeks of resistance training. Vascular blood flow restriction training is an alternative form of resistance training that allows trainees to potentially induce muscle hypertrophy faster and while training with lighter loads. Established benefits of vascular blood flow restriction training are: sparing the joints from heavy loads, a potential to induce muscle hypertrophy and, in some cases, increase maximal strength and reduce delayed onset muscle soreness. More research on the mechanisms and practical applications of this alternative resistance training method are needed to further understand the potential benefits.

CHAPTER 3:

METHODS

Participants

Twenty-six trained, college-aged (18-25 yrs. old) males were recruited in Tampa, Florida. All participants were screened to ensure they meet the criterion for qualifying as trained by indicating on their exercise history questionnaire (appendix B) form that they had been resistance training two times per week for the past year. If they did not qualify, the participant was excluded from the study. All participants were required to sign an informed consent and complete a pre-activity screening questionnaire and qualify as "low-risk" on the risk stratification according to the American College of Sports Medicine [ACSM] (2014). Low-risk participants are those who do not have diagnosed cardiovascular, pulmonary, and/or metabolic disease as well as no more than one cardiovascular risk factor. Low risk participants may participate in exercise without needing a medical examination or clearance due to the low risk of an acute cardiovascular event (ACSM, 2014). Informed consent procedures were expressed verbally and shown to participants as required by the USF Institutional Review Board. Participants were informed of the early stopping criteria of having extreme muscle soreness and/or intolerable joint pain. Participants were also reminded they could voluntarily exit the study at any time. Each participant was informed on the potential benefits and risks of participation in the study prior to preliminary testing. Prior to the beginning of the training program, participants were shown the blood flow restriction procedure by wrapping the limb with the elastic knee wrap to the point of a 7 out of 10 perceived pressure. Once the desired pressure was confirmed with each participant, the participants practiced the blood flow restriction technique until they were comfortable with confirming the necessary 7 out of 10 pressure. Participants were then shown proper technique and form used in every exercise performed in the training program. Figure 1 describes the participant flow through the research study.

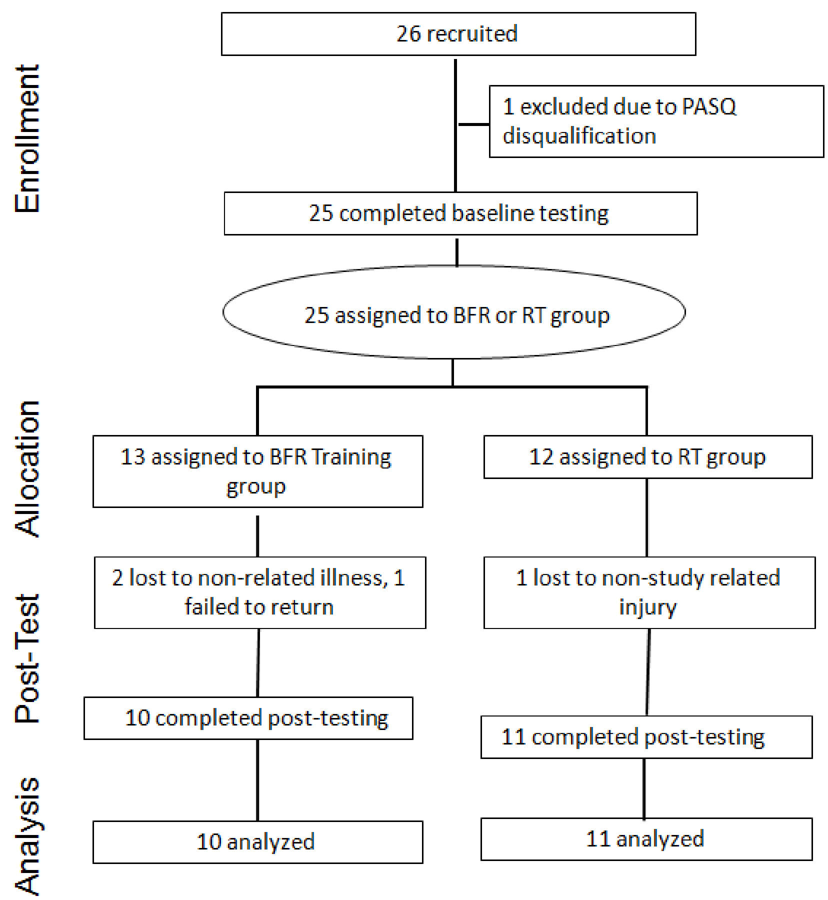

Figure 1. Participant flow through the study.

Risks and Benefits

According to Loenneke & Wilson (2011), blood flow restriction training provides a safe training alternative and is similar to normal resistance training in its safety risk. Physiological responses to blood flow restriction training are similar to regular resistance training. Participants incurred the same risks regularly associated with activities they perform multiple times a week.

Benefits to the participants in this study included potential increases in muscular hypertrophy and muscular strength. Yamanaka et al. (2012) has shown increases in maximal muscular strength and muscle thickness using practical blood flow restriction in trained populations with a similar design to this study. Participants also received training in proper use of the blood flow restriction technique and gained knowledge in the programming of training that was used in the study.

Instrumentation

A pre-activity screening questionnaire (appendix C) was given to participants prior to inclusion in the study. The purpose of the questionnaire was to screen possible participants to meet the inclusion criteria of "low-risk" according to the ACSM (2014) on the risk stratification. Once screened and included, participants completed a 3-day food log (appendix D) prior to the first training session of the study. Participants were then given a copy of their food log and instructed to follow a diet nutritionally similar to the 3-day food log completed prior to the beginning of the study. The purpose of the food log was an attempt to control for nutritional influences on body composition. Whey isolate protein (Dymatize® Nutrition, Inc.) was given as a nutritional control and provided to participants on training days. It is common practice among weight training athletes to ensure positive protein balance. The same amount (25g weighed on a food scale) of whey protein was given to each participant upon completion of training. Prior to participation, participants were asked if they have allergies to whey protein and those who were allergic were excluded from the study. Participants were also encouraged not to perform any additional exercise outside of the study.

Equipment

Pretesting and post testing assessments were performed at the University of South Florida's Exercise & Performance Nutrition Laboratory in Tampa, FL. The equipment used to measure muscle hypertrophy and body composition was a BodyMetrix™ Pro Ultrasound device by IntelaMetrix (IntelaMetrix) and a spring-loaded tape (Power Systems Inc., Knoxville, TN) for back-up anthropometric measures. The BodyMetrix™ Pro Ultrasound device is a 2.5 MHz A-mode ultrasound that measures body fat and muscle thickness. Ultrasound waves penetrate tissue, where reflections occur at different tissue boundaries such as muscle to fat and muscle to bone. According to IntelaMetrix, the BodyMetrix™ system has been found to be more accurate than skin fold caliper assessments and bio-electrical impedance body fat measures, as well as providing accurate measurements of body composition comparable to underwater weighing and air displacement methods. A study conducted by Johnson et al. (2012) sought to validate three body composition techniques while comparing the ultrasound abdominal fat depths against an octopolar bioelectrical impedance device. The study used the BodyMetrix™ Pro system as their ultrasound assessment method and used the 3-site method for measuring body fat percentage. Air-Displacement was conducted using the BodPod® and the bioelectrical impedance was measured using the TANITA BC-418 MA (Johnson et al., 2012). The study measured college aged men (n= 18) and women (n=8) and resulted in significantly high correlation (>.85) reporting the percentage body fat between all three devices, despite slightly different formulas being used. No significant differences were found using 1-way ANOVA. The results of this study suggest that the BodyMetrix™ Pro system is a validated device to measure body fat percentage. The BodyMetrix™ Pro device includes the BodyView™ Professional software that will be used to interpret data obtained with the BodyMetrix™ Pro device.

Practical vascular blood flow restriction was applied to subjects with elastic knee wraps (Harbinger, 76mm width) at the same pressure that results in venous, but not arterial, constriction (moderate, 7 out of 10 pressure) verified by ultrasound (Wilson et al., 2013). The same perceived pressure scale that was used in Wilson's practical vascular blood flow restriction training study was used in this study. Participants were also familiarized and confirmed the 7 out of 10 moderate pressure needed for proper vascular blood flow restriction. The knee wraps that were used in this study are Harbinger Red Line© knee wraps, 78 inches long and 3 inches wide (Harbinger Inc., Fairfield, CA). The 4-week resistance-training program was performed at the Exercise & Performance Nutrition Laboratory at the University of South Florida in Tampa, FL.

Roles of Study Staff

The study staff involved in the research project aided the primary investigator. To reduce bias, one selected study staff member conducted the ultrasound pre and post training measurements and spring-loaded tape measure measurements. The same investigator was not involved in overseeing participants training. Other study staff members assisted the primary investigator in guiding participants through the training protocol. Roles included data collection, loading weights for exercises, spotting exercises, and ensuring the participant was using proper exercise form. Study staff involved in the training protocol were certified personal trainers.

Procedures

Screening

Potential participants in the study were brought into the lab and given a health and exercise history questionnaire to determine eligibility. They were also given a pre-activity screening questionnaire and risk was determined according to the ACSM risk stratification form (appendix C). Only "low-risk" participants were included in the study. If the potential participant met the inclusion criteria of the study, the participant was informed on the potential benefits and risks of the research and shown the blood flow restriction training technique along with all the exercises performed in the study. Once cleared to participate and familiarized with procedures, participants were randomly assigned to either the resistance-training group with practical vascular blood flow restriction (pBFR) or the resistance-training group without vascular blood flow restriction (RT). The participants were also scheduled for pre-training baseline measurements.

Participant Data: Pre-training

Pre and post training measurements were taken at the Exercise & Performance Nutrition Laboratory at the University of South Florida in Tampa, FL. All measurements and data was taken by a researcher that was not the primary investigator and was blinded to the resistance-training groups.

Ultrasound and Anthropometric Measures

Body mass and height were taken first followed by an ultrasound on the right thigh and right arm. The ultrasound measurement was conducted on the right biceps and right vastus lateralis to determine the cross-sectional area of the skeletal muscle. Vascular blood flow restriction training occurred at these two parts in the body. Additionally, anthropometric measures were taken with a flexible, spring-loaded tape measure (Power Systems, Inc. Knoxville, TN). Measurements of the right arm and right thigh were taken pre-training and upon completion of the 4-week training program. The measurements were taken anatomically according to the National Strength and Conditioning Association’s recommended standards. All measurements occurred on the right side of the body, the right upper arm was measured at the point of maximal circumference with the elbow fully flexed, palm up, and arm abducted to parallel with the floor. The right thigh measurement was taken at the point of maximal circumference, usually just below the buttocks (Baechle & Earle, 2008).

1-RM Testing

Participants then performed a dynamic warm-up of 5-10 minutes, preparing muscles used in the leg press and bench press exercise, in preparation for 1-RM strength testing. Testing protocols were administered according the National Strength and Conditioning Association's protocol and was administered by NSCA certified personal trainers (CPT) or strength and conditioning specialists (CSCS). Prior to the leg press and barbell bench press 1-RM test, sub maximal loads were used for multiple sets to ensure the athlete warmed up. The barbell bench press equipment at Exercise & Performance Nutrition Laboratory at the University of South Florida was a multi-rack barbell bench press by Life Fitness, which was used for baseline and post-testing 1-RM bench press measures. The leg press was performed using a Nebula 6000-A 35˚leg press (Russia, OH). The leg press exercise involved participants to engage the platform and releasing the safety bars. Once the safety bars were moved, the participant lowered the weight through a full range of motion, where the thighs were slightly beyond parallel in relation to the leg press platform. At that moment, the weight was pressed until the knees were fully extended. The barbell bench press exercise was performed under the rules set by USAPL (2001). The participant started lying flat on the weight bench with feet flat on the ground and the shoulders, butt, and head touching the bench at all times throughout the lift. The bar was then lifted off the rack by the participant, with assistance if requested, and held at full extension. The bar was lowered to the chest and then pressed until the arms were fully extended. Typically, the first attempt of both lifts was usually about 50% of the participants estimated 1-RM load (Baechle & Earle, 2008). The participant rested enough to feel recovered from the previous attempt prior to the next attempt (1-5 minutes typically). The load was then increased 5-15% between trials until the maximum amount of weight was moved for 1 repetition. This protocol was performed for both 1RM tests. Once pre-training measurements were taken for the participant, the participant was then told to not resistance train for the time between the pre-training testing and beginning of the training for the study which was scheduled to begin 3 days after pre-testing.

Resistance Training

Training occurred at the Exercise & Performance Nutrition Laboratory at the University of South Florida in Tampa, FL. All training was monitored by NSCA-CPT or CSCS certified graduate students to ensure proper technique and instruction was occurring. Participants in each group performed a 4-week periodized workout program, resistance training all major muscle groups 2-3 times per week. Training days occurred two times a week during the first week of training on Monday and Thursday and three times a week on Monday, Wednesday, and Friday for the remaining three weeks of the study intervention. Participants also followed the training program based on the ASCM recommendations (2009) for hypertrophy training. The periodized workout program was exactly the same between both groups, except specific exercises for each main muscle group that could be blood flow restricted and performed each workout was blood flow restricted for the pBFR group while the RT group performed the same exercise without vascular blood flow restriction. The volume between groups was also approximately equated. The program was designed to mimic a typical, practical bout of resistance training that would employ vascular blood flow restriction training as a training technique to elicit greater metabolic fatigue in addition to regular resistance training. The protocol for vascular blood flow restriction training was as recommended by the literature (Loenneke & Pujol, 2009), 30% of 1-RM was used for 3-5 sets for 15-30 repetitions. The first set of vascular blood flow restriction training for each exercise that was restricted was performed for 30 repetitions. The following three sets was performed for 15 repetitions. The model of 4 sets of 30, 15, 15, and 15 repetitions was recommended and used in the practical BFR study performed by Wilson et al. (2013) The non-vascular blood flow restriction group completed the same amount of sets at the recommended repetition range to elicit hypertrophy gains (ACSM, 2009). The resistance used was determined prior to beginning the training program for each participant. The training program that was used in this study is provided in appendix A. There was one training block following a non-linear periodization model. This was done as the ASCM (2009) recommends periodized training for hypertrophy training. The resistance-training workout was then performed to completion.

Post-testing Data Collection

Pre and post training measurements were taken at the Exercise & Performance Nutrition Laboratory at the University of South Florida in Tampa, FL. Participants came into the lab when scheduled to have data taken. All measurements were taken and data recorded by a researcher that was not the primary investigator and that was blinded to the resistance training groups. The same procedures used in the pre-training measurements were replicated exactly as performed in the pre-training baseline measures.

Statistical Analysis

A 2x2 repeated measures analysis of variance (ANOVA) was used to assess group, time, and group by time interactions. The 2x2 ANOVA involves two factors that are time and group. The independent variable of time includes two levels: pre training and post training. The independent variable of group involves two levels: the practical blood flow restriction training group and the resistance training group. An independent samples T-test was used to assess total training volume between each group. Statistical significance was set to $p \leq 0.05$. Data was analyzed with SPSS version 20.

CHAPTER FOUR:

RESULTS

No differences were reported for total lifting volume (lbs.) between the groups (pBFR = 491,081 ± 60,894 lbs.; RT = 545,455 ± 111,631 lbs., $p = .185$). The pBFR group performed 62% of their training volume using the blood flow restriction technique.

Ho_1 stated that there will be no difference (no interaction effect) between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in biceps skeletal muscle hypertrophy (cross-sectional area) as measured by ultrasound following four weeks of resistance training. No statistically significant differences were found between groups in biceps skeletal muscle hypertrophy (pBFR-Pre: 33.2 ± 3.6 mm, pBFR-Post: 34.5 ± 4.5 mm, $d = .32$, RT-Pre: 31.9 ± 3.3 mm, RT-Post: 33.5 ± 3.7 mm, $d = .46$, $p = 0.779$). Based on the findings, the null hypothesis is not rejected. It is important to note that there was a significant main effect for time in relation to skeletal muscle hypertrophy ($p = 0.004$).

Ho_2 stated that there will be no difference (no interaction effect) between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in vastus lateralis skeletal muscle hypertrophy (cross-sectional area) as measured by ultrasound following four weeks of resistance training. No statistically significant differences were found between groups in vastus lateralis skeletal muscle hypertrophy (pBFR-Pre: 38.1 ± 9.3 mm, pBFR-Post:

37.5 ± 9.0 mm, d = .07, RT-Pre: 36.5 ± 6.8 mm, RT-Post: 35.3 ± 6.1 mm, d = .19, p = 0.721). Based on the findings, the null hypothesis is not rejected. There was also no main effect for time relative to changes in cross-sectional area of the vastus lateralis (p = 0.337).

Ho_3 stated that there will be no difference (no interaction effect) between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in upper arm circumference following four weeks of resistance training. No statistically significant differences were found between groups in upper arm circumference (pBFR-Pre: 38.2 ± 2.3 cm, pBFR-Post: 38.1 ± 2.2 cm, d = .04, RT-Pre: 36.6 ± 3.0 cm, RT-Post: 37.0 ± 2.8 cm, d = .14, p = 0.208). Based on the findings, the null hypothesis is not rejected. There was also no main effect for time relative to changes in upper arm circumference (p = 0.274).

Ho_4 stated that there will be no difference (no interaction effect) between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in thigh circumference following four weeks of resistance training. No statistically significant differences were found between groups in thigh circumference (pBFR-Pre: 60.5 ± 4.5 cm, pBFR-Post: 61.9 ± 4.2 cm, d = .32, RT-Pre: 57.4 ± 4.5 cm, RT-Post: 59.9 ± 4.7 cm, d = .54, p = 0.343). Based on the findings, the null hypothesis is not rejected. It is important to note that there was a significant main effect for time in relation to increases in thigh circumference (p = 0.002).

Ho_5 stated that there will be no difference (no interaction effect) between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in bench press strength following four weeks of resistance training. No statistically significant differences were found between groups in bench press strength (pBFR-Pre: 220.5 ± 65.1 lbs., pBFR-Post: 235.0 ± 50.6 lbs., d = .25, RT-Pre: 245.9 ± 60.9 lbs., RT-Post: 257.7 ± 53.5 lbs., d = .21, p =

0.708). Based on the findings, the null hypothesis is not rejected. It is important to note that there was a significant main effect for time in relation to increases in bench press strength ($p = 0.001$). This was an average increase of 13.1 lbs. (5%) from pre training measures.

Ho_6 stated that there will be no difference (no interaction effect) between the vascular blood flow restriction training group and the non-vascular blood flow restriction training group in leg press strength following four weeks of resistance training. No statistically significant differences were found between groups in leg press strength (pBFR-Pre: 822 ± 135.9 lbs., pBFR-Post: 952.5 ± 168.9 lbs., $d = .86$, RT-Pre: 780.5 ± 192.4 lbs., RT-Post: 957.3 ± 213.4 lbs., $d = .87$, $p = 0.134$). Based on the findings, the null hypothesis is not rejected. It is important to note that there was a significant main effect for time in relation to increases in leg press strength ($p = 0.000$). This was an average increase of 154.8 lbs. (16%) from pre training measures.

Table 1: Results

Variable	pBFR - Pre Training	pBFR - Post Training	RT - Pre Training	RT - Post Training	p-value (time* group interaction)	p-value (time)
Biceps csa (mm)	33.2 ± 3.6	34.5 ± 4.5	31.9 ± 3.3	33.5 ± 3.7	0.779	0.004*
Vastus Lateralis csa (mm)	38.1 ± 9.3	37.5 ± 9.0	36.5 ± 6.8	35.3 ± 6.1	0.721	0.337
Upper arm circ. (cm)	38.2 ± 2.3	38.1 ± 2.2	36.6 ± 3.0	37.0 ± 2.8	0.208	0.274
Upper leg circ. (cm)	60.5 ± 4.5	61.9 ± 4.2	57.4 ± 4.5	59.9 ± 4.7	0.343	0.002*
Bench Press 1RM (lbs.)	220.5 ± 65.1	235.0 ± 50.6	245.9 ± 60.9	257.7 ± 53.5	0.708	0.001*
Leg Press 1RM (lbs.)	822 ± 135.9	952.5 ± 168.9	781 ± 192	957.3 ± 213.4	0.134	0.000*

Table 1 summarizes all cross-sectional area, limb circumference, and muscular strength data across time for both the blood flow restricted training group and the traditional resistance training group. * denotes significance where $p \leq 0.05$.

CHAPTER 5:

DISCUSSION

The present study aimed to see if differences exist in skeletal muscle hypertrophy using practical vascular blood flow restriction training within a training program when compared to a traditional, heavy resistance-training program. The current study was the first, to the best of our knowledge, to approximately equate volume between groups where one group performed primarily blood flow restriction training (approximately 62% of all sets performed were blood flow restricted at 20-30% of 1-RM) while the other lifted 70%+ of 1-RM in a traditional resistance training program. Other studies have shown muscle hypertrophy occurs using solely practical vascular blood flow restriction training over the course of 4-8 weeks (Abe et al., 2005a; Abe et al., 2005b; Abe et al., 2005c). Most of these studies compared the blood flow restriction group to a non-blood flow restriction group that performed exercise at the same percentage of 1-RM as the blood flow group (20-30% of 1-RM).

This study found significant changes over time in both the resistance training and blood flow restriction group in 1-RM strength (bench press and leg press 1RM), thigh circumference, and peak bicep measurement via ultrasound. However, there were no significant differences detected between the two groups. It could be postulated that both groups improved from training, though the stimulus may not be as important. Another reason for the outcome may be that the trained population responded to a well-designed, periodized, and supervised training program. The intensity of both programs was designed to recruit large motor units and fatigue the muscle to near failure. Failure to complete the assigned repetitions occurred in both groups, primarily in the first and second week of training. Performance in the workouts improved over the 4 weeks as participants became stronger and adapted to the program. It is also important to note that there were no significant differences between groups in total training volume performed. The program was designed to equate volume between groups and in practice this was achieved by the participants of the study.

Yamanaka et al. (2012) conducted a study that was somewhat similar in design to the current investigation. In that study, like this one, blood flow restriction training was performed in addition to regular strength training. The differences were that the blood flow restriction was performed within the regular strength training program in the present study, while the Yamanaka study had division 1 football players perform either blood flow restriction or unrestricted exercise after regular strength training. In the Yamanaka et al. (2012) study, both groups performed additional exercise at the same volume and intensity (20-30% 1-RM) while the current study had the same total calculated volume, but exercise was performed at different percentages of 1-RM; 20-30% of 1-RM while blood flow restricted, while the resistance training group performed all exercise in the 70-80% of 1-RM. The present study induced increases in bench press and leg press strength (+13.1 lbs. and +154.8 lbs., an increase of 5% and 16%, respectively) over 4 weeks of training, similar to the results seen in the Yamanaka et al. study (7.0% increase in 1-RM bench press strength and an 8.0% increase in 1-RM squat strength). There may be other practical benefits to training this way and should be explored. If the blood flow restriction group gained similar results to the traditional strength training group, there may be times when traditional strength training is not possible and this technique can be utilized for hypertrophic and strength benefits.

The present study used a BodyMetrix™ Pro A-mode Ultrasound to measure muscle thickness. There potentially could be discrepancies in the reliability or quality of measurement the device was able to collect compared to other similar methods such as MRI. The present study found conflicting trends in thigh muscle cross-sectional area (PBFR-Pre: 38.1 ± 9.3 mm, PBFR-Post: 37.5 ± 9.0 mm, RT-Pre: 36.5 ± 6.8 mm, RT-Post: 35.3 ± 6.1 mm; $p = 0.721$) when compared to tape-measurements of the thigh over time (PBFR-Pre: 60.5 ± 4.5 cm, PBFR-Post: 61.9 ± 4.2 cm, RT-Pre: 57.4 ± 4.5 cm, RT-Post: 59.9 ± 4.7 cm, $p = 0.343$). Specifically, there were significant differences over time in thigh girth measured by tape circumference measures ($p = 0.002$), but no differences over time were reported in muscle cross-sectional area as measured via the ultrasound device. The difference in the tape measurement and ultrasound could be from where the primary investigator instructed measurement to take place using the ultrasound or that specifically the vastus lateralis did not significantly hypertrophy over time, whereas the entire thigh (measured by tape measure) did hypertrophy significantly over time. The additional musculature of the thigh (biceps femoris, semitendinosus, semimembranosus, rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius) may have responded greater as a whole and hypertrophied more than the vastus lateralis specifically. A study performed by Abe et al. (2005a) used MRI to measure the day-to-day changes in muscle size over 7 days of blood flow restriction training. Blood flow restriction training was performed using the KAATSU device and was set to 160 mmHg-220 mmHg; a pressure recommended to restrict arterial blood flow. This study captured MRI images of the quadriceps muscle using a General Electric Signa 1.5 Tesla scanner. Measurements were taken prior to training daily for 7 days to track changes. Though this was a case study on one individual, the study found a 3.5% increase in the cross-sectional area of the quadriceps and a 4.8% increase in quadriceps volume after 7 days of training. The present study found increases over time in thigh thickness, but not in the ultrasound cross-sectional area measure of the vastus lateralis. The use of MRI may explain the differences between the results of both studies, as well as the use of a KAATSU device compared to the practical method utilized in this study.

Another explanation for the results in the present study may be caused by the use of the practical blood flow restriction training over the KAATSU device seen in other studies (Abe et al., 2005a; Abe et al., 2005c). A potential weakness of the present study is using the perceived pressure scale as reported in the Wilson et al. (2013) study. Though the Wilson et al. (2013) study confirmed arterial, but not vascular occlusion at 7 out of 10 pressure when wrapping the to-be occluded limb, variance in the comfort and ability to determine 7 out of 10 pressure of the participants may make the validity of using the practical blood flow restriction training technique in research questionable. A participants 7 out of 10 may not feel like 7 out of 10 to another participant, yet this may or may not yield the desired occlusion. The technique and pressures were confirmed with each participant prior to training and the primary investigator reminded participants every single time they were performing blood flow restriction training of the pressure they should feel. Another potential weakness of the study was the total training length of 4 weeks in which a total of 11 workout sessions were completed. Participants performed resistance exercise 2 times per week for week 1, then 3 times per week for the last 3 weeks. The ACSM position stand (2009) states that, for advanced trainees and to achieve a hypertrophic response, exercise should be performed at least 4-6 days per week. This may explain the results found in the traditional resistance training group, but other literature has shown increases in strength and some increases in muscle hypertrophy with the use of 3 days per week of blood flow restriction training (Yamanaka et al., 2012). The present study reported similar findings as the Yamanaka et al. (2012) investigation in which practical vascular blood flow restriction training was performed 3 times per week for 4 weeks. Future research should use similar methodology, but train for a longer period of time to examine the potential additional adaptations that were not observed in the present study. Additionally, further research can compare practical vascular blood flow restriction training using Wilson's (2013) perceived pressure scale to KAATSU device training to see if there are differences in the use of these devices when training.

Practical Applications

According to the data reported presented in this investigation, the vascular blood flow restriction training group did not experience greater gains in hypertrophy or maximal strength as compared to the RT group. Even though there was no statistical difference between the groups in total lifting volume, a practical difference was observed. Specifically, the blood flow restriction-training group achieved a total lifting volume that was 11% lower than the traditional lifting group. Despite this difference of 11%, there were no differences between the groups in any measures of strength or hypertrophy. Future research can investigate the potential for blood flow restriction training to achieve a higher total training volume than traditional resistance training and to see the strength and hypertrophy benefits this may cause.

This type of training could also be beneficial to athletic populations. Maintaining overall muscle size and strength while minimizing muscle damage and perceived muscle soreness would be beneficial to the athlete in-season. As seen in the study by Abe et al. (2005c), blood flow restriction training did not elevate markers for muscle damage (myoglobin, CPK, and lipid peroxide). Though this study did not measure blood markers for muscle damage, the previous literature provides insight on the practical application of using this style of training for an athlete in-season. A well-planned training schedule could consider involving practical vascular blood flow restriction training at times closest to an athlete's performance when the athlete would want to be refreshed, but still able to train. In conclusion, practical blood flow restriction training does not appear to be superior to traditional resistance training over a short-term training period of four weeks. However, there may be other benefits associated with this novel training strategy.

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APPENDIX A: TRAINING PROGRAM

Training Program for Blood Flow Restriction Group (pBFR)

Week 1 Day 1

Exercise	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Average RPE
45 Degree Leg Press @70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
Lying Leg Curl @70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
Barbell Bench Press@70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
Barbell Curl @70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
Lying Triceps Extension @70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							

Week 1 Day 2

Exercise	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Average RPE
Barbell Bench Press @ 80% then 30%	X7	X7	X30	X15	X15	X15	
RPE							
Bent Over Row @ 80%	X6	X6	X6	X6			
RPE							
45 Degree Leg Press @ 80% then 30%	X7	X7	X30	X15	X15	X15	
RPE							

Week 2-4 Day 1

Exercise	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Average RPE
45 Degree Leg Press @70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
Lying Leg Curl @70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
Barbell Bench Press@70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
Barbell Curl @70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
Lying Triceps Extension @70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							

Week 2-4 Day 2

Exercise	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Average RPE
Barbell Bench Press @ 80% then 30%	X30	X15	X15	X15			
RPE							
Bent Over Row @ 80%	X6	X6	X6	X6			
RPE							
45 Degree Leg Press @ 80% then 30%	X30	X15	X15	X15			
RPE							

Week 2-4 Day 3

Exercise	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Average RPE
Bent Over Row @ 70%	X12	X12	X12	X12			
RPE							
Barbell Curl @ 70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
45 Degree Leg Press @ 70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
Lying Leg Curl @ 70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
Bench Press @70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							
Lying Triceps Extension @ 70% then 30%	X12	X12	X30	X15	X15	X15	
RPE							

Resistance Training Group (RT)

Week 1 Day 1

Exercise	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Average RPE
45 Degree Leg Press @ 70%	X12	X12	X12	X12	X12		
RPE							
Lying Leg Curl @ 70%	X12	X12	X12	X12	X12		
RPE							
Barbell Bench Press @ 70%	X12	X12	X12	X12	X12		
RPE							
Barbell Curl @ 70%	X12	X12	X12	X12	X12		
RPE							
Lying Triceps Extension @ 70%	X12	X12	X12	X12	X12		
RPE							

Week 1 Day 2

Exercise	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Average RPE
Barbell Bench Press @ 80%	X7	X7	X7	X7	X7	X7	
RPE							
Bent Over Row @ 80%	X6	X6	X6	X6			
RPE							
45 Degree Leg Press @ 80%	X7	X7	X7	X7	X7	X7	
RPE							

Week 2-4 Day 1

Exercise	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Average RPE
45 Degree Leg Press @ 70%	X12	X12	X12	X12	X12		
RPE							
Lying Leg Curl @ 70%	X12	X12	X12	X12	X12		
RPE							
Barbell Bench Press @ 70%	X12	X12	X12	X12	X12		
RPE							
Barbell Curl @ 70%	X12	X12	X12	X12	X12		
RPE							
Lying Triceps Extension @ 70%	X12	X12	X12	X12	X12		
RPE							

Week 2-4 Day 2

Exercise	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Average RPE
Barbell Bench Press @ 80%	X7	X7	X7	X7			
RPE							
Bent Over Row @ 80%	X6	X6	X6	X6			
RPE							
45 Degree Leg Press @ 80%	X7	X7	X7	X7			
RPE							

Week 2-4 Day 3

Exercise	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Average RPE
Bent Over Row @ 70%	X12	X12	X12	X12			
RPE							
Barbell Curl @ 70%	X12	X12	X12	X12	X12		
RPE							
45 Degree Leg Press @ 70%	X12	X12	X12	X12	X12		
RPE							
Lying Leg Curl @ 70%	X12	X12	X12	X12	X12		
RPE							
Bench Press @70%	X12	X12	X12	X12	X12		
RPE							
Lying Triceps Extension @ 70%	X12	X12	X12	X12	X12		
RPE							

Periodized training program for the research study. Rest times between sets will be limited to 30-60 seconds for both group for all exercises except for bench press and leg press exercises. These exercises will use 2-3 minutes as recommended by the ACSM (2009). Rest time between exercises will be no longer than 2-3 minutes, this also applies when applying the vascular blood flow restriction apparatus to the correct participants. During week one of training participants will perform day 1 and day 2 of the training program. Weeks 2-4 will consist of training days 1, 2, and 3.

As each participant completes the workout, supervised by qualified researchers, completion of sets and resistance used will be recorded. During the workout, weight will be lowered if the participant can't complete assigned repetitions to ensure volume remains constant. Exercise resistance values will be assessed prior to 1st week of training.

APPENDIX B: EXERCISE HISTORY QUESTIONNAIRE

Exercise History Questionnaire for Resistance Training Athletes

Think about all the exercise training including any vigorous activities which take hard physical effort that you did in the last 7 days. Vigorous activities make you breath harder than normal and may include aerobic, heavy lifting, or fast bicycling. Think only about those physical activities that you did for at least 10 minutes at a time.

1. Do you compete in any resistance training sport on a regular basis? If so, how often?

Yes or No If so, _______________ times/year

2. How long have you been resistance training?

_______________ years

3. How many hours of resistance training do you perform on average each week?

_______________ hours/week

4. How many times do you resistance train per week? Please indicate if you do more than once a day.

_______________ days/week Average_______________ times/day

5. Please describe your resistance training intensity based on your self-estimated maximum load.

_______________ % your maximum

6. Do you incorporate any aerobic training? If so, how many times per week?

Yes or No If so, _______________ times/week

7. Please describe your average aerobic training intensity on a scale below (as close as possible):

1 2 3 4 5 6 7 8 9 10

Very Light Light Moderate Intense Very Intense

8. Do you currently compete in strength events? If so, for whom?

Yes or No If so, name:_______________ and when:________________

If not please provide the name and the time of the last event that you most recently attended - name:_______________ and when:_______________

9. When you compete, which sport do you compete in (Powerlifting, Strongman, or Bodybuilding)? Event:_____________________________________
10. In your opinion, before you take part in an experimental session, do you believe that you will increase muscle volume with occlusion training (RTO) being used in your training program or not (RT)?

RTO:_______________ RT:________________ No Difference:________________

11. Are you currently taking anabolic steroids of any kind? ____ Yes _____ No
12. Are you allergic to whey protein? ____ Yes _____ No
13. Do you have a history of deep vein thrombosis? ____ Yes _____ No

14. Please best describe your occupation or daily activities other than your exercise training.

APPENDIX C: PASQ

Pre-Activity Screening Questionnaire (PASQ)

Section 1-Diagnosed Medical Conditions

Please mark either Y (Yes) or N (No) *for* each of the items below that you have had diagnosed by a physician.

Cardiovascular (Heart) Disease

Y❑ N❑ Heart attack
Y❑ N❑ Heart surgery
Y❑ N❑ Coronary angioplasty (PTCA)
Y❑ N❑ Heart valve disease
Y❑ N❑ Heart failure
Y❑ N❑ Heart transplantation
Y❑ N❑ Congenital heart disease
Y❑ N❑ Abnormal heart rhythm
Y❑ N❑ Pacemaker/implantable cardiac defibrillator
Y❑ N❑ Peripheral vascular disease (PVD or PAD): disease affecting blood vessels in arms, hands, legs, and feet
Y❑ N❑ Cerebrovascular disease (stroke or transient ischemic attack): disease affecting blood vessels in the brain

Pulmonary (Lung) Disease

Y❑ N❑ Emphysema
Y❑ N❑ Chronic bronchitis
Y❑ N❑ Interstitial lung disease
Y❑ N❑ Cystic fibrosis
Y❑ N❑ Asthma
↪If Yes to asthma, is this a current condition **Y❑ N❑**

Metabolic Disease

Y❑ N❑ Liver disease
Y❑ N❑ Diabetes
Y❑ N❑ Thyroid disorders
Y❑ N❑ Kidney disease

Y❑ N❑ Do you have any other medical conditions diagnosed by a physician (such as musculoskeletal problems, recent surgery, seizures, pregnancy, cancer, etc.) that may limit your physical activity?
Y❑ N❑ Do you take any prescription medications?

Section 2- Signs or Symptoms

Please mark either Y (Yes) or N (No) for each item below that you have recently experienced.

Y❑ N❑ Pain, discomfort in the chest, neck, jaw or arms at rest or upon exertion
Y❑ N❑ Shortness of breath at rest or with mild exertion
Y❑ N❑ Dizziness or loss of consciousness during or shortly after exercise
Y❑ N❑ Shortness of breath occurring at rest or 2-5 hours after the onset of sleep
Y❑ N❑ Edema (swelling) in both ankles that is most evident at night or swelling in a limb
Y❑ N❑ An unpleasant awareness of forceful or rapid beating of the heart
Y❑ N❑ Pain in the legs or elsewhere while walking; often more severe when walking upstairs/uphill
Y❑ N❑ Known heart murmur
↪If Yes to known heart murmur, is this a current condition **Y❑ N❑**
Y❑ N❑ Unusual fatigue or shortness of breath with usual activities

Section 3- CVD Risk Factors

Please mark Y (Yes) or N (No) for each the following:

Positive Risk Factors

Y❑ N❑ I am a man who is 45 years or older or a woman who is 55 years or older.
Y❑ N❑ I have a father or brother who had a heart attack, coronary (heart) by-pass surgery, or who died suddenly before age 55 or I have a mother or sister who had a heart attack, coronary (heart) by-pass surgery, or who died suddenly before age 65.
Y❑ N❑ I am a smoker or I have quit smoking in the last 6 months or am exposed to environmental tobacco smoke.
Y❑ N❑ In the last 3 months, I have **not** been physically active - meaning I have **not** participated in 30 min of moderate intensity physical activity at least 3 days/week.
Y❑ N❑ I have a BMI greater than or equal to 30 (see BMI chart on page 2 to determine your BMI).

Please mark Y (Yes), N (No), or DK (Don't Know) for each the following:

Y❑ N❑ DK❑ My blood pressure is greater than or equal to 140/90 mm Hg.
Y❑ N❑ DK❑ My blood cholesterol level is greater than or equal to 200 mg/dL.
Y❑ N❑ DK❑ My fasting blood glucose is greater than or equal to 100 mg/dL.

Negative Risk Factor

Y❑ N❑ DK❑ My high-density lipoprotein (HDL) cholesterol level is greater than or equal to 60 mg/dL.

Section 4- Acknowledgment, Follow-up, and Signature

I acknowledge that I have read this questionnaire in its entirety and have responded accurately, completely, and to the best of my knowledge. Any questions regarding the items on this questionnaire were answered to my satisfaction. Also, if my health status changes at any time, I understand that I am responsible to inform this health/fitness facility of any such changes.

(Participant's Name-Please Print) (Participant's Signature) (Date)

Risk Stratification-American College of Sports Medicine

Appropriate recommendations for medical examination, physical activity/exercise, exercise testing, and physician supervision are made based on a risk stratification process that assigns participants into one of three risk categories: a) low, b) moderate, or c) high risk. The process by which individuals are assigned to one of these risk categories is called risk stratification and is based on:

- The presence or absence of known cardiovascular, pulmonary, and/or metabolic disease.
- The presence or absence of signs or symptoms suggestive of cardiovascular, pulmonary, and/or metabolic disease.
- The presence or absence of cardiovascular risk factors

Low risk: Individuals classified as low risk are those who do not have diagnosed cardiovascular, pulmonary, and/or metabolic disease and have no more than one CVD risk factor. The risk of an acute cardiovascular event in this population is low, and a **physical activity/exercise program may be pursued safely without the necessity for medical examination and clearance**.

Moderate risk; Individuals classified as moderate risk do not have signs of or diagnosed cardiovascular, pulmonary, and/or metabolic disease, but have two or more CVD risk factors. The risk of an acute cardiovascular event in this population is increased, although in most cases, individuals at moderate risk mar safely engage in low- to moderate-intensity physical activities without the necessity for medical examination and an exercise test before participation in vigorous intensity exercise.

High risk: Individuals classified as high risk are those who have one or more signs/symptoms of or diagnosed cardiovascular, pulmonary, and/or metabolic disease. The risk of an acute cardiovascular event in this population is increased to the degree that a thorough medical examination should take place and clearance given before initiating physical activity or exercise at any intensity.

The exercise or health/fitness professional may evaluate the individual's medical/health history information and follow a logical sequence considering this risk stratification process to determine into which appropriate risk category an individual should be placed. Exercise or health/fitness professionals should have a thorough knowledge of a) the criteria for known cardiovascular, pulmonary, and metabolic diseases; b) the descriptions of signs and symptoms for these diseases; c) the specific criteria that determine the CVD risk-factor schemes; and d) the criteria for each risk category.

APPENDIX D:

DIETARY RECORD INSTRUCTIONS

1. Use the Dietary Record Forms provided to record everything you eat or drink for each day of this study.
2. Indicate the name of the FOOD ITEM, the AMOUNT eaten, how it was PREPARED (fried, boiled, etc.), and the TIME the food was eaten. If the item was a brand name product, please include the name. Try to be accurate about the amounts eaten. Measuring with measuring cups and spoons is best, but if you must make estimates, use the following guidelines:

   Fist is about 1 cup

   Tip of Thumb is about 1 teaspoon

   Palm of the hand is about 3 ounces of meat (about the size of a deck of cards)

   Tip of Thumb is about 1 ounce of cheese

3. Try to eat what you normally eat and record everything. The project will only be useful if you are HONEST about what you eat. The information you provide is confidential.
4. MILK: Indicate whether milk is whole, low fat (1 or 2%), or skim. Include flavoring if one is used.
5. VEGETABLES and FRUITS: One average serving of cooked or canned fruits and vegetables is about a half cup. Fresh whole fruits and vegetables should be listed as small, medium, or large. Be sure to indicate if sugar or syrup is added to fruit and list if any margarine, butter, cheese sauce, or cream sauce is added to vegetables. When recording salad, list items comprising the salad separately and be sure to include salad dressing used.
6. EGGS: Indicate method of preparation (scrambled, fried, poaches, etc.) and number eaten.
7. MEAT / POULTRY / FISH: Indicate approximate size or weight in ounces of the serving. Be sure to include any gravy, sauce, or breading added.
8. CHEESE: Indicate kind, number of ounces or slices, and whether it is made from whole milk, part skim, or is low calorie.
9. CEREAL: Specify kind, whether cooked or dry, and measure in terms or cups or ounces. Remember that consuming 8 oz. of cereal is not the same as consuming one cup of cereal. 1 cup of cereal generally weighs about 1 ounce.
10. BREAD and ROLLS: Specify kind (whole wheat, enriched wheat, rye, etc.) and number of slices.

11. BEVERAGES: Include every item you drink excluding water. Be sure to record cream and sugar used in tea and coffee, whether juices are sweetened or unsweetened and whether soft drinks are diet or regular.
12. FATS: Remember to record all butter, margarine, oil, and other fats used in cooking or on food.
13. MIXED DISHES / CASSEROLES: List the main ingredients and approximate amount of each ingredient to the best of your ability.
14. ALCOHOL: Be honest. Record amounts in ounces. Specify with “light” or “regular” beer.

DIETARY RECORD FORM

Day of the Week: ___________________

Date: ______________________

FOOD ITEM	AMOUNT	TIME

- Express approximate measures in cups (C), tablespoons (T), teaspoons (t), grams (g), ounces (oz.), pieces, etc.