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The Effect Of Practical Blood Flow Restriction Training On Body Composition And Muscular Strength In College-Aged Individuals

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DEDICATION

Mom, Dad, McKenzie, Josh, Kasey and Carter, this thesis is dedicated to you. Without the love, support and understanding that you all have provided me through this time, I would have not been able to do this without you guys. Thank you so much for everything that you have done for me over the course of my life.

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ABSTRACT

PURPOSE: To determine the effects of practical blood flow restriction training on body composition and muscular strength in college-aged individuals when compared to a traditional resistance training protocol. **METHODS:** This study consisted of two randomized groups, an experimental group (BFR), and a traditional resistance training (TRT) control group. The 9 subjects' characteristics were 8 males, 1 female; age: 22 ± 2 years; height: 175 ±7.6 centimeters; weight: 83.4±18.1 kg.; body fat percentage: 21±9%. All participants completed pre-testing measures of girth of both arms and legs, upper chest, and shoulders. Body composition was determined using air displacement plethysmography via BodPod (COSMED USA, INC., Concord, CA) to determine fat free mass and body fat percentage. Maximal strength was assessed on the bench press and back squat to determine workloads during the training programs. Both groups completed a four-week training program consisting of both upper and lower body training. The BFR program consisted of four sets (1 set x 30 repetitions and 3 sets x 15 repetitions). Loads progressed from 20 to 32% of each person's 1RM over the four weeks. The TRT program consisted of four sets with progressive loads of 65%, 75%, 80% and 85% with 15, 10, 8, and 6 repetitions respectively. Post testing measures followed the pre-testing regimen. Within and between group differences from pre-to post testing were determined via paired and independent t-tests. **RESULTS:** No significant differences were found among any of the body composition measurements as well as squat performance. The BFR group demonstrated significantly greater increases in bench press performance (pre: 198 ±79 lbs.; post: 211±83 lbs.) after the training program (p=0.004) compared to the TRT group. **CONCLUSION:** In a limited sample, BFR training was shown to be a comparable training method when compared to traditional hypertrophy training. The findings were specific to increases in bench press performance.

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I. INTRODUCTION

Introduction to Blood Flow Restriction Exercise

To achieve skeletal muscle hypertrophy during resistance training, loads must be lifted of at least 70% of an individual's one repetition maximum (ACSM, 2009). For some individuals, the joints of the body cannot tolerate this extreme load. Blood flow restriction (BFR) training, the method of applying external restriction to a variety of muscle groups, was developed to allow individuals to lift much lower loads while under vascular occlusion to possibly achieve muscular hypertrophy. During the late 1960's Dr. Yoshiaki Sato, Ph.D., of Japan was struck with the idea of KAATSU training during his attendance of a Buddhist memorial. During the memorial, Dr. Sato's calves became numb from the position that he was sitting in and noticed that his calves were swollen similar to when he completed strenuous calf exercises (Sato, 2005). He attributed the swelling sensation to the lack of blood flow from the seated position he was in, and postulated that the swelling and numbness sensation was associated to the reduced blood flow to the calf muscle. This finding led Dr. Sato to do more investigation on this topic.

One of the primary mechanisms that illicit hypertrophy in general resistance training is metabolic stress. A recent meta-analysis examined the potential mechanisms that elicit muscle hypertrophy from resistance training (Schoenfeld, 2013). Metabolic stress is discussed as having a pivotal role in inducing hypertrophy due to the accumulation of lactate, inorganic phosphate (Pi) and hydrogen ions (H+) within the muscle that lead to hypertrophy. This theory can be supported by observing the training methods used by most bodybuilders where they routinely perform 6-12 repetitions of submaximal loads with very small rest periods. Not allowing the muscles to fully recover and remove the metabolites between sets causes more accumulation of metabolic by-products when compared to lower repetitions with heavier loads (Schoenfeld, 2013). Metabolic stress has been postulated as a primary mechanism for hypertrophy with BFR training. According to Wilson, Lowery, Joy, Loenneke and Naimo (2013), practical vascular occlusion can be administered by using elastic knee wraps as a wrapping device around the proximal end of the desired limb. Once under constriction individuals perform 20-30 repetitions of at least 20% of their predetermined one repetition maximum (1RM) with 30-45 seconds of rest in between each set of exercise. This form of training has become widely used with older adults and the clinical rehabilitation settings due to the greatly reduced loads on the joints (Vechin, et al., 2015).

Mechanisms of Hypertrophy with Blood Flow Restriction Training

Many theories have been postulated as to how skeletal muscle hypertrophy could occur with lower exercise loads with BFR. Further research is needed to determine the primary mechanism for increasing hypotrophy and growth hormone with occluded exercise. A primary potential mechanism by which blood flow restriction training can stimulate growth is the increased metabolite accumulation. Metabolites are substances that are formed during or that are necessary for metabolism. These metabolites are increased during BFR training from the lack of blood clearance out of the localized muscle due to the occlusion of the venous structures. This in turn increases anabolic growth factors such as protein synthesis via the m-TOR pathway, and fast twitch muscle fiber recruitment (Loenneke, 2009). Secondary mechanisms may include: mechanotransduction, muscle damage, systemic and localized hormones, cellular swelling, and reactive oxygen species (Pearson & Hussain, 2015). These mechanisms have been postulated to help attenuate strength and hypertrophy with BFR training.

Blood Flow Restriction Training Adaptations to Strength and Hormones

Although research is still unclear as to the primary cause that increases growth hormone upon completion of occluded exercise, BFR has been shown to create increases in hormones such as growth hormone and norepinephrine levels in the blood stream when compared to non-occluded exercise. According to Craig, Brown, and Everhart (1989), growth hormone has been shown to have an impact on increasing strength in both young and older adults during normal resistance training. Furthermore, other researchers have shown that occluded exercise could be used in the clinical rehabilitation setting, athletic populations, and the older adult population (Loenneke & Pujol, 2009). Older adults have been shown to have increases in both lower body strength and quadricep cross sectional area after completing a 12-week program of low load resistance BFR training (Vechin et al., 2015). One recent study conducted by Yamanaka, Farley and Caputo (2012) examined National Collegiate Athletic Association Division I football players during their offseason training program. Athletes completed four sets of bench press and four sets of back squats while under arterial occlusion, which occurred 3 times per week. The occluded training group showed significant increases in strength on the bench press by 7% and the back squat by 8%, as well as increases in upper and lower chest girth measurements of 3% each. This study was one of the first studies conducted that examined the effects of both strength and increases in muscle size while using BFR training. Although many studies have been conducted utilizing similar loads used (20-30% of 1RM), no study to date has utilized a linear progressive model to progress the workloads throughout the training program.

Need for the Study

The current body of literature in terms of BFR research is mainly focused on the acute benefits of BFR training. Little research has focused on the chronic strength and hypertrophy benefits when performing a BFR training regimen (Yamanaka, Farley and Caputo, 2012; Fajita et al, 2008). The studies mentioned only utilized trained males in their studies, the current will utilize both males and females. To date, only about 17% of the population of analyzed in BFR research is females (Counts et al, 2016). Incorporating females in the current study will allow for more research to be done on the muscular strength and hypertrophy during a four-week BFR training protocol. As well as incorporating females, the current study will compare the effectiveness of BFR training against a traditional hypertrophy training protocol. Many of the studies that have compared BFR training to other training methods have compared BFR against low intensity training (Yamanaka, Farley, Caputo, 2012; Takarada et al, 2000b; Fajita et al, 2008). To the author's knowledge, this will be the first study that will utilize a progressive model for training loads within the BFR training protocol.

Purpose of the Study

Strong evidence has been shown for BFR's effectiveness in the clinical rehab setting, as well as in older adults. Although there is a wealth of information regarding the effectiveness of this training method in the clinical rehab setting, there is a lack of evidence that demonstrates BFR as an effective training method for increasing muscular strength and hypertrophy. A lack of evidence has been shown on the effectiveness of a periodized BFR program. Many of the studies have utilized a standard program of BFR training that uses 20-30% of an individual's 1RM, rather than a progressive model. This shows a need to enhance the body of literature that exits. Therefore, the purpose of the current study is to determine the effect of practical blood flow restriction training on body composition and muscular strength in college-aged individuals when compared to a traditional resistance training protocol. It was hypothesized that where will be no significant differences in body composition or muscular strength between the control and experimental group, showing that BFR training is just as effective as a traditional hypertrophy protocol.

Assumptions

Within this study, the following assumptions will be made: (a) participants will be truthful in their reporting of past exercise history; (b) each participant will adhere to the testing protocol and will attend all required meeting times within the study; (c) subjects will not perform additional exercise sessions beyond what is asked for in the study; and (d) the participants will not be taking any sort of performance enhancing drugs before or during the exercise testing protocol.

Delimitations

The delimitations of the current study are the following:

1. The age will be delimited to both males and females with ages ranging from 18- 29 and with at least one year of resistance training experience.
2. The subjects will be volunteers.
3. The training duration will be delimited to a four (4) week period.
4. The training frequency will be three (3) training days per week.
5. The total number of training sessions will be delimited to 14 sessions.

Limitations

One of the limitations of this study is that a convenience sample will be used. A random sample will not be used and, therefore, statistical extrapolation to the greater population will be limited. Another limitation of the current study is the lack of scientific research on this topic. Though the research is limited, this allows for the opportunity to expand the current body of literature on the effects of practical blood flow restriction training. Another limitation is the primary researcher was unable to determine the exact level of occlusion due to not having an ultrasound machine that would show how much occlusion had taken place.

Definition of Terms

Growth hormone (GH): a hormone that stimulates growth in animal or plant cells, especially (in animals) a hormone secreted by the pituitary gland.

Insulin-like growth factor 1 (IGF-1): insulin-like growth factor 1, also called somatomedin C, is a protein that in humans is encoded by the IGF-1 gene. IGF-1 has been shown to mediate the effects of circulating growth hormone, which in turns increases muscular hypertrophy.

Blood lactate: lactic acid that appears in the blood as a result of anaerobic metabolism and decreased oxygen delivery to the tissues.

One (1) repetition max (1RM): the maximum amount of resistance that can be lifted for one repetition during a given resistance exercise. This value is an indicator of maximal strength.

Mechanotransduction: the ability of the muscle cells to sense the forces applied to them during exercise and translate them into biochemical and biological responses.

M-TOR pathway: an intracellular signaling pathway that is a crucial regulator of skeletal muscle hypertrophy and can prevent muscle atrophy.

Practical blood flow restriction: resistance training with blood flow restriction to the muscle while using a simple wrapping apparatus such as a knee wrap that occludes the veins, but not the arteries which supply the working muscles.

Reactive oxygen species (ROS): molecules and ions of oxygen that have an unpaired electron, thus rendering them extremely reactive which may result in cell damage. This is also known as oxidative stress.

Skeletal muscle hypertrophy: the increase in cross-sectional area of the muscle via growth of the myofibrils. Sarcoplasmic hypertrophy can also occur, which states that there is an increase in the sarcoplasmic fluid within the muscle cell with no increases in muscular strength.

II. REVIEW OF LITERATURE

Blood flow restriction (BFR) training has become a popular resistance training technique over the past few years. Recent studies have examined the effects of incorporating this type of training into individual's already existing workout routines and its effects on different aspects of muscle physiology. The purpose of this review is to analyze the body of research in terms of general hypertrophy training. Once general muscle hypertrophy guidelines can be established, it will help demonstrate the effectiveness of BFR training in different populations. This review will discuss the general guidelines for using BFR training in the clinical rehabilitation setting, older adults, the mechanisms of action and hormone adaptations that occur with BFR training, and how those adaptations can lead to muscular strength and hypertrophy increases in the general population.

Hypertrophy Training

The American College of Sports Medicine (ACSM) Position Statement for Muscular Hypertrophy training (2009) recommends that both men and women should partake in concentric, eccentric and isometric muscle actions for all levels of progression. Effective training programs that optimize the most muscle hypertrophy in trained individuals include greater loads, short rest intervals and moderate to high volume within the training program. A review of the literature conducted by the ACSM (2009) showed that training loads can range from 70-85% of 1RM for 8-12 repetitions per set, with sets ranging from 1-3 per exercise.

Exercise selection should include both single and multiple joint exercises as well as a combination of free weight and machine exercises for both novice and advanced individuals. General recommendations state that multiple joint exercises should be performed before single joint but the ACSM recognizes that multiple joint exercises have a slower time course of hypertrophy due to the longer neural adaptations that occur with multiple joint exercises. Rest intervals for novice and intermediate lifters should be 1-2 minutes. More advanced lifters should use 2-3 minutes of rest between the core lifts such as squat and deadlift, and 1-2 minutes between other exercises of less intensity. When performing these lifts, the ACSM (2009) recommends repetition velocity should be slow to moderate for novice and intermediately trained lifters. For advanced lifters, repetition velocity can be slow, moderate or fast, depending on the load, the repetitions of the set, and the goals of their training program.

The ACSM position statement (2009) recommends novice lifters should partake in training 2-3 days per week to illicit hypertrophy. Intermediate trained lifters should have total body workouts 4 days per week performing upper and lower body training splits. Advanced lifters should perform 4-6 days of training per week with 1-3 muscle groups trained per workout.

Inflammatory Process to Muscle Damage

Regardless of the type of training an individual will perform, some form of muscle damage will most likely occur. Anytime that a muscle group is lengthened beyond its normal limit, muscle damage occurs. Once muscle damage occurs, there are three main stages for repairing muscles, the first stage being the acute phase; the second being the sub-acute phase and the third being the chronic phase (Tidball, 1995). During the acute phase, inflammation occurs at the site of injury by a rapid increase of neutrophils that activate and attract other inflammatory cells. This can be seen during lifting as an increase in the “pump” of the muscle. This is mainly due to the increased edema, which is protein filled fluid that helps rebuild and repair the damaged muscles. Depending on the severity of the muscle injury, during the acute phase neutrophils can cause additional damage by releasing free-radicals that help break down the muscle cells even more to cause more inflammation. (Tidball, 1995). After the initial stage, an increase in macrophages dumped into the muscle. These macrophages will ensure sure that no debris is left behind before moving into the next phase of repair. Once the debris has been removed, an additional number of macrophages are released into the muscle. This second population of macrophages are specialized regeneration of the damaged muscle (Tidball, 1995). Understanding the basics of the inflammatory process is important for both the clinical rehabilitation setting as well as the recreational training setting. Utilizing the proper training technique and programming is important to ensure that no additional damage is done, this could delay the timeline for the repair process.

Introduction of Blood Flow Restriction Training

Blood flow restriction training (BFR) is a training technique that is performed by the constriction of blood vessels in a targeted limb. While under constriction individuals will perform 20-30 repetitions at 20-30% of their predetermined one repetition max (1RM) on the selected exercise. This form of training has become widely used in all populations, especially in the clinical rehabilitation setting. One of the potential mechanisms that allows this training technique to be effective is the buildup of metabolic by-products that accumulate in the working muscles. Since the main blood vessels to the targeted area are occluded, it does not allow for full clearance of byproducts to be filtered out by the blood. A meta-analysis done by Schoenfeld (2013) examined the potential mechanisms that elicit muscle hypertrophy from resistance training. Metabolic stress is discussed as having a pivotal role in increasing muscle hypertrophy. Schoenfeld discussed how the accumulation of lactate, inorganic phosphate (Pi) and hydrogen ions (H+) lead to stimulation of hypertrophy within the muscles, this hypothesis can be supported by observing the training done by bodybuilders. This type of training is designed to increase the buildup of metabolic by-products due to the higher volume of work done. Bodybuilding regimens usually consist of moderate intensity (70%-80% of max) with 6-12 repetitions with and rest periods. This type of training followed by little rest in between sets causes the body to accumulate more metabolic waste products. Some research has indicated that bodybuilding-type training programs increase greater muscle growth compared to traditional high intensity Olympic-type training (Schoenfeld, 2013).

A recent meta-analysis done by Leonneke et al. (2012) examined the optimal hypertrophy training regimen by examining 11 peer reviewed journals on BFR training. The analysis showed BFR training is best performed among untrained individuals who participate in BFR training two to three times a week for at least four weeks with no longer than 10 weeks of BFR training. Individuals who perform this training protocol typically see greater increases in muscular hypertrophy and strength when compared to a lower intensity exercise performed without blood flow restriction training.

Clinical Blood Flow Restriction (BFR) Training

Blood flow restriction training use has great potential for the clinical and athletic rehabilitation setting. BFR training has been a popular modality for individuals recovering from reconstructive anterior cruciate ligament (ACL) surgery. Takarada et al. (2000a) examined the effects of BFR training rehabilitation training on individuals who had reconstructive ACL surgery (3 and 14 days' post-surgery). Participants (N=16, m=8, f=8) were randomly split into two groups, the control group completed rehab protocols that consisted of keeping the injured leg in a stable brace, and the experimental group that performed five minutes of occlusion followed by three minutes of non-occlusion for five sets. These training procedures were completed for 14 days' post-surgery. Data analysis showed that there was no significant difference between the two groups when looking at the overall cross-sectional area of the thigh muscles. The experimental group did have a significantly slower ($p<.05$) decrease in the knee flexor muscle when compared to the control group. This study suggested that combining BFR into a rehabilitation program can help slow the atrophy of the knee flexor muscles after major ACL reconstruction surgery.

Further studies were conducted to examine similar effects at a later period in the rehabilitation process. Ohta et al. (2009) examined the effects of BFR training 16 weeks post ACL reconstruction surgery. In this study, researchers examined subjects (N=44, m=25, f=19) who were randomly split into two groups, the BFR group consisted of normal rehabilitation with the inclusion of blood flow restriction and the control group performed the same rehabilitation as the experimental group, but without the use of blood flow restriction. The rehab program took place 16 weeks after reconstructive ACL surgery and both groups completed exercises that consisted of straight leg raises, hip joint abduction, half-squat, walking lunges and an elastic tube exercise. Evaluation of muscular torque of knee extensor and flexor groups, cross sectional area of femoral muscle group, and single muscle fiber diameter assessed by fiber type were examined pre-and post-testing. Data analysis showed there was slightly more atrophy of type 2 fibers when compared to type 1. They also found that both type 1 and type 2 fibers were slightly larger in the experimental group when compared to the control group, but no significant differences were found in either analyses. This study suggests that incorporating blood flow restriction training later in the rehabilitation may not be as beneficial as incorporating it immediately post-surgery.

Blood Flow Restriction Training and the Older Adults

One of the many potential populations that BFR training can be used in is the older adult population. BFR training can help increase the muscle mass and strength of older adults who are unable to have extreme loads placed on their bodies, due to conditions such as arthropathies and osteoporosis. A study conducted by Vechin et al. (2015) compared the effects of a 12-week training program that consisted of low- resistance training BFR training (LRT-BFR) or a high resistance training program (HRT) without blood flow restriction. In this study, 23 (n=23, m=14, f=9) healthy older adults with ages ranging from 59-71 were examined. Each of the subjects were ranked per their initial quadriceps size and split into three groups, the control group (n=7), HRT group (n=8) and the LRT-BFR group (n=8). The HRT performed 4 sets of 10 reps at 70% of their 1RM. The LRT-BFR completed 1 set of 30 reps and 3 sets of 15 reps at 30% 1RM of their max with blood flow restriction. Each group had 1-minute rest periods in between sets. Once the training program began, subjects completed the leg press exercise 2 days a week for the 12-week training program. Data analysis showed that the LRT-BFR group had the greatest increase in 1RM max on leg press, and an increase in quadricep cross sectional area (p=<.001) when compared to the HRT and control groups. This study suggests how valuable BFR training could be for individuals who are unable to complete higher load resistance training.

Mechanisms of Action

Many studies have been conducted to examine the mechanisms of action for hypertrophy when performing blood flow restrictive exercises. Recently a literature review conducted by Pearson and Hussain (2015) was performed to help clarify some of the mechanisms during BFR training. In this review, they examined articles from 2000 to 2014 and found a set of primary mechanisms. One of the primary mechanisms was found to be mechanical tension. Through the review, mechanical tension seemed to induce muscle hypertrophy by inducing mechanotransduction, increased localized hormone production, muscle damage, and an increase in fast-twitch muscle fibers. The remaining mechanism for hypertrophy was noted to be metabolic stress. Research has shown that after a bout of blood flow restrictive exercise blood lactate concentrations have been shown to be significantly greater when compared to the same exercises performed without blood flow restriction (Takarada, 2000b). The secondary mechanisms associated with metabolic stress were elevated systemic hormone (growth hormone, norepinephrine, lactate) production, increased fast twitch fiber recruitment, cell swelling, muscle damage and an increase in reactive oxygen species (chemically reactive species that contain oxygen). These mechanisms have all been theorized to help produce protein signaling or satellite cell proliferation to help induce muscle hypertrophy. Research conducted by Loenneke, Wilson, and Wilson (2009) examined the mechanisms of action for restrictive exercise much like Pearson and Hussain (2015). Within their review, it was hypothesized that during restrictive exercise there is limited amount of oxygen available. The lack of oxygen (hypoxia) could potentially cause an increased number of motor units to be recruited to help compensate for the low force development. The researchers also stated that past research has shown significant increases in motor unit firing rate as well as motor unit spike amplitude during bouts of occluded exercise. This suggests that motor unit recruitment is not only affected by the speed and force produced but by the amount of oxygen that is present. Another key factor found in this article was the inhibition of myostatin. Myostatin negatively regulates muscle growth as well as limits the amount of satellite cell proliferation (Pearson & Hussain, 2015). Blood flow restrictive exercise has shown to limit the myostatin gene from the overloading of the muscle that occurs. It is hypothesized that the metabolic buildup that occurs during occluded BFR training may cause hypertrophic changes in the myostatin gene. Many theories have been postulated that have analyzed the most optimal metabolic accumulation to maximize muscle hypertrophy.

Leonneke et al. (2011) found similar findings as the previously stated articles. The purpose of his article was: (a) to determine what role the intensity of blood flow restricted exercise had with muscle protein synthesis and hypertrophy; (b) is fast-twitch fiber recruitment the most important factor for muscle hypertrophy; and (c) do systemic elevations of endogenous hormones play a role in muscle protein synthesis or hypertrophy. The literature stated that muscle protein synthesis can occur if the volume of training or metabolic stress is high enough to recruit fast twitch muscle fibers. ACSM guidelines state that to produce muscle hypertrophy, the exercise intensity must be greater than 70% of the individual’s one rep maximum. Recent research on blood flow restriction exercise has shown that muscle hypertrophy can still occur with an exercise intensity as little as 20-30% of their 1RM. As stated earlier, it is hypothesized that during occluded exercise the amount of available oxygen is limited, and this can cause the body to recruit fast-twitch muscle to help compensate for the force development demands.

Hormone Adaptations to Blood Flow Restriction (BFR) Training

Acute and chronic changes to endogenous hormones have been heavily researched as a primary theory for hypertrophy when completing blood flow restricted exercise. Research conducted by Takarada et al. (2000b) examined the hormonal and inflammatory responses to low intensity exercise with blood flow restriction in six males. Subjects performed bilateral knee extension with 20% of their 1RM with and without occlusion. Lactate, growth hormone and norepinephrine levels were all significantly greater 15 minutes after the occluded exercise session compared to the non-occluded session. Peak levels of lactate and norepinephrine were found immediately after completion of the exercise and growth hormone levels peaked at 15 minutes after cessation of exercise. Lactate levels were three times higher during the occluded trial compared to the non-occluded trial, this was mainly due to the increased metabolic buildup from the BFR occlusion.

BFR Chronic Adaptations on Strength

Recent studies have been conducted to examine the chronic effects of BFR training on strength in college athletes. Studies done by Yamanaka et al. (2012) and Luebbers et al. (2014) examined the effects of BFR training on strength in the bench press and the back squat. Both studies examined college football players during their off-season programs. Yamanaka et al. found over the course of the training period, individuals assigned to the BFR training protocol had significantly greater increases in strength on both the bench press and back squat. Luebbers et al. (2014) also examined the effects of different training protocols on strength in the back squat and bench press. One of the four groups that were included in the study was a low intensity BFR training protocol. Unlike Yamanaka et al. there were no significant findings on strength measures throughout the course of the study. Luebbers et al. included a very specific training routine that included many different upper and lower body accessory lifts whereas Yamanaka et al. used a much simpler approach that involved just the bench press and the back squat. The addition of accessory lifts into the training programs that incorporate BFR training may influence the results.

BFR in Women

In the current literature regarding BFR training, the number of female subjects that have been examined is limited. An article conducted by Counts et al, 2016 examined the number of females that have been examined in BFR training. They found that out of the

4335 participants that have been examined in BFR studies, with 2324 participants being a part of chronic studies and 2011 being from acute studies. From the total samples size, 29% of population was represented by females in the acute studies and an even less percentage (17%) being from chronic studies.

III. METHODOLOGY

Participants

The purpose of this study was to examine the effects of BFR training on body composition, muscular strength, and muscular hypertrophy in college-aged individuals. This study examined 12 recreationally trained college aged student volunteers ranging from 18 to 29 years old at Eastern Kentucky University. These participants were physically active with at least one year of resistance training experience. The participants in the study were recruited out of various courses on the campus of EKU, and where given an oral presentation about the study, then asked to volunteer. This study consisted of two randomized groups, an experimental group, and a control group

Procedures

All participants were required to read and complete an informed consent form. The primary researcher was available to answer any questions or concerns. Participants were given stopping criteria if they experienced extreme muscle soreness and/or joint pain during the testing. All participants were required to complete a pre-activity questionnaire (PAR-Q) to classify their readiness for physical activity. All participants were required to fill out a health/medical questionnaire, which gave the primary researcher insight into their health and medical history. Any participants who had a past health history that would limit them from participation in the current study were excluded from the current study. Exclusion criteria included: (a) individuals who answered yes to any of the seven questions on the PAR-Q; (b) any individual who has had any past musculoskeletal injury that would limit their full participation in the current study. Once the subjects were cleared to participate, the subjects were randomly split into one of the two groups using computer generated randomization: (a) blood flow restriction (BFRT), or (b) traditional resistance training (TRT). The informed consent was read and signed by the participant prior to completing pre-testing measurements.

Prior to beginning the training program, participants were shown the BFR procedure as well as proper lifting technique for each of the lifts within the program.

Equipment

Pre-testing and post-testing was performed in the Weaver Gym and the Moberly Exercise Physiology Lab located on the campus of Eastern Kentucky University. Air Displacement Plethysmography was used via the COSMED BODPOD machine to determine body composition for all participants. The BODPOD has been found to be a highly valid and reliable instrument for measuring body composition as well as having a significant intraclass correlation coefficient (ICC) of .996 (p=.001) (Noreen and Lemon, 2006).

The current study adhered to a similar protocol as conducted by Wilson, Lowery, Joy, Loenneke and Naimo (2013). Subjects went through a familiarization trial to get accustomed to the BFR pressure protocol and then confirmed a 7/10 perceived pressure. Practical blood flow restriction was applied to subjects using elastic knee wraps (Harbinger, 76mm width) at a constant pressure that resulted in venous, but not arterial constriction. The 7/10 pressure was verified by ultrasound and adhered to by Wilson, Lowery, Joy, Loenneke and Naimo (2013).

Procedures

Participant Data: Pre/Post Testing

Data collection during both pre-testing and post-testing sessions was performed in the Weaver Gym and the Moberly Exercise Physiology Lab located on the campus of Eastern Kentucky University.

Body Composition Measures

Body weight was determined using the calibrated BodPod scale and height using a standard tape measure were taken first followed by a Bod Pod scan to determine the subject's body fat percentage, and lean body mass. Additionally, girth measurements of the upper and lower chest, as well as both the right and left thighs and right and left arms were taken. ACSM (2014) guidelines for circumference assessment were adhered to (see table 1).

Table 1. Girth Measurements Landmarks

Body Part	Landmarks
Right and Left Arm	A horizontal measure midway between the acromion and olecranon processes
Right and Left Leg	A measure is taken midway between the inguinal crease and the proximal border of the patella
Chest	A measure at the nipple level, under the arms
Chest and Shoulder	A measure at the nipple level, over the arms

One Repetition Max (1-RM) Testing

Assessment of a subject's 1-RM adhered to NSCA guidelines (see Appendix B). Participants performed a general warm-up lasting 5-10 minutes in length of aerobic exercise which prepared the muscles used during the bench press and back squat. Prior to the completion of the 1-RM, submaximal loads were performed for multiple reps on both the bench press and back squat. For completion of the bench press, subjects laid supine on the bench. Five points of body contact were maintained during the entire lift: (a) head, (b) shoulders, (c) buttocks, (d) right foot, and (e) left foot. The bar was then lifted off the rack by the participant, with the assistance from the spotter if needed and lowered to the chest and lifted off their chest until full elbow extension was achieved. For the back squat, subjects positioned the barbell behind their head on the back of their shoulders and grasp the bar on both sides and un-rack the bar. Subjects then squatted down by bending the hips back while allowing the knees to bend forward and descended until the knees and hips are flexed to a 90-degree angle. Subjects then extended the knees and hips unto the legs were straight, then racked the bar. Three warm-up sets of both the bench press and back squat were performed that consisted of 5-10 repetitions for the first warm-up set, 3-5 repetitions for the second set, and 2-3 repetitions for the third set. The weight was increased after each warm-up set by 5-10% for upper body and 10-20% for lower body. Upon completion of the warm-up sets, individuals attempted their one repetition max on both of the given exercises. If the participant successfully completed one repetition, the weight was increased until the subject was unable to complete one repetition (Baechle & Earle, 2008).

Four Week Resistance Training Program

Resistance training occurred at the Weaver Wellness Center located on the campus of Eastern Kentucky University. All training was monitored by the primary researcher. Participants in each group performed the training program for four (4) weeks. Participants lifted 3days per week on alternating days during the length of the study intervention. The training program was based upon NSCA recommendations (2009) for hypertrophy training. The exercises in both groups were identical, except the TRT group performed the training program without blood flow restriction and the BFR group performed the exercises with blood flow restriction. For the TRT group, workloads were progressed over four weeks with the first week at 65% of 1RM for 15 repetitions; week two at 75% of 1RM for 10 repetitions; week three at 80% 1RM for 8 repetitions and week four at 85% of 1Rm for 6 repetitions. The blood flow restriction (BFR) protocol included one set of 30 repetitions at 30% of their 1-RM followed by the remaining three sets at 15 repetitions. The BFR protocol also followed linear progression over the four-week training period with the first week starting at 20% of their 1-RM, the second week at 25% of 1RM, week three at 30% of 1RM and the fourth week ending at 32.5% of their 1-RM. Due to concern of having the participants performing a bar loaded back squat while under occlusion, these individuals performed the squat exercise using the percentage of total system weight. The formula for calculating system weight can be seen below.

Body weight *(80%) +1-RM= Total System Weight

This training protocol was recommended and used in a BFR study conducted by Wilson, Lowery, Joy, Loenneke and Naimo (2013). The training programs that were used in the current study are provided below (see Appendix C).

BFR Wrapping Protocol

Individuals who were assigned to the BFR training group performed the training program while under vascular occlusion. Vascular occlusion was obtained by wrapping an elastic knee wrap around the proximal part of the desired limb. Many studies have utilized an elastic knee wrap to wrap both the arms and legs to occlude the desired limb (Yamanaka,2012; Wilson, 2013; Lowery, 2014; Behringer, 2017). Individuals had the knee wrap placed on the desired body part by the primary researcher. Before wrapping, each participant was introduced to the perceived scale (RPE) of 0-10. In this scale, a 0 was considered no pressure, 7 was considered moderate pressure, and a 10 was considered to be intense pressure and pain. This scale was explained to the subject until full comprehension was achieved. The wrapping process involved 3 different wrapping procedures of the proximal part of either the arms or legs. The first wrap was wrapped at a relative pressure of 0/10 on the RPE scale, the second wrap was done at a 7/10 and the third wrap was done at a 10/10. This process allowed the individual to feel the difference between the 7/10 and the 10/10 on the RPE scale. During the training program, the individuals were wrapped at the 7/10 pressure. This relative pressure (RPE) was verified via and ultrasound of the femoral blood vessels by Wilson, Lowery, Joy, Loenneke & Naimo, 2013. This was the first study that showed the practicality of using elastic knee wraps as a valid BFR device. This wrapping procedure has been used in recent study that examined the effect of BFR on 100-meter dash sprint times (Behringer, Behlau, Montag, McCourt & Mester, 2017).

Statistical Analysis

To analyze changes from pre-to post testing, change scores were calculated. Within and between group differences from pre-to post testing for all dependent variables were determined via paired and independent t-tests respectively. The dependent variables in the current study are the subjects 1RM on bench and squat, girth circumferences of the right and left arms, right and left legs, the chest and chest and shoulder measurements. Percent change scores were calculated for the dependent measurements and group differences were analyzed via independent t-tests. An independent samples t-test was used to assess total training volume between each group. The significance level for all t-tests was set at <.004. This significance level was determined by a Bonferroni correction due to the utilization of 12 t-tests. All data analyses were conducted using the Statistical Package for Social Sciences (SPSS; Armonk, NY, USA version 23.0) An alpha level of .05 and a beta level of .80 sample size was determined to be 15 subjects per group for an 8.1kg difference between groups for the bench press. An alpha level of .05 and a beta level of .80 sample size was determined to be 32 subjects per group for an 8-kg difference between groups for the back squat.

IV. RESULTS

The participants included in the current study involved 9, recreationally training individuals who were recruited from Eastern Kentucky University. The 9 subject's characteristics were: sex, 8 males, 1 female; age: 22 ± 2 years; height: 175 ±7.6 centimeters; weight: 83.4±18.1 kg.; body fat percentage: 21±9%. Further analysis was used to determine the differences between the percent change scores between the group the exclusion of the female subject. The remaining 8 subject's characteristics were: age, 22.1 ± 1.5 years; height 176.8 ±4.1 centimeters; weight, 86.6± 15.7 kg.; and body fat percentage, 21.2±8.6%.

Strength Measures

Significant differences were found from pre-to posttests within the BFR group on the bench press (p=.003) but no significant differences were found between the groups. No significant differences were found from pre-to post tests on the squat (Table 2).

Table 2. Strength Measures

Strength Measure	Group	Pre-Test (kg)	Post Test (kg)	Percent Change	Absolute Change (kg)
Bench Press	TRT	101.2± 14.4	102.8±13.3	1.3%	1.5± 2.6
	BFR	102.8±15.8	105.2±12.4	2.3*	6.4± 1.9
Squat	TRT	130.7±32.2	145.2±21.8	11.1%	14.4± 11.6
	BFR	134.3±27.7	139.7±27.7	4.0%	5.5± 4.1

* Denotes statistical significance (p=<.004); kg= kilograms; TRT= traditional resistance training; BFR= blood flow restriction

Table 2 demonstrates that the BFR group had significantly greater increases from their pre-to post tests on the bench press, whereas the TRT group did not have significant increases. In terms of the squat, the TRT group had a greater increase than the BFR group, but this was found statistically insignificant

Girth Measurements

There were no significant differences observed within or between groups from pre-to post measurements in any of the girth measurements taken (Table 3).

Table 3. Girth Measurements

Girth Measurement	Group	Pre-Test (cm)	Post Test (cm)	Absolute Change (cm)	Percent Change
Right Arm	TRT	33.0± 3.3	32.5±3.8	-.1± .2	- 1.5%
	BFR	32.5± 4.8	31.5± 4.8	-.1± .2	-3.1%
Left Arm	TRT	32.3±3.3	31.5±3.8	-.1± .2	-2.4%
	BFR	32.4± 4.1	32.0± 3.6	-.03± .2	-1.2%
Right Leg	TRT	54.8±7.9	54.9±9.1	0± .2	0%
	BFR	52.5± 3.8	55.6± 3.6	.4± .4	5.9%
Left Leg	TRT	54.9±8.1	56.1± 7.8	.2± .1	2.3%
	BFR	51.8± 3.8	55.3± 4.5	.6± .4	6.8%
Chest	TRT	99.3± 6.9	94.7± 13.2	-.7± 1	-4.6%
	BFR	95.3± 8.4	93.2± 9.6	-.3± .3	-2.2%
Chest & Shoulder	TRT	125.2± 8.3	121.7± 10.4	-.5± .6	-2.8
	BFR	121.4± 11.2	120.9± 12.9	-.1± .4	-.4%

*Cm= centimeters; TRT= Traditional resistance training; BFR= blood flow restriction

Table 3 demonstrates neither group had significant increases from their pre-to post measurements as well as no significant differences between the groups. The BFR group had greater increases in right and left leg girth measurements compared to the TRT group, but those were found to be statistically insignificant.

Body Composition

There were no statistical differences observed within or between groups in any of the body composition measurements from pre-to post testing (Table 4).

Table 4. Body Composition Measurements

Body Measurement	Group	Pre-Test (kg)	Post Test (kg)	Absolute Change (kg)	Relative Change
Weight	TRT	90.6±22.1	90.8±21.7	.3± .4	.39%
	BFR	79.9±17.2	80.3±17.8	.6± 1.5	.72%
Body Fat %	TRT	24.3±10.6	24.9± 9.3	.6± 1.3	5.0%
	BFR	19.7± 8.1	18.5± 7.3	-1.1± 1.8	-5.0%
Fat Free Mass	TRT	67.1± 9.8	67.1±10.1	-.01± .6	-.1%
	BFR	63.7±12.5	65.1±13.1	1.5± 1.7	2.2%
Fat Mass	TRT	23.5±13.5	23.9±12.5	.3± .9	5.2%
	BFR	16.1±9	15.2±8.1	-.9± 1.7	-4.2%

*****Kg= Kilogram; TRT= Traditional Training group; BFR= blood flow restriction group

Table 4 demonstrated the BFR group had greater increases in lowering body fat percentage and fat mass compared to the TRT group, although there were no significant differences between the groups in terms of changes from their pre-to post tests as well as the absolute or relative change scores among the group. The BFR group also demonstrated greater increases in overall fat free mass when compared to the TRT group, again showing no statistical significance in terms of changes from pre-to posttests measurements as well as the absolute and relative change scores.

Total Training Volume

No significant differences were found between the training volumes between the two groups (TRT: 87675 kg; BFR: 81913 kg) (Table 5).

Table 5. Weekly Training Volume

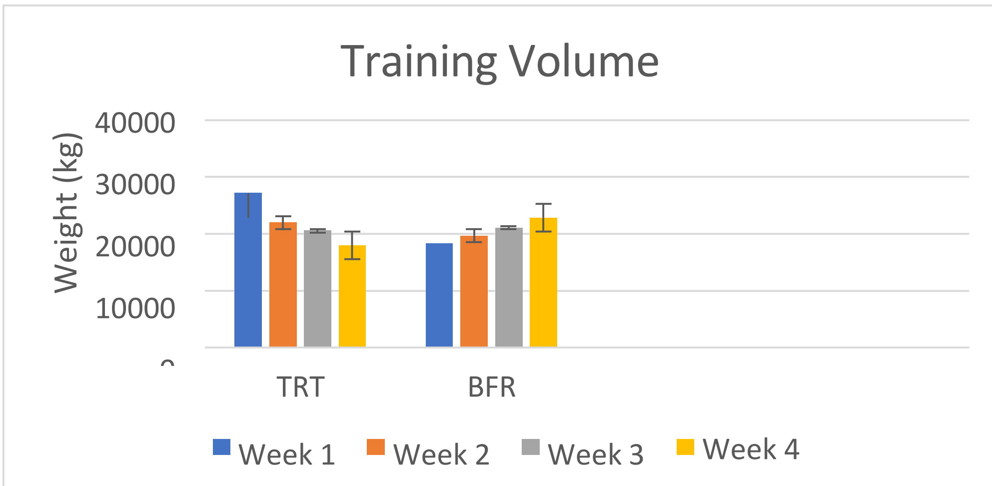

Table 5 shows the overall training volume for both groups that were completed for each week of the training program.

Absolute and Relative Percent Change Measurements

Absolute and Relative change scores were calculated for each participant on the bench press and squat, girth measurements and body composition measurements. No significant differences were found between the two groups with their absolute and relative change scores for both the bench press and back squat. No significant differences were found between the two groups with their absolute and relative change scores for any of the girth measurements taken. No significant differences were found between the two groups with their absolute and relative change scores for any of the body composition measurements taken.

V. DISCUSSION

The overall goal of the current study was to determine the effectiveness of blood flow restriction training (BFR) on increasing muscular strength and hypertrophy when compared to a traditional hypertrophy training program. The major findings of the current study demonstrated that BFR training significantly increased ($p=.003$) the one repetition maximum on the bench press when compared to the control group, whereas there were no significant changes within or between the groups for any of the girth measurements that were taken. In terms of strength gains, the average percent change for the bench press was 2.3% in the BFR training group from pre-to post testing, which was significantly greater ($p=.003$) than the 1.3% increase in the control group. This is in contrast to the researcher's hypothesis that stated there would be no significant differences between the two groups in terms of muscular strength gains. Further analysis for the current study was used to determine the differences between groups for the percent change scores for all the dependent variables with the exclusion of the female subjects. Subjects in the BFR group had a higher percent change score when compared to the TRT group (TRT= 1.6%; BFR= 6.7%) in the bench press, but were not found to be significantly different. This contrasts the results that were found for the squat, where the TRT had a higher average percent change when compared to the BFR group (TRT= 12.4%; BFR= 3.8%), but these results were shown to be statistically insignificant. Subjects who completed the BFR training protocol had higher percent change scores in both the right and left leg girth measurements when compared to those of the TRT group (RL: TRT= -.2%; BFR= 5.6%) (LL: TRT=2.5%; BFR= 7.1%), although these results were found to be non-significant. The results of the current study agree with those of Yamanaka, Farley and Caputo, 2012 where they were not able to find significant differences between the percent change scores for both the right and left legs. This agreement in results could show that BFR training may not have as much of an effect on hypertrophy of the lower body than was to be expected. Yamanaka, Farley and Caputo, 2012 utilized a larger sample size (n=32) compared to the current study (n=8), future research should look at the effect of BFR on hypertrophy of the lower body in a sample greater than 32 subjects.

Strength Improvements

The strength gains that were found in the current study were consistent with those that have been reported in the literature for increasing muscular strength with BFR training (Yamanaka, Farley, Caputo, 2012; Cook, Kilduff & Beaven, 2014; Fujita et al., 2008). Both Yamanaka, Farley and Caputo, 2012, and Cook, Kilduff & Beaven, 2014 found significant increases in maximal strength on the bench press with overall percent changes of 7% and 1.4% increases, respectively. Fujita et al., (2008) found significant increases in lower body strength ($p<.05$), specifically an increase of 6.7% in maximal leg extension strength after 12 total training sessions over a two-week training program. These findings contradict the current study's findings where no significant changes occurred in lower body maximal strength. The conflicting results between the two studies could be from the population that was used. Yamanaka, Farley and Caputo, (2008) utilized Division 1 athletes. These athletes may have had better form and past training experience which would help them increase their muscular size and strength greater than recreationally trained individuals. Yasuda et al., (2006) used BFR training with untrained individuals and demonstrated muscle activation in both the triceps brachii and pectoralis major was significantly greater than the control group, (which completed the bench press without BFR). The authors also stated that the increases in muscle activation could be due to the BFR training producing an acidic environment. This would result in lactic acid accumulation, and would cause a greater increase in fast-twitch muscle fiber activation. The increases in fast-twitch muscle activation could be a factor for increases maximal muscle strength. These finding coincide with the findings of Takarada et al., (2000b) which demonstrated that an accumulation of lactic acid in the muscle fiber would lead to a greater amount of motor unit activation to sustain a given work output. These findings could help explain the mechanisms that occur with BFR as well as the strength gains that were found in the current study.

Muscular Hypertrophy

The current study was unable to find significant changes in muscle hypertrophy in both the BFR and control groups. These findings contradict many of the studies that have examined significant muscle hypertrophy found with BFR training (Yamanaka, Farley, Caputo, 2012; Fujita et al., 2008; Yasuda et al., 2006; & Takarada et al., 2000b). One of the limitations to the current study was the inability to determine exactly how much venous occlusion was occurring. This was due to not having access to an ultrasound machine to determine the level of occlusion occurring. The lack of hypertrophy could have been caused from having both venous and arterial occlusion, not the desired venous occlusion without arterial occlusion. Another possible limitation to the current study could be the use of the same sized occlusion wrapping device for both the upper and lower body. Previous research has suggested the use of a narrow cuff (5 cm) for the upper body and a wider cuff (13.5 cm) for the lower body (Laurentino et al, 2016). This suggestion was mainly given induce a lower pressure on the arms to achieve venous occlusion, in contrast to the legs needing a higher pressure. Narrow cuffs generally produce a lower pressure compared to larger, wider cuffs.

Observed Limitations

Limitations did exist in the current study. One limitation was that many of the subjects in the TRT group were unable to complete all the repetitions assigned for each set. This limitation could have occurred due to the subjects being unfamiliar with higher repetitions used in the current study. The primary researcher recorded the amount of repetitions the subject was able to complete to calculate overall training volume. Another limitation was the lack of reliability assessing the girth measurements taken by the primary researcher. There was no inter-rater reliability taken for the current study, this limitation could have affected the measurements taken at each girth site. It was assumed the participants would not participate in training outside of the training program. With many of the participants were already being physically active, and outside training could have taken place which may have affected the overall results of the current study.

A final limitation of the current study was the amount of overall training session that occurred. The current study utilized 12 total training sessions over a four-week period, this to date is one of the lowest amounts of overall training sessions used for a BFR training program. One other study has implemented 12 total training sessions (Fajita et al., 2008). This study completed 12 total sessions over a six-day period. This is vastly different from the current study that completed the 12 sessions over a four-week period. The subjects in the Fajita study completed two sessions per day over the six days and found significant differences in strength measures in the leg extension exercise. These findings could demonstrate that when completing fewer overall training sessions with BFR, completing the total amount of sessions in a shorter period of time may have greater benefits on increasing strength than completing them over a longer period of time.

Power Analysis

An alpha level of .05 and a beta level of .80 sample size was determined to be 15 subjects per group for an 8.1 kg difference between groups for the bench press. An alpha level of .05 and a beta level of .80 sample size was determined to be 32 subjects per group for an 8-kg difference between groups for the back squat. The current study was underpowered in terms of the desired N size to achieve the desired benefits. The current study utilized 6 subjects in the experimental group and 3 subjects in the control group. Utilizing a greater sample size could have affected the overall significance difference in the dependent variables of the current study. The sample size of the current study utilized and extremely lower sample size than those in the current literature (Yamanaka, Caputo, and Farley, 2012; Caputo, 2012; Fujita et al., 2008; Yasuda et al., 2006; and Takarada et al., 2000b; Wilson, Lowery, Joy, Loennekke & Naimo, 2013) that had sample sizes ranging from 12 subjects up to 32 subjects. Utilizing a smaller sample size could have affected the overall significance of the findings, leading to no significant findings.

In summary, BFR training demonstrated greater increases in maximal bench press strength than a traditional hypertrophy training program in terms of absolute strength gains. When absolute and relative strength gains were analyzed between the groups, there showed to be no significant differences between the groups. Future research is needed to examine the effects of BFR training in other populations of trained individuals, such as collegiate athletes, as well as the overall effect of different cuff widths in those trained individuals.

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APPENDICES

Appendix A: Circumference Assessment

Circumference Assessment

ACSM's Guidelines for
Exercise Testing & Prescription (2006; 7th Ed.) *

General Procedures

For measuring circumferences

- Use an inelastic, flexible tape measure.*
- Do not pull tape so hard so that it indents the skin.*
- Take duplicate measures at each site.*
- Take a 3rd measure if the 2nd is not within 5 mm.*
- Rotate through the sites consecutively.*
- Muscles should be in a relaxed state.
- Do chest measurement during exhalation.

General Procedures (cont.)

- Assessment should be done before exercise.
- Skin should be dry (not sweaty, no lotion).
- Perform unilateral measurements on the right side of the body.
- For trunk measurements, keep the tape parallel to the floor.
- For limb measurements, keep the tape perpendicular to the long axis of the limb.

Sites

ACSM's Guidelines for
Exercise Testing & Prescription (2006; 7th Ed.) *

Site → Mid-Thigh

Description

- Place foot on bench with knee at 90 degrees.
- Measure ½ way between the proximal border of patella and inguinal crease.

Site → Mid-Thigh

Site → (Upper) Arm

Description

- Measure at a point ½ way between acromion process (of shoulder) & olecranon process (of elbow).

Site → (Upper) Arm

Site → *Chest

Description

- Measure at the nipple level, under the arms.

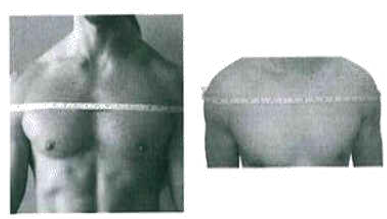
Site → *Chest

Site → *Chest & Shoulders

Description

- Measure at the nipple level, over the arms.

Site → *Chest & Shoulders



Appendix B: 1RM NSCA Guidelines

Steps for 1RM Strength Testing

(1RM = 1 Repetition Max)

Steps for 1RM Strength Testing

- "GENERAL" WARM-UP:
- Perform 5-10 minutes of some type of aerobic exercise...
- Ex: treadmill, elliptical, bike, etc.

Steps for 1RM Strength Testing

- The following guidelines [1-9] are recommended for 1RM testing of muscular strength (NSCA, Baechle & Earle, 2008).

Steps for 1RM Strength Testing

1. Warm Up Set #1.

Do a warm up set with a very sub-max load that allows 5-10 repetitions (~ 10 reps).

Steps for 1RM Strength Testing

2. Take a one (1) minute rest period. During this time, another athlete may do their warm up set.

Steps for 1RM Strength Testing

3. Warm up set #2.

Do a warm up set with a sub-max load that allows 3-5 repetitions (~ 5 reps).

Upper Body: add 10-20 lbs or 5-10%

Lower Body: add 30-40 lbs or 10-20%

Steps for 1RM Strength Testing

4. Take a two (2) minute rest period. During this time, a different athlete may take their turn.

Steps for 1RM Strength Testing

5. Warm up set #3.

Do a warm up set with a sub-max load that allows 2-3 repetitions (~ 3 reps).

Upper Body: add 10-20 lbs or 5-10%

Lower Body: add 30-40 lbs or 10-20%

Steps for 1RM Strength Testing

6. Take a two to four (2-4) minute rest period. During this time, someone else may take their turn.

Steps for 1RM Strength Testing

7. Make another load increase by adding:

Upper Body: add 10-20 lbs or 5-10%

Lower Body: add 30-40 lbs or 10-20%

8. Attempt the 1-RM.
9. If successful, go to step 7.

Steps for 1RM Strength Testing

- Upon *failure*, take a two to four (2-4) minute rest period.
- Then *decrease* the load by subtracting:

Upper Body: add 5-10 lbs or 2.5 - 5.0%

Lower Body: add 15-20 lbs or 5-10%

- Return to step #8 (attempt 1-RM).

Steps for 1RM Strength Testing

- Continue increasing or decreasing until the athlete can complete one repetition with proper technique.
- Ideally, the 1-RM will be measured within 3-5 testing sets.

Appendix C: Training Program

Week 1

BFRT Group

Day 1- Monday

Participants will be progressed by the following program which follows the basic principle of linear progression (Baechle & Earle, 2008)

- Week 1- 20%
- Week 2- 25%
- Week 3- 30%
- Week 4- 32.5%

Exercise	% of 1RM	Set 1	Set 2	Set 3	Set 4	Rest
Squat	20%	30 reps	15 reps	15 reps	15 reps	45 seconds
Machine Leg Curl	20%	30 reps	15 reps	15 reps	15 reps	45 seconds
Machine Leg Extension	20%	30 reps	15 reps	15 reps	15 reps	45 seconds

Week 1

BFRT Group

Day 2- Wednesday

Exercise	**% of 1 RM**	**Set 1**	**Set 2**	**Set 3**	**Set 4**	**Rest**
Bench Press	20%	30 reps	15 reps	15 reps	15 reps	45 seconds
Squat	20%	30 reps	15 reps	15 reps	15 reps	45 seconds

Participants will be progressed by the following program which follows the basic principle of linear progression (Baechle & Earle, 2008)

- Week 1- 20%
- Week 2- 25%
- Week 3- 30%
- Week 4- 32.5%

Week 1

BFRT Group

Day 3-

Friday

Exercise	% of 1 RM	Set 1	Set 2	Set 3	Set 4	Rest
Bench Press	20%	30 reps	15 reps	15 reps	15 reps	45 seconds
Barbell Bicep Curl	20%	30 reps	15 reps	15 reps	15 reps	45 seconds
Cable Tricep Extension	20%	30 reps	15 reps	15 reps	15 reps	45 seconds

Participants will be progressed by the following program which follows the basic principle of linear progression (Baechle & Earle, 2008)

- Week 1- 20%
- Week 2- 25%
- Week 3- 30%
- Week 4- 32.5%

Week 1

TRT Group

Day 1- Monday

Exercise	% of 1 RM	Set 1	Set 2	Set 3	Set 4	Rest
Squat	65%	15 reps	15 reps	15 reps	15 reps	90 seconds
Machine Leg Curl	65%	15 reps	15 reps	15 reps	15 reps	90 seconds
Machine Leg Extension	65%	15 reps	15 reps	15 reps	15 reps	90 seconds

Participants will be progressed by the following program which follows the basic principle of linear progression (Baechle & Earle, 2008)

- Week 1- 65% for 15 repetitions
- Week 2- 75% for 10 repetitions
- Week 3- 80% for 8 repetitions
- Week 4- 85% for 6 repetitions

Week 1

TRT Group

Day 2- Wednesday

Exercise	% of 1 RM	Set 1	Set 2	Set 3	Set 4	Rest
Bench Press	65%	15 reps	15 reps	15 reps	15 reps	90 seconds
Squat	65%	15 reps	15 reps	15 reps	15 reps	90 seconds

Participants will be progressed by the following program which follows the basic principle of linear progression (Baechle & Earle, 2008)

- Week 1- 65% for 15 repetitions
- Week 2- 75% for 10 repetitions
- Week 3- 80% for 8 repetitions
- Week 4- 85% for 6 repetitions

Week 1

TRT Group

Day 3- Friday

Exercise	% of 1 RM	Set 1	Set 2	Set 3	Set 4	Rest
Bench Press	65%	15 reps	15 reps	15 reps	15 reps	90 seconds
Barbell Bicep Curl	65%	15 reps	15 reps	15 reps	15 reps	90 seconds
Cable Tricep Extension	65%	15 reps	15 reps	15 reps	15 reps	90 seconds

Participants will be progressed by the following program which follows the basic principle of linear progression (Baechle & Earle, 2008)

- Week 1- 65% for 15 repetitions
- Week 2- 75% for 10 repetitions
- Week 3- 80% for 8 repetitions
- Week 4- 85% for 6 repetitions

Reference

Baechle, T. R., & Earle, R. W. (2008). *Essentials of strength training and conditioning*. Champaign (IL): Human Kinetics.

Appendix D: Informed Consent

Consent to Participate in a Research Study

Effect of Practical Blood Flow Restriction Training on Body Composition and Muscular Strength in College-Aged Individuals

Why am I being asked to participate in this research?

You are being invited to take part in a research study on the Effect of Practical Blood Flow Restriction Training on Body Composition and Muscular Strength in College-Aged Individuals. If you take part in this study, you will be one of about 30 people to do so. You cannot take part in this study if you are injured, or have any injury that could limit your full participation in the study. Any females who are currently pregnant will not be allowed to participate in the study.

Who is doing the study?

The person in charge of this study is Zach Salyers, a graduate student in the Exercise and Sports Science department at Eastern Kentucky University. There may be other people on the research team that will assist with implementing the training program.

What is the purpose of the study?

The purpose of this study is to determine the effect of practical blood flow restriction training on body composition and muscular strength in college-aged individuals when compared to a traditional resistance training protocol for hypertrophy.

Where is the study going to take place and how long will it last?

The research procedure will be conducted in the Exercise Physiology Laboratory and Weaver Wellness Center on the campus of Eastern Kentucky University. You will need to come in for total of 14 session for this study. Testing visits will take approximately 60 minutes. Each training session will take roughly 25-60 minutes depending on which group you are randomly assigned to.

What will I be asked to do?

You are asked to come into the weight room, or laboratory, dressed appropriately for physical activity. Your necessary information will be recorded (first and last name, and age). The first session will be for baseline testing to get your one rep maximum on both the back squat and the bench press, as well as 6 girth circumference measurements. Also during this time, you will be screened for general health and drug/supplement consumption (done by a health history questionnaire). If you have any major health conditions, or any injury that could affect your full participation in the study, you will be excluded from the remainder of the study.

Your first meeting session will begin once all participants are recruited. The first training session will consist of a general warm-up consisting of aerobic exercises, this will allow for the body to deliver oxygen more effectively and prepare your body for the workout. You will be randomly assigned into either the control group or the experimental group. Individuals who are assigned to the experimental group will complete the required lifts that are assigned while having either the arms or legs wrapped with an elastic knee wrap. If you are assigned to the control group, you will perform the same exercises as the experimental group, but without having the arm or leg wrapped during the completion of each lift. Following the warm-up, you will then complete the workout for which group you are assigned to.

Wrapping Protocol- Individuals who are assigned to this group will complete the exercises of the training program while under occlusion. Occlusion will be administered using an elastic knee wrap that will be wrapped on the proximal end of the desired body part. The researcher will wrap the band around the limb until the wrap feels “snug”, there should not be any pain associated with the wrapping procedure. If you experience any pain during the study or training program, please let the primary researcher know, and I will rewrap the band to ensure that there is no pain during the training program.

The same testing procedures that will be conducted during the pre- testing will be completed again once the individual has completed the 4 week training program.

Each training session will take about 25-60 minutes, depending on which group that you have been assigned to. Once the training session is done, you will schedule a time to come in for the remaining sessions at a time that works best with your schedule. You will be asked to refrain from strenuous physical activity for the next 24 hours after the completion of the training.

For the entirety of the study, you will be required to attend at least 90% of the required meeting sessions. So, for a total of 14 meeting sessions, you will be required to attend at least 12. Once you have missed more than 2 days, you will be removed from the study.

Are there reasons why I should not take part in this study?

Like all maximal exercise performance tests, there could be risks of physical injury. Because the testing involves exercises for the upper and lower portions of the body, it is possible that muscle injuries such as sprains or strains could occur during performance of the exercises. However, each testing session will be monitored and supervised by a member of the research team with knowledge of muscle injuries and how to manage them should they occur. The researchers will be present to make sure that any risk to you is minimal, and if necessary will stop the testing. All researchers in this study are either certified Strength and Conditioning Coaches.

What are the possible risks and discomforts?

To the best of our knowledge, the physical activity you will be performing has no more risk of harm than you would experience in your everyday sport training and/or conditioning. You may experience the sensation of fatigue or muscle soreness once the test is complete. Although we will have made every effort to minimize this, you may find some questions we ask you (or some procedures we ask you to do) to be upsetting or stressful. If so, we can tell you about some people who may be able to help you with these feelings.

Will I benefit from taking part in this study?
We cannot and do not guarantee that you will receive any benefits from this study.

Do I have to take part in this study?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you chose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering.

If I don't take part in this study, are there other choices?

If you do not want to be in the study, there are no other choices except to not take part in the study.

What will it cost me to participate?

There are no costs associated with taking part in this study.

Will I receive any payment or rewards for taking part in the study?

Upon full completion of the study, you will be given a free DXA scan from Dr. Michael Lane.

Who will see the information I give?

Your information will be combined with information from other people taking part in the study. When we write up the study to share it with other researchers, we will write about this combined information. You will not be identified in these written materials.

We will make every effort to prevent anyone who is not on the research team from knowing that you gave us information, or what that information is. For example, your name will be kept separate from the information you give, and these two things will be stored in different places under lock and key.

However, there are some circumstances in which we may have to show your information to other people. For example, the law may require us to show your information to a court. Also, we may be required to show information that identifies you to people who need to be sure we have done the research correctly; these would be people from such organizations as Eastern Kentucky University.

Can my taking part in the study end early?

If you decide to take part in the study, you still have the right to decide at any time that you no longer want to participate. You will not be treated differently if you decide to stop taking part in the study.

The individuals conducting the study may need to end your participation in the study. They may do this if you are not able to follow the directions they give you, if they find that your being in the study is more risk than benefit to you.

What happens if I get hurt or sick during the study?

If you believe you are hurt or if you get sick because of something that is done during the study, you should call Zach Salyers at 859-496-6700 immediately. It is important for you to understand that Eastern Kentucky University will not pay for the cost of any care or treatment that might be necessary because you get hurt or sick while taking part in this study. That cost will be your responsibility. Also, Eastern Kentucky University will not pay for any wages you may lose if you are harmed by this study.

Usually, medical costs that result from research-related harm cannot be included as regular medical costs. You should ask your insurer if you have any questions about your insurer's willingness to pay under these circumstances.

What if I have questions?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions about the study, you can contact the investigator, Zach Salyers at 859-406-6700. If you have any questions about your rights as a research volunteer, contact the staff in the Division of Sponsored Programs at Eastern Kentucky University at 859-622-3636. We will give you a copy of this consent form to take with you.

What else do I need to know?

You will be told if any new information is learned which may affect your condition or influence your willingness to continue taking part in this study.

I have thoroughly read this document, understand its contents, have been given an opportunity to have my questions answered, and agree to participate in this research project.

______________________________________ ______________________________

Signature of person agreeing to take part in the study | Date

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Printed name of person taking part in the study

____

Name of person providing information to subject