INCREASING LEAN MASS AND STRENGTH: A COMPARISON OF HIGH FREQUENCY STRENGTH TRAINING TO LOW FREQUENCY STRENGTH TRAINING

by

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An Abstract
of a thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science
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ABSTRACT

by

Michael H. Thomas

Purpose: Determine the effect strength training frequency of equal volume has on improvements in lean mass and strength. **Methods:** Participants were 7 women and 12 men, age ($\bar{x}$ = 34.64 years ± 6.91 years), training age ($\bar{x}$ = 51.16 months ± 39.02 months). Participants were placed into one of two groups. High frequency training group (HFT) trained each muscle group 3 times per week. Low frequency training group (LFT) trained each muscle group one time per week. **Results:** HFT increased lean mass 1.06 kg ± 1.78 kg, (1.9%), LFT increased lean mass .99 kg ± 1.31 kg, (2.0%). HFT strength improvements on chest press 9.07 kg ± 6.33 kg, (11%) and hack squat 20.16 kg ± 11.59 kg, (21%). LFT strength improvements on chest press 5.80kg ± 4.26 kg, (7.0%) and hack squat 21.83 kg ± 11.17 kg, (24 %). No mean differences between groups were significant. **Conclusion:** HFT and LFT result in similar improvements in lean mass and strength, following 8 weeks of strength training.

Key Words: *strength training frequency, exercise prescription, lean mass, hypertrophy.*

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CHAPTER 1
INTRODUCTION

Strength training exercise offers many benefits for individuals of all ages and is perhaps critically important for the elderly (Phillips & Winett, 2010). The benefits associated with strength training are: 1) increase in lean body mass; 2) increase in metabolic rate; 3) increase in bone density ; 4) decrease risk of injury; and 5) perhaps the most striking benefit of strength training is its ability to build back lost muscle tissue (Phillips & Winett, 2010). As individuals age they tend to lose skeletal muscle, which results in less strength to perform basic necessary activities such as squatting to stand or sit, grooming oneself, or preparing a meal. Loss of skeletal muscle may lead to an individual losing independence and represents a major concern for the aging. Progressive strength training may build back some if not all of this lost muscle tissue (Phillips, 2007). Loss of skeletal muscle is also the largest contributor to a reduction of resting metabolic rate (Phillips & Winett, 2010).

Strength training is also important to athletes in many sports that require speed, power, and strength (Fry, 2004). Additionally, strength training may benefit athletes involved in distance running, cycling, or weight class events such as wrestling and boxing to aid in preserving lean body mass (Fry, 2004). According to Wernbom, Augustsson, and Thomee´ (2007) the major challenge of strength training research is to isolate variables responsible for increasing lean body mass and strength. Wernbom et al. (2007) conclude that there is limited research available to determine optimal training parameters for increasing lean body mass and strength.

Purpose of Study

The purpose of this study was to determine if equal volume high frequency muscle group training produces greater increases in lean mass and strength compared to low frequency muscle group training, in healthy adults. The results of this study may lead to improved training methods for many populations.

Hypothesis

It was hypothesized that:

1. Equal volume high frequency muscle group strength training results in greater increases in lean mass than low frequency training; and
2. Equal volume high frequency muscle group strength training results in greater strength gains than low frequency training.

Significance of the Study

Strength training, experts do not agree about which training variables produce the greatest results (Carpinelli, Otto, & Winnett, 2004). Frequency of training is possibly the most debated topic amongst coaches and fitness professionals (Carpinelli et al., 2004). Some research appears to demonstrate that a lower frequency of training may be as effective as higher frequency training (DiBrezzo, Fort, & Hoyt, 2002; Difrancisco-Donoghue, Werner, & Douris, 2007; Graves, Pollock, Leggett, Braith, Carpenter, et al., 1988; Izquierdo, Ibanez, Hakkinen, Kraemer, Larrion, et al., 2004; Kamandulis, Skurvydas, Brazaitis, Imbrasienė, Masiulis, et al., 2010). Although other research indicates that two or three training sessions per muscle per week may produce up to twice the increase in cross sectional area of the quadriceps and elbow flexors, using magnetic resonance imaging, compared to one training session per week per muscle group (Vikne, Refsnes, & Medbø, 1995; Wirth, Atzor, & Schmidtbleicher, 2002). However, weekly training volume (sets multiplied by number of repetitions completed) was not equal between groups in these investigations (Vikne, Refsnes, & Medbø, 1995; Wirth, Atzor, & Schmidtbleicher, 2002). According to Vikne et al. (1995) and Wirth et al. (2002) without equal volume training among groups, determining the variable responsible for increases in lean mass and strength is difficult. Tesch, Trieschmann, and Ekberg (2004) observed elite strength athletes and bodybuilders training each muscle group just once per week, incorporating many sets per muscle group and concluded that it is unknown if the training programs elite athletes and bodybuilders employ are superior for increasing lean body mass and strength.

On a broader scale, the obesity epidemic is creating a huge demand for detailed relevant research on adaptations to all types of exercise (Stiegler, & Cunliffe, 2006). Research must continue to isolate factors related to obesity and solutions to this trend. Health care concerns such as osteoporosis, Diabetes, Alzheimer's, heart disease, and many others require detailed study. Strength training is one form of exercise that may aid in the battle against these health concerns by increasing metabolic rate (Phillips, 2007).

Delimitations

The study was delimited to:

1. Adults with normal resting blood pressure, non-diabetic, and orthopedically sound in all major joints;
2. Nineteen adults separated into two groups of nine and 10. One group performed higher frequency training (HFT) while the other group performed lower frequency training (LFT);

3. Eight weeks of training;
4. Pre and post training data collection on weeks zero and week nine for strength and fat free mass;
5. Use of the DEXA to determine body fat and lean body mass;
6. Strength testing consisting of lower body and upper body using the hack squat and flat chest press exercise performing a one repetition max after three-four warm up sets per exercise;
7. Attendance at 22 of the 24 possible workouts; and
8. Participants were required to record repetitions completed and resistance used during all strength training sessions.

Limitations

The study was limited by:

1. A small sample size;
2. Commitment and participant motivation;
3. Precision of DEXA for body composition measurement; and
4. Experience level of participants affecting adaptation to strength training.

Assumptions

It was assumed that:

1. The DEXA is a reliable and valid measure of lean mass changes; and
2. The hack squat and flat chest press are reliable and valid means to measure strength changes in the upper and lower body.

Definition of Terms

Anabolism - Building of complex substances from simple ones; the opposite of catabolism (Zatsiorsky & Kraemer, 2006).

Body composition - A term used to describe the different components that make up a person's body mass (fat mass, lean body mass).

Catabolism - Tearing down of complex substances into simple substances; the opposite of anabolism (Zatsiorsky & Kraemer, 2006).

Frequency- How often a particular muscle group is trained or how often training exists during a set period.

Metabolic Rate - Speed at which the body uses energy (Zatsiorsky & Kraemer, 2006).

Muscle Atrophy - Wasting or loss of muscle tissue because of disuse or disease (Bompa & Haff, 2009).

Muscle Hypertrophy - A term for growth and an increase in size of muscle cells (Zatsiorsky & Kraemer, 2006).

Overload - Training load (intensity, volume) exceeding prior loads (Zatsiorsky & Kraemer, 2006).

One RM – One repetition maximum.

Power – A unit of work expressed per unit of time (power= work/time) (Bompa & Haff, 2009).

Progressive Overload - A progressive increase in the training load (intensity, volume) beyond a normal magnitude (Bompa & Haff, 2009).

Recovery/Supercompensation - Time in which there is an enhanced status of the body systems (skeletal muscle) (Zatsiorsky & Kraemer, 2006).

Repetition - Number of times a movement is performed in a set (Zatsiorsky & Kraemer, 2006).

Set - A group of repetitions performed consecutively without rest.

Specificity - Simlarity between adaptation induced by mode of training and that required by main sport movement (Bompa & Haff, 2009).

Split Training - Training different body parts on different days (Zatsiorsky & Kraemer, 2006).

Strength - Ability to overcome an external resistance by muscular force (Zatsiorsky & Kraemer, 2006).

Total Body Training - A training session that involves training all muscle groups.

Training Volume – Repetitions completed multiplied by resistance used (Bompa & Haff, 2009).

Weight - Resistance applied to the body due to gravity (Zatsiorsky & Kraemer, 2006).

Work - Force multiplied by distance (Zatsiorsky & Kraemer, 2006).

CHAPTER 2
REVIEW OF LITERATURE

The purpose of this review is to examine published literature related to adaptations of strength training, recovery from strength training, and frequency protocols. The review is broken down into nine sections: 1) muscle fiber types and adaptations; 2) recovery from high intensity and eccentric training; 3) supplementation and enhancement of recovery; 4) intensity for strength and hypertrophy; 5) training volume and adaptations; 6) overtraining syndrome; 7) opposing views; and 9) summary.

Muscle Fiber Types and Adaptations

The timeline for myofiber remodeling may take seven-10 days (Grobler, Collins & Lambert, 2004). Adams (2006) describes the process of skeletal muscle hypertrophy and satellite cell proliferation. Satellite cells are described as small mononuclear cells positioned closely to myofibers (muscle cells). These satellite cells may function as reserve myoblasts. Within 24 hours following strenuous exercise immune cells and revascularization of the muscle fiber occurs (Grobler, et al., 2004). During this time, satellite cells migrate to the damaged myofibril. At 24-48 hours post trauma, activated satellite cells begin to express myogenesis and by 48 hours, myoblasts fuse to form myotubes. At three-seven days post exercise or muscle fiber trauma fusion of myoblasts and myotubes occurs. At seven-10 days post trauma myotubes fuse to form myofibrils that mature into recovered myofibers (Grobler et al., 2004). Additionally, some satellite cells fuse to undamaged muscle cells as part of the response to exercise and ultimately hypertrophy occurs (Adams, 2006). According to Adams (2006) the limited ability of myofibers to hypertrophy may be due to a limited supply of reserve myonuclei, which limits translational capacity. Hyperplasia may also have an impact on the hypertrophy process (Folland & Williams, 2007).

Characteristics of muscle fibers and their adaptations may reveal strength programming recommendations. Skeletal muscle consists of Type I and Type II fibers (Fry, 2004). Type II fibers are fast twitch muscle fibers and possess the largest potential for hypertrophy, and strength. Further Type II fibers can be broken down into Type II A and Type II B. Type II B muscle fibers are capable of extremely powerful contractions and an individual who possesses a large percentage of these fibers will be capable of large increases in strength, hypertrophy, power, and speed (Fry, 2004). Chronic strength training exercising with a high percentage of one repetition maximum (RM) appears to transform some Type II B fibers into hybrid fibers labeled Type II AB and eventually into Type II A(Fry, 2004). The cause of this transformation is unknown and needs further study. Type I fibers, otherwise known as slow twitch fibers, appear to be capable of hypertrophic changes but probably to a lesser degree (Fry, 2004; Zatsiorsky & Kraemer, 2006). Optimal training loads for improving lean mass are very similar to loads with strength as the goal, (80-95% of one RM) (Fry, 2004). Elite bodybuilders have demonstrated significant hypertrophy of Type I fibers not seen in advanced powerlifters, or Olympic weight lifters, who primarily focus their training on strength and power (Fry, 2004). The increase in Type I fiber size of bodybuilders may be due to chronic training stimuli present in bodybuilders routines, which appears to differ from powerlifters and Olympic lifters (Bompa & Haff, 2009; Fry, 2004). Powerlifters and Olympic lifters primarily train with loads >90% of one RM compared to bodybuilders training with loads

< 75% of one RM with resultant higher volumes that may result in the hypertrophy of type I fibers (Bompa & Haff, 2009).

Adaptations to strength training in young versus older adults present differences. Kosek, Kim, Petrella, Cross, and Bamman (2006) compared the adaptations from strength training three days per week in young (20-35 years) versus older (60-75 years) adults for six months. The authors concluded that young participants may demonstrate greater increases in lean mass compared to older participant's, especially young men. Young participants increased Type I cross sectional area (CSA) by 18% and were the only group that showed an increase in Type I myofibers. Type II A fibers increased in CSA by 16% in older participants versus 25% in younger participants and mean increase in Type II CSA was 23% for older participants and 32% for younger (Kosek et al., 2006).

Hypertrophy (increase in lean mass) in response to strength training appears to occur during the early weeks of training. Seynnes, de Boer, and Narici (2007) examined the response of quadriceps muscle during a 35-day training period using an MRI. Seven young healthy participants performed bilateral leg extensions three days per week. Following the 35-day training period, central quadriceps CSA had increased 6.5 ± 1.1 % and distally 7.4 ± 0.8%. The authors concluded that increases in lean mass may contribute to early strength gains and improvements in lean mass appears to occur during initial weeks of quadriceps training.

Recovery from High Intensity and Eccentric Training

High intensity exercise decreases strength during the initial recovery period. Nottle and Nosaka (2007) found that following 40 minutes of downhill running of -7.0% on a treadmill resulted in decreases in strength of ~15%, measured on an isokinetic leg extension and leg curl, at 0.5 – 24 hours post training. A decrease in peak power ~5% on the Wingate Anaerobic test was apparent at 0.5 hours and by 24 hours post training peak power returned to pre testing levels (Nottle & Nosaka, 2007). Increases in muscular soreness were present from 0.5 to 72 hours post training along with an increase in plasma creatine kinase from 0.5-120 hours post training. Nottle and Nosaka conclude that eccentric training has less of an effect on power than strength during recovery.

The timeline for recovery from high intensity exercise differs among individuals. Nosaka, Chapman, Newton, and Sacco (2006) had 89 participants perform 24 eccentric contractions of the elbow flexors. Changes in maximum isometric strength ranged from 17.6-72.8% loss of strength during the post exercise phase. The authors concluded that no single point in the recovery period is optimal at assessing the magnitude of muscle injury and strength loss does not correlate with common markers of muscle damage. It was suggested that decreases in strength during initial phases of recovery may differ in cause from decreases seen many days following intense exercise.

High intensity exercise may take many days for recovery. However, complete recovery may not be necessary for long-term improvements in strength. Chen and Nosaka (2006) had 51-trained athletes perform 30 eccentric contractions of the elbow flexors with 100% of their maximal isometric strength. Three days following the initial eccentric exercise they separated the 51 athletes into three groups, a control group (n=12) that exercised during the second session with 100% of original load, a second group who exercised with 90% of the original load (n=12), and a third group exercised with 80% of original load (n=14). Changes in maximal isometric force were examined along with range of motion, perceived muscle soreness, upper arm circumference, muscle proteins in blood and ultrasound images to assess muscle damage. Measurements were taken for nine days following the first exercise session. All measurements exhibited significant changes from baseline. However, no significant differences were evident between the groups. Maximal isometric force was reduced ~12% in all groups at nine days post exercise. The authors concluded that a second bout of eccentric exercise performed in the early stages of recovery did not damage muscle fibers more or inhibit recovery regardless the intensity of the second bout.

Extreme high intensity exercise may result in a decrease of strength. Fry, Schilling, Weiss, and Chiu (2006) had 16 weight trained college students divided into two groups. The control group performed two days of strength training per week for two weeks using a maintenance protocol on a Tru Squat machine (Southern Xercise, Cleveland, TN) while the overtraining group performed high intensity training with 10 sets of one repetition at 100% of their 1 RM on the Tru Squat (Southern Xercise, Cleveland, TN) every day for two weeks. The overtraining group demonstrated a significant decrease in power (36% decrease) and strength (pre =159.3 ± 10.1 kg, post = 151.4 ± 9.9 kg) and could not resume normal training for up to eight weeks (Fry et al., 2006).

High intensity and low intensity strength training appear to present similar adaptations. Paschalis, Koutedakis, Jamurtas, Mougious, and Baltzopoulos (2005) examined the effects of two eccentric quadriceps sessions, in untrained young men. During the first exercise, session participants performed a high intensity (HI) quadriceps session of 12 sets of 10 maximal repetitions. Two weeks following the first session participants performed a low intensity (LI) exercise session at 50% of peak torque until the work completed was equal to that of the HI session. No significant differences were found between the two exercise protocols except for significant elevation of creatine kinase (CK) at 24 hours post exercise for HI. Muscle performance was significantly impaired following HI compared to LI with isometric peak torque impaired at 24 hours (86.4% versus 102.8%) and at 96 hours (86.8% versus 114.4 %). The authors concluded that HI and LI eccentric exercise have similar effects on muscle damage when volumes of exercise are equal, but HI may have a greater impact on recovery of isometric peak torque.

Post exercise muscle soreness and strength deficits may be resolved early in the recovery process. Pettitt, Udermann, Reineke, Wright, Battista, et al. (2010) examined intensity of eccentric exercise and its effect on recovery rate of lumbar extensor musculature. They had 12 participants in three groups perform two sets of 25 eccentric repetitions at 50%, 70%, or 90% of their one RM. Delayed muscle soreness was resolved at 96 hours regardless of the group, all three groups' strength decreases were greatest at 24, 48 hours post exercise, and strength was completely restored at 72 hours.

Timeline for recovery between men and women is similar. Rinard, Clarkson, Smith, and Grossman (2000) had 83 women and 82 men perform eccentric elbow flexion exercise for 70 maximal repetitions. Each repetition took three seconds to complete with a five-minute break midway through the exercise session. Immediately after exercise, strength loss was 69% for women and 63% for men and at 168 hours, post exercise women demonstrated a loss of 27% and men 24%. Soreness between both sexes peaked at 32-48 hours post exercise. Women did experience a greater loss of range of motion at 72 hours post exercise, which was still present at 168 hours post exercise and the authors concluded that both sexes demonstrated similar muscle damage to strenuous eccentric exercise of the elbow flexors.

Weiss, Wood, Fry, Kreider, Relyea, et al. (2004) examined the effect of abstaining from resistance training on strength and power. Twenty five young, experienced in strength training men performed the bench press at various recovery intervals, two, three, four, or five days. Results indicated that following two and four days of complete, rest bench press performance was modestly enhanced. Weiss et al. (2004) concluded that prescribing pre competition tapering from resistance training is uncertain and that four days of training abstinence may result in improvements in strength and power.

Muscle damage following high volume exercise in older and younger men appears to be similar. Roth, Martel, Ivey, Lemmer, Tracy et al. (1999) had seven younger men (20-30 years old) and eight older men (65-75 years old) complete nine weeks of heavy resistance unilateral leg extension exercise. The protocol involved five sets of 5-20 repetitions, three days per week with the emphasis on reaching near maximal effort on each set. Biopsies were taken of the vastus lateralis of both the exercised and non-exercised leg before and after training. Following heavy resistance exercise 6 to 7% of muscle fibers exhibited damage in both younger and older men with no significant difference between groups. Strength increased 27% in both groups. The authors concluded that both groups of men appear to exhibit similar levels of muscle damage following strenuous strength exercise.

Supplementation and Enhancement of Recovery

Creatine supplementation may not improve recovery. Twenty-two healthy, experienced in strength training, young men (19-27 years) ingested creatine or a placebo for 10 days (Rawson, Conti, & Miles, 2007). On day six, subjects performed a squat exercise protocol consisting of five sets of 15-20 repetitions at 50% of one RM. Post exercise, significant decreases in maximum strength and range of motion were observed in both groups with no difference between groups. Following exercise and up to 72 hours post exercise significant increases in muscle soreness with movement and palpation was observed. Rawson et al. (2007) conclude that creatine supplementation does not reduce skeletal muscle damage or improve rate of recovery.

Muscle cell damage following intense exercise delays glycogen replenishment. Zehnder, Muelli, Buchli, Kuehne, and Boutellier (2004) had 20 athletes reduce glycogen stores by performing several episodes of sprinting (reduce fast twitch muscle fiber glycogen content) followed by one hour of treadmill jogging (reduce slow twitch muscle fiber glycogen content). Following treadmill, exercise participants were separated into two groups, a DOMS group, and a CONTROL group. The CONTROL group rested while the DOMS group performed high intensity eccentric exercise of the gastrocnemius consisting of 10 sets of 20 second eccentric toe raises with 40 seconds of rest between repetitions (Zehnder, et al., 2004). Following exercise all subjects consumed a carbohydrate rich diet of >10 g/kg of body mass/24 hours. Within 24 hours, the CONTROL group reached resting glycogen levels while the DOMS group was depleted of glycogen by 35% compared to pre exercise levels. Indicators of muscle injury: inorganic phosphate and phosphocreatine increased post exercise in the DOMS group but not in CONTROL and the authors conclude that following intense eccentric exercise glycogen replenishment is delayed probably due to muscle cell damage.

Whey protein consumed during early recovery appears to have no effect on muscle recovery. Betts, Toone, Stokes, and Thompson (2009) had 17 highly trained athletes participate in two 90-minute sessions of high intensity shuttle running. Participants either consumed a 9% sucrose solution (1.2g/kg/hour) during and for four hours after or consumed the same solution with additional whey protein isolate (0.4 g/kg/hour) for the same period (Betts et al., 2009). Muscle function after exercise immediately declined below baseline levels for both nutritional intake groups and continued for 48 to 168 hours post exercise. Both groups demonstrated elevations of myoglobin, serum creatine kinase and lactate dehydrogenase over the first 24 hours. Both groups experienced the same level of muscle soreness, which peaked at 24 hours post exercise and gradually diminished returning to baseline at 120 hours of recovery. The authors concluded that whey protein isolate ingested with carbohydrates during and following intense exercise did not lessen the effects of muscle damage or systemic indices of muscle damage.

Intensity for Strength and Increasing Lean Mass

Greatest increases in strength appear to be at intensities of 80-95% of an individual's one RM (Kraemer, Fleck, & Evans, 1996; Staron, Leonardi, & Karapondo, 1991). Resistances at these intensities can be translated into a load in which an individual could perform <10 repetitions to a point of failure for a particular set (Bompa & Haff, 2009). However when analyzing long term training programs strength improvements can be seen with training loads at lower percentages of a 1 RM (Fry, 2004).

Heavy load resistance training may produce superior improvements in lean mass and strength compared to lower load resistance training (Hoim, Reitelseder, Pedersen, Doessing, Petersen, et al., 2008). Hoim et al. (2008) had 11 sedentary men performing resistance exercise at 70% of one RM (HL) for one leg while the other leg exercised at 15.5% of one RM (LL) three times per week for 12 weeks. Total training volume per leg was equal (repetitions completed x resistance). Quadriceps cross sectional area increased 8 ± 1% in HL and 3 ± 1% in LL legs. Strength was increased in both legs with HL improving 36 ± 5% and LL 19 ± 2% and Hoim et al. (2008) concluded that HL resistance training is superior for improvements in lean mass and strength compared to LL training.

Training Volume and Adaptations

Moderate training volume appears to improve strength at a higher rate than low and high volume (González-Badillo, Izquierdo, & Gorostiaga, 2006). González-Badillo et al. (2006) had 29 experienced junior level weight lifters and assigned them to one of three groups. The low intensity group performed 46 repetitions daily, the moderate intensity group performed 93 repetitions, and the high intensity group performed 184 repetitions. Significant increases in the clean and jerk of 10.5% for the moderate volume group and 3% for low volume training group. Squat improvements were 9.5% for moderate volume and 5.3% for low volume. The high volume group only improved in the squat at 6.9%. González-Badillo et al. (2006) concluded that moderate volumes of strength training with relative high intensities demonstrate greater improvements in weight lifting performance in experienced, young participants compared to high or low volumes of equal intensity.

Training to failure may produce greater improvements in strength than training without reaching muscular failure. Drinkwater, Lawton, Lindsell, Pyne, Hunt et al. (2005) assigned 26 elite junior male basketball players to one of two groups. Both groups performed the bench press exercise three times per week with either four sets of six repetitions leading to muscular failure or eight sets of three repetitions in which all repetitions were completed without muscular failure. They concluded that greater improvements in strength and power were present in the repetition failure group (strength 9.5% vs 5.0 %, power 10.6% vs. 6.8%).

Periodization models may not be superior in improving strength during early weeks of training. Buford, Rossi, Smith, and Warren (2007) compared three types of periodization: daily undulating (load and repetitions changing daily), weekly undulating (load and repetitions changing weekly), and linear training. Twenty eight college aged, experienced in strength training volunteers of both genders strength trained three days per week. Training loads were assigned as heavy (90% of one RM), medium (85% of one RM), or light (80% of one RM). Measurements were taken of one RM on the bench press and leg press, body fat percentage, chest circumference, and thigh circumference. No significant differences were observed between groups for any criterion measured and concluded that all three periodization models may produce similar results during the first nine weeks of training.

Single set protocols may not be optimal for increasing lean mass and strength (Bompa & Haff, 2009; Kraemer & Zatsiorsky 2006). Peterson, Rhea, and Alvar (2005) examined the dose response relationship foundational to strength research and concluded that multiple sets are necessary for long term progression in strength and increases in lean mass. The ideal frequency for recreational trainees is two days per week with four sets per muscle group using a resistance of ~ 80% of their one RM. Advanced trainees receive greatest benefit from two days per week of training each muscle group with eight training sets per muscle group. The investigators indicated untrained subjects achieved best improvements by training three days per week with a relatively lightweight (60% of 1RM) performing four sets per muscle group per session. According to Bompa and Haff (2009) a minimum of three sets are needed to maximize strength gains for both trained and untrained individuals engaging in strength exercise. Rønnestad, Egeland, Kvamme, Refsnes, Kadi et al. (2007) concluded that an increase in training volume does result in an increase in (CSA) of the quadriceps. Rønnestad et al. (2007) report a training group that performed six total sets improved quadriceps CSA by 11.3 % versus the two set group that improved by 7.6%.

Multiple set protocols appear to produce greater improvements in athletic performance for collegiate women. Kraemer, Ratamess, Fry, Triplett-McBride, Koziris, et al. (2000) had 24 collegiate women tennis players randomly placed into one of three groups: a control group (no resistance exercise), a multiple set periodized group (non linear-varying workout volume and intensity daily), or a one set circuit resistance training group. At four, six, and nine months the periodized training group demonstrated a significant increase in power and maximum strength for the bench press, shoulder press, and leg press along with an increase in lean mass and a decrease in percent body fat. The single set group only demonstrated increases in strength after four months of training and the authors concluded that multi set protocols are superior to single set protocols in improving capabilities of collegiate female tennis players.

Moderate rest intervals between sets are probably the best choice for increases in strength and lean mass. Willardson and Burkett (2005) compared three different between set rest intervals. Relatively short rest intervals of 30-60 seconds revealed to have benefits for increasing lean mass but not enough rest to maintain strength levels throughout a given workout. Moderate rest intervals of one-two minutes were found to be enough recovery time for participants to maintain strength for a few sets but not enough recovery time to maintain strength the whole exercise session. Willardson and Burkett concluded that long rest intervals of three-five minutes, was enough time to maintain strength throughout most of the training session.

Overtraining Syndrome

Smith (2004) discussed over training syndrome (OTS), which is valuable to the measurement of recovery. Smith indicates that trauma to tissue results in excessive amounts of cytokines which has adverse effects on the athlete. Cytokines are "emergency" molecules not found in healthy individuals but in athletes exposed to high levels of training (Smith, 2004). Initially, the athlete shows symptoms of depression or a distinct change in mood, followed by a decreased performance period that many times, lasts six to 12 weeks or longer (Smith, 2004). Cytokines have a direct impact on many body systems resulting in loss of muscle tissue, increased risk for infection due to immune suppression, decreased body fat, decrease in appetite, muscle aches and pains, difficulty concentrating, lower academic performance, loss of strength, and more according to Smith. Weekly training periods must have complete days off scheduled (Smith, 2004). More research on recovery and methods of measuring recovery is needed according to Smith. Smith states that OTS shortens many careers and severely limits performance in others.

Training Frequency

Measuring recovery and recommending training frequency is difficult and appears to vary between muscle groups. Jones, Bishop, Richardson, and Smith (2006) had 10 experienced resistance trained individuals and measured their performance using different recovery intervals (48, 72, 96, and 120 hours). Participants performed six basic exercises daily of two sets of 10 reps. Using a formula of total repetitions performed divided by the subjects baseline or initial performance on all six exercises, resulting in a number closest to 1.0 to determine optimal recovery. It was concluded that after 48 hours, 70% of the subjects were performing at or above their prior performance indicating recovery. One limiting factor to this research was the instability of muscle group recovery. Some muscle groups improved in performance faster than others did. Factors such as fatigue, nutrition, and hydration could have had an effect on this variability. Performance was not likely to improve in all six exercises at every recovery interval.

Bird, Tarpenning, and Marino (2005) recommend that for increasing lean mass, training frequency be three to five days per week. During these training sessions, these investigators advise performing four-six sets per exercise of 8-15 repetitions per set. Within an exercise session, larger muscle groups should be exercised before smaller muscle groups. Training to increase lean body mass involves relatively short rest intervals of one to two minutes. It was further explained that experienced trainees may benefit from split routine training (upper body, and lower body days) with four to six training days per week. Long-term training at this advanced level may need to include tapering.

Benefits of twice daily training may exist (Hartman, Clark, Bemben, Kilgore, & Bemben, 2007). Hartman et al., (2007) randomly assigned elite male weight lifters to train either once or twice daily for three weeks. Both groups performed the same workouts (four days per week); the only difference was one group split the workload into two sessions per day. The twice daily group did exhibit a greater change in isometric knee extension strength (+5.1% vs. 3.2%) EMG (+20.3% vs. 9.1%, testosterone (10.5% vs. 6.4%), and testosterone: cortisol ratio (-10.5% vs. 1.3%) and concludes that twice-daily training might reduce the risk of overtraining in elite male weight lifters with little evidence of improvements in performance.

Judge and Burke (2010) discovered that recovery from high intensity bench press exercise may differ between male and female athletes. Twelve college aged athletes (six males and six females) performed a three day per week bench press routine for three weeks to be become familiar with the protocol. Following the three week, preparatory phase, participants continued bench press training for an additional three weeks at two sessions per week, a baseline session and a recovery session at 4, 24, and 48 hours. No difference existed in female participant's strength at any recovery interval while male participants demonstrated a decrease in strength at four (2.3%) and 24 hours (4.0%) recovery. They concluded that female athletes may strength train in the bench press exercise at a higher frequency than equally trained male athletes may.

Possible increases in strength and lean mass with high frequency training are evident. Raastad, Glomsheller, Bjoro, and Hallen (2003) compared the effects of two training programs in 22 participants. The lower volume-training group trained each muscle group two days per week performing lower body exercises on one day, followed by upper body exercises the next day. The higher volume-training group trained in the same way as the lower volume group, with the addition of two leg exercises added each day. Therefore, the higher frequency group trained their lower body four times per week. Both groups performed three to four sets of six to eight reps taken to momentary muscular failure on all exercises. The results of the study indicate that the higher volume training group showed a marked improvement in strength.

High frequency low intensity strength training may produce large increases in lean mass. Wernbom, Augustsson, and Thomeé (2007) analyzed measurement of cross-section area (CSA) in the quadriceps and elbow flexors using an MRI scanner or CT scanner in healthy participants (ages 18-59). This investigation determined that many training protocols produced increases in lean mass. The results indicated that a frequency per muscle group of two to three times per seven days resulted in a .11% per day increase in CSA for both frequencies. An interesting finding within this study is, a group that experienced the largest increases in lean mass per day was training at an extremely high frequency of 12 muscle group stimulations per week and demonstrated an increase in CSA of .55% per day. Participants in this high frequency group were training with a very light load at about 20-30% of their 1RM, performing many repetitions per set. The study only lasted two weeks so it cannot be concluded that those improvements in lean body mass would continue. Nevertheless, this raises the question of the possibilities of high frequency training and its inducement of increases in lean mass.

According to Wernbom et al. (2007) anecdotal evidence of lower frequency training producing increases in lean mass exists. Many bodybuilders and powerlifters train at low frequencies, each muscle group receiving one workout per week, and report substantial increases in lean mass at these frequencies.

High frequency and low frequency training appears to produce similar gains in CSA and strength of quadriceps in active participants. Kamandulis, Skurvydas, Brazaitis, Imbrasiene, Masiulis, et al. (2010) had 14 physically active men divided into two training groups, E-1 (frequent loads of low volume) and E-2 (rare loads of high volume). Group E-1 performed the leg press exercise three times per week with total sets per day of 3, 3, and 4, totaling 10 sets per week. Group E-2 performed leg presses one day per week at 10 sets. Following seven weeks of training, group E-1 increased quadriceps thickness by 10.6 ± 9.5% and improved maximal strength on the leg press 17.7 ± 11.2%. Group E-2 increased quadriceps thickness by 12.6 ±11.3% and increased strength by 19.2 ±12.3%. Both high frequency low volume and low frequency high volume protocols produced similar gains in quadriceps thickness and strength during a seven-week training phase.

McLester, Bishop, and Guilliams (2000) conducted a study demonstrating that high frequency training may produce gains in strength and lean mass. The investigators randomly placed 25 experienced participants into one of two groups. The first group performed one set per muscle group three times per week, while the second group performed three sets per muscle group just once per week. The lower frequency group demonstrated only ~62% of the strength gains of the higher frequency group and concluded that higher frequency, same volume training may result in greater increases in lean mass and strength.

Candow and Burke (2007) compared training frequency of two and three times per week per muscle group. Each group performed the same total body workout, one group performed the workout twice per week (3 sets of 10 repetitions per exercise), while the other group performed the workout, three times per week (two sets of 10 repetitions per exercise) for six weeks. They revealed very little difference between the two groups concerning strength or increases in lean mass and concluded that volume of exercise may be more important than frequency for strength and lean mass improvements.

Higher frequency training appears to produce greater results for collegiate athletes. Hoffman, Kraemer, Fry, Deschenes, and Kemp (1990) gave 61 NCAA Division IAA football players the option of training three, four, five, or six days per week. Along with resistance training participants followed football conditioning two days per week for 10 weeks and concluded that a frequency of four and five days per week appeared to exhibit the greatest improvement in strength, lean mass, and endurance.

Frequencies of two and three sessions per week improve strength of leg musculature similarly. Carroll, Abernethy, Logan, Barber, and McEniery (1998) had 17 participants resistance train their leg extensor and flexor muscles for either two or three sessions per week. Following 18 total sessions, nine weeks for the twice per week group and six weeks for the three times per week group, resulted in similar strength improvements between the groups.

A training frequency of two and three training days per week appears to improve torso strength greater than once per week. DeMichele, Pollock, Graves, Foster, Carpenter, et al. (1997) had 33 men and 25 women participants placed into one of four groups for 12 weeks of training: a control group that did no exercise, and groups that performed strength exercise one, two, and three days per week. Training consisted of 8-12 repetitions of torso rotation exercise to failure for both left and right rotation. Strength improvements per group were 4.9 % onetime per week, 16.3 % two times per week, and 11.9 % three times per week. The authors concluded that improvements in torso rotation strength are best accomplished at frequencies of two and three times per week while one time per week training frequency demonstrated small improvements.

One day of strength training followed by one day of endurance training may be enough resistance training to produce significant increases in lean mass and strength in older population. Izquierdo, Ibanez, Hakkinen, Kraemer, Larrion, et al. (2004) analyzed the effects of two days per week of resistance training, two days per week of endurance training, or combined training of one day of resistance and one day of endurance training for 16-weeks on 31 elderly healthy men (65-74 years). No significant differences in lean mass was observed between strength training versus strength and endurance groups (11% and 11%). Improvement in maximal strength for leg musculature was 41% for strength only and 38% for the strength and endurance group. Increases in arm strength were greater in the strength group at 36% compared to the strength combined with endurance group of 22%; the endurance only group demonstrated a 0% improvement in arm strength. The authors concluded that resistance training and resistance plus endurance training lead to similar gains in lean mass and maximal strength. Resistance training combined with endurance training produces similar gains in maximum workload to endurance only training in older adults and these discoveries may influence exercise prescription.

Strength training a muscle group one time per week may maintain strength. Graves, Pollock, Leggett, Braith, Carpenter, et al. (1988) had 26 women and 24 men participate in 12 weeks of a reduced training frequency protocol. Participants training two days per week lowered training frequency to one day per week and participants training one day per week performed no strength training. Participants that stopped strength training lost 68% isometric strength in knee extension and flexion however, participants that reduced training from two days per week to one demonstrated no significant loss in strength. The authors concluded that strength may be maintained by reducing training frequency to one day per week during a 12-week phase.

Training frequency of one and two days per week may produce similar results. Difrancisco-Donoghue, Werner, and Douris (2007) had 18 participants (7 women and 11 men) 65-79 years assigned to one of two groups: one and two training days per week. Regardless of the group, the program consisted of one set of three upper body and three lower body exercises. No significant differences in strength changes were observed between groups. The authors concluded that one set of six exercises per week may provide as much benefit in strength gains as the same routine performed twice per week for older adults.

Two and three days of strength training for women may produce similar gains in strength and reduction of bodyfat. DiBrezzo, Fort, and Hoyt (2002) had 59 women ages 40-65 years were randomly placed in either a twice or three times per week training frequency for each muscle group training with equal volumes for eight weeks. Greater strength increases were observed in the three times per week group in standing lat pull, triceps extension, and leg press. Both groups demonstrated significant increases in strength and reduction of body fat. The authors concluded that two times per week of strength training is effective for improving muscular strength in women.

Opposing Views

Not all of the published research agrees with the mainstream current recommendations of the ACSM. Carpinelli, Otto, and Winnett (2004), dispute recommendations on strength training by breaking down strength training into its many variables. The authors point out that many of the recommendations by the ACSM are not supported by all research, and some research may oppose the recommendations of the ACSM. These investigators supports single set protocols versus multiple set protocols supported by the ACSM and illustrates the differences that exist among exercise scientists with regard to recommendations of productive strength training.

Summary

Comparing frequencies of training and its role on increasing lean mass and strength is a large undertaking. As can be seen from the review, many variables produce increases in lean mass and strength. Frequency has been studied in many of the projects, and some projects demonstrate that higher frequency training (2-4 muscle group stimulations per week) may result in greater improvements in lean mass and strength compared to lower frequency training (1 muscle group stimulation per week)(Candow & Burke, 2007; DeMichele, Pollock, Graves, Foster, Carpenter, et al., 1997; Hoim, Reitelseder, Pedersen, Doessing, Petersen, et al., 2008; Kraemer, Ratamass, Fry, Triplett-McBride, Koziris, et al., 2000). However, there appears to be a volume of research to support lower frequency training resulting in at least similar adaptations as higher frequency training (DiBrezzo, Fort, & Hoyt, 2002; Difrancisco-Donoghue, Werner, &

Douris, 2007; Graves, Pollock, Leggett, Braith, Carpenter, et al., 1988; Izquierdo, Ibanez, Hakkinen, Kraemer, Larrion, et al., 2004; Kamandulis, Skurvydas, Brazaitis, Imbrasienė, Masiulis, et al., 2010).

Research on recovery from extreme high intensity exercise may reveal that recovery takes a week or longer to regain pre testing strength (Nosaka, Chapman, Newton, & Sacco, 2006; Paschalis, Koutedakis, Jamurtas, Mougios, & Baltzopoulos, 2005; Raastad, Glomseller, Bjoro, & Hallen, 2003). Weiss, Wood, Fry, Kreider, Relyea, et al. (2004) presented possible increases in strength after four days of complete rest and scientists may conclude that a frequency of one muscle group stimulation per four to seven days is warranted. Muscle remodeling appears to take seven-10 days, which may support the low frequency high volume approach (Adams, 2006; Grobler, Collins, & Lambert, 2004). Contradicting the lower frequency approach is research demonstrating that 48 hours of recovery was enough time to restore strength to pre testing levels (Jones, Bishop, Richardson, & Smith, 2006; Judge, & Burke, 2010)(see Table 1).

The possible cause for differences in recovery rate may be the magnitude of a training session. For instance, studies presenting a long recovery interval consisted of participants involved in extremely high intensity exercise, eccentric accentuated, or a significant volume of exercise (sets x reps x resistance)(Nosaka, Chapman, Newton, & Sacco, 2006; Paschalis, Koutedakis, Jamurtas, Mougios, & Baltzopoulis, 2005; Raastad, Glomsheller, Bjoro, & Hallen, 2003). Studies demonstrating a recovery interval of 48 hours or less, participants were exercising with a smaller volume of exercise (Jones, Bishop, Richardson, & Smith, 2006; Judge & Burke, 2010; Paschalis, Koutedakis, Jamurtas, Mougios, & Baltzopoulos, 2005). Perhaps both high frequency low volume training and low frequency high volume training are equally effective at improving lean mass and strength (Difrancisco-Donoghue, Werner, & Couris, 2007; Graves, Pollock, Leggett, Braith, Carpenter, et al., 1988; Izquierdo, Ibanez, Hakkinen, Kraemer, Larrion, et al., 2004; Kamandulis, Skurvydas, Brazaitis, Imbrasienė, Masiulis, et al., 2010)(see Table 1).

Kamandulis, Skurvydas, Brazaitis, Imbrasienė, Masiulis, et al. (2010) in an almost identical project to the current project concluded very little difference in strength or changes in lean mass of the quadriceps following a seven-week training period regardless of the frequency. The current study measured whole body lean mass changes with a DEXA and strength gains for both upper and lower body while Kamandulis et al. analyzed changes in just one muscle group.

Table 1

Summary of studies investigating adaptations and recovery to strength training at various frequencies and intensities

Research	Participants	Exercise Intervention	Frequency Muscle Group	Load (% 1 RM)	Sets & Repetitions	LBM% Increase	Strength % Increase	Conclusion
Candow & Burke (2007)	29 untrained men & women	Total Body strength exercise	2 or 3 d./wk.	60-90%	3x10 or 2x10	Increase 3% Both Freq.	22-30% Inc. both Freq.	Freq. of 2 and 3d./wk. similar imp. in strength/LBM/ of equal volume
Carroll et al. (1998)	17 untrained men & women	Leg ext./flexion	2 or 3 d./wk.	N/A	N/A	N/A	N/A	2 and 3 d./wk similar imp. in strength
Chen & Nosaka (2006)	51 trained 41 men, 10 women	30 eccentric elbow flexions 100% 1RM	1 time followed by 2nd bout 3d. after initial bout	100%, 90%, 80%	30 maximal eccentric reps	N/A	N/A	2nd bout of eccentric ex. 3 d. after1st bout did not retard recovery
DeMichele et al. (1997)	33 men, 25 women	Torso Rotation exercise	0d./wk, 1d./wk, 2d./wk,3d./wk.	~75-80%	1x8-12 to failure	N/A	4.9%/1d./wk., 16.3%/2d./wk. , 11/9%/3d./wk.	Freq. of 2 and 3 d./wk. was superior for inc. rotation strength

(continued)

Research	Participants	Exercise Intervention	Frequency Muscle Group	Load (% 1 RM)	Sets & Repetitions	LBM% Increase	Strength % Increase	Conclusion
DiBrezzo et al. (2002)	59 untrained females (40-65 yrs.)	Total Body Strength exercise	2 or 3d./wk.	2d./wk 50% 3d./wk 60%	3x14, 3x8	Increase in both groups	Increase in both groups	Freq. of 2 and 3d./wk demonstrated similar imp.in strength and LBM
Difrancisco-Donoghue et al. (2007)	11 men, 7 women (65-79 yrs)	3 upper body, 3 lower body exercises	1 or 2 d./wk.	N/A	1 set to failure	N/A	N/A	No significant difference between 1 or 2d./wk.
Graves et al. (1998)	24 men, 26 women	Knee ext./flexion	Reduce from 2d. to 1 d./wk, and 1d. to 0 d./wk	N/A	N/A	N/A	0 d./wk lost 68 % isometric strength 1 d./wk. maintained	1 d./wk. maintained knee ext. and flexion strength over a 12wk. period
Hartman et al. (2007)	10 competitive male wt. lifters	Squat, Front squat, jerk, push press	4 d./wk 1 session/d or 2 session/d.	80-95%	3-5x5	3.2 % CSA, 2.1% CSA	1/d. snatch imp. 0.6 kg, clean & jerk 0.3, 2/d. snatch imp. 0.5 clean & jerk 1.9 kg.	Splitting training volume into 2 sessions did not improve strength

(continued)

Research	Participants	Exercise Intervention	Frequency Muscle Group	Load (% 1 RM)	Sets & Repetitions	LBM% Increase	Strength % Increase	Conclusion
Hoffman et al. (1990)	61 male NCAA football players	Strength Training 3,4,5,6 d./wk. for 10 wks.	2 or 3d./wk. per m. group	Varied	Wk. 1-4 4x8, 3x10, Wk. 5-8, 5x6, 3x10, Wk. 9-10, 1x10,8,6,4,2 ,3x10	N/A	N/A	2 and 3d./wk per m. group with total freq. at 4.5 d./wk. may be superior for NCAA football athletes
Izquierdo et al. (2004)	33 male (65-74 yrs)	Total body strength, Total body strength combined with endurance, endurance only	2 d./wk. of strength or 1d. strength and 1d. endurance, 2 d. endurance only	First 8 wks. 50-70%, Last 8 wks 70-80%, 30-50% and 30-40 %	First 8 wks. 3-4x10-15, Last 8 wks 3-5x5-6, plus 3-4x6-8	11%, 11%	41%, 38%, 0% (endurance only)	1d./wk strength combined with 1 d./wk. endurance produced similar gains in LBM and strength of 2d./wk.
Jones et al. (2006)	10 trained men	6 exercises of upper and lower body	48 hrs, 72, hrs, 96 hrs	10 RM	3x10 per exercise	N/A	N/A	70% of participants had returned to prior strength at 48 hrs recovery

(continued)

Research	Participants	Exercise Intervention	Frequency Muscle Group	Load (%1RM)	Sets & Repetitions	LBM % Increase	Strength % Increase	Conclusion
Judge & Burke (2010)	12 college aged (6 men, 6 women)	Bench Press	4 hrs, 24 hrs, 48 hrs	50-100% of 5 RM	1x10 (50%), 1x5 (70%), 1x4 (85%), 1x2(95%), 1x failure (100%)	N/A	Men decrease in strength at 4 hrs.(-2.3%) 24 hrs (-4%)	Decrease strength in men at 24 hrs., both men and women restored strength at 48 hrs.
Kamandulis et al. (2010)	14 active men	Leg Press	1d./wk or 3 d./wk.	N/A	1d./wk 10x10, 3d./wk 3x10, 3x10, 4x10	1d./wk 12.6 % increase in quad thickness, 3d./wk. 10.6%	19.2 % 1d./wk, 17.6 % 3d./wk	No significant differences between 3d./wk and 1d.wk.of equal volume quad training
Kosek et al. (2006)	12 women, 13 men (60-75 yrs) 11 women, 13 men (20-35 yrs)	Leg Press, Squat, Leg Ext.	3d./wk	75-85%	3x8-12	38-49% in all groups	Mean increase type II fibers 23% (60-75 yrs), 32 % (20-35 yrs)	Young men appear to demonstrate slightly greater gains. Freq. 3d./wk.

(continued)

Research	Participants	Exercise Intervention	Frequency Muscle Group	Load (% 1RM)	Sets & Repetitions	LBM % Increase	Strength % Increase	Conclusion
McLester et al. (2000)	Exp. participants	Total Body Strength Exercise	1d./wk vs. 3d./wk	Periodized 75-90% of 1 RM	1d./wk 3x3-10, 3d./wk 1x3-10 per day.	3d./wk superior gains.	3d. per week superior lean mass gains	Equal volume 3d./wk produced greater strength and lean mass than 1d./wk.
Nottle & Nosaka (2007)	13 men (18-25 yrs)	-7% decline treadmill running	One time event.	N/A	40 minutes	N/A	N/A	Strength restored at 72 hrs. post.
Nosaka et al. (2006)	89 men	24 maximal eccentric contractions elbow flexors	One time event.	100%	24/3s. Contraction	N/A	N/A	Mean strength loss 60% 4 d. post exercise
Paschalis et al. (2005)	12 untrained men	Knee extension	2 isokinetic quadriceps sessions separated by 2 wks.	High int. maximal eccentric effort, Low int. 50% of peak torque	High int. 10x12 max. Low int. until work equaled High Int.	N/A	N/A	96 hrs. post Low int. strength was restored. 96 hrs post High int. Isometric peak torque not restored (86.8%)

(continued)

Research	Participants	Exercise Intervention	Frequency Muscle Group	Load (% 1RM)	Sets & Repetitions	LBM % Increase	Strength % Increase	Conclusion
Pettitt et al. (2010)	18 men, 18 women untrained	Lumbar extension	One time event followed by post testing.	50%, 70%, 90%	2x25	N/A	24-48 hrs. post exercise greatest strength deficit	96 hrs. post exercise soreness was resolved.
Raastad et al. (2003)	83 women, 82 men	Elbow flexion	One time event followed by post testing.	Max. effort	70 maximal repetitions with 5 min. break	N/A	7d. post exercise men decrease 24%, women 27%	Decrease in strength during recovery similar between men and women.
Seynnes et al. (2007)	5 men, 2 women	Leg Ext.	3d./wk for 35 d.	Max. effort	4x7 to failure	6.5% CSA central quadriceps	N/A	Inc. in lean mass appears to occur during early weeks of training

(continued)

Research	Participants	Exercise Intervention	Frequency Muscle Group	Load (% 1RM)	Sets & Repetitions	LBM % increase	Strength % increase	Conclusion
Tesch et al. (2004)	21 men/women	Leg Ext or No Leg Ext.	2-3d./wk for 5 wks or No Training	Maximal effort or No Training	4x7 to failure	7.7% increase (training), 8.8% decrease (no training)	Decrease 24-32 % (No training group)	Relatively small amounts of strength training preserves lean mass
Weiss et al. (2004)	25 experienced	Bench Press	Testing followed by 2,3,4,5 d. rest/ post training	100%	6x1	N/A	2 and 4 days rest resulted in small improvements in strength	4 days post training rest appears to augment strength modestly

Note. 1 RM = one repetition max, wk. = week, freq. = frequency, d. = day, int. = intensity, ext. = extension, N/A = not assessed, s= seconds, hrs = hours, LBM = lean body mass, inc. = increased, ext. = extension, wt. = weight, post = post exercise.

CHAPTER 3
METHODS

The methods described below are designed to determine if the hypothesis that frequency of strength exercise has an effect on strength and muscle hypertrophy. Discovering the most efficient ways to train may improve the health of individuals choosing to strength train through the building back of lost muscle tissue resulting in many positive changes to an aging adult and athlete (Phillips & Winett, 2010). The following chapter is divided into five sections: 1) selection of participants; 2) strength assessment; 3) lean mass assessment; 4) description of intervention; and 5) statistical analysis.

Selection of Participants

All participants read and signed a university approved informed consent (Appendix A) after filling out a pre participation-screening questionnaire (Appendix B), and physical activity readiness questionnaire, PARQ, (Appendix C). The participants were healthy, males, and females, over the age of 18. Participants were physically active with a variety of strength training experience, free of cardiovascular disease or any major orthopedic condition that would limit their participation in a strength training program.

Strength Assessment

Prior to and following participation in eight weeks of exercise intervention, participants engaged in strength assessments to determine improvements in strength. Participants did not strength train within 48 hours prior to strength testing. Lower body strength assessment was measured on a 45-degree hack squat (Life Fitness, Schiller Park, IL). The warm up protocol for the hack squat consists of one set of 10 repetitions with a load at 50% of participants’ one RM followed by three to four sets to reach the load required for a one RM. Rest interval between warm up sets and all one RM attempts was three minutes. Hack squat range of motion consists of beginning at full extension followed by 90 degrees of knee flexion returning to full extension. Foot placement on the hack squat exercise will be approximately shoulder width and measured to the nearest centimeter to aid in consistent exercise performance. Participants back and hips remained firmly against the support padding on the hack squat.

Upper body strength assessment was measured through the chest press exercise on a flat bench in a smith machine (Keys Fitness, Garland, TX). Warm ups on the chest press involved 10 repetitions with 50% of predicted one RM followed by three-four sets of one-two repetitions to achieve the resistance for a one RM. Rest intervals between warm up sets and all one RM attempts were three minutes. Chest press range of motion consisted of the guards being positioned on level four in the smith machine allowing the bar to travel no lower than 2-3 centimeters from participants chest. A full repetition started from full extension controlling the bar down to the guards followed by full extension. Setting the smith machine (Keys Fitness, Garland, TX) guards provided for stable assessment of strength regardless of participant. Participants performed the chest press with hips, and back positioned squarely on the bench and subjects feet placed flat on the floor. Distance between index fingers was measured to the nearest centimeter per participant to ensure equal exercise performance at pre and post testing. Repetitions were controlled with a one-second eccentric phase to eliminate momentum typical with the chest press followed by maximal effort concentrically.

Lean Mass Assessment

Body composition was determined by dual energy x-ray absorptiometry (DEXA) (GE-LUNAR Prodigy) pre and post training that has a SEE of ~1.0% body fat (Pineau, Filliard, & Bocquet, 2009). DXA analysis was used to determine baseline information of percent body fat, lean mass, and fat mass and compared to the posttest.

Description of Intervention

Participants were placed into a high frequency training group (HFT) or a low frequency group (LFT). Participants were placed in groups by researcher to equal group demographics from information presented on pre participation questionnaire (Appendix B). LFT trained each muscle group one time per week, splitting the body over three days. Low frequency split routine: Day 1) pectoralis, deltoids, and triceps, Day 2) upper back and biceps, Day 3) quadriceps, hamstrings, calves, and abdominals. HFT trained each muscle group three times per week by training the whole body on three different days. All workouts were separated by 48 hours. The number of sets performed per week was the same for both groups, which consisted of nine total sets per muscle group per week. All nine sets performed on one day per week for LFT while HFT performed three sets on three occasions per week (see Table 2 and Table 3).

After one to two warm up sets, participants then performed workout sets. All sets were performed to momentary muscle failure. Repetitions per set were eight-12, which puts intensity of the load at ~75-85% of the participants one RM (Zatsiorsky & Kraemer, 2006). Both HFT and LFT were designed to induce hypertrophy and strength improvements. Once a participant could perform 12 repetitions with a given resistance, the participant increased the resistance on the following workout by 3% to the nearest 2.5

pounds or 1.3 kilograms. A high level of effort was encouraged and progressive overload was the emphasis in both groups. Repetitions were performed with complete control during both the eccentric and concentric phases. Both groups rested one to two minutes between sets. Daily workouts lasted ~45-60 minutes and the total training period was eight weeks. Eight weeks of resistance, training appears to be long enough to result in increases in lean mass and strength (Seynnes, deBroer, & Narici, 2007). All sets per exercise were completed for a given exercise before moving to the next exercise. Larger muscle groups were trained first in all workouts. Workouts were performed in the order they appear on log sheets (see Appendices D and E).

Table 2

Example week High Frequency Training

Muscle Group	Monday	Wednesday	Friday
Pectoralis	Flat Presses	Flat Presses	Incline Presses
Upper Back	Pulldowns	Pulldowns	Rows
Quadriceps	Leg Press	Lunges/Squats	Hack Squats
Gastrocnemius	Standing Calf Raises	Standing Calf Raises	Standing Calf Raises
Deltoids	Shoulder Presses	Lateral Raises	Lateral Raises
Biceps	Seated Dbell Curls	Seated Dbell Curls	1 Arm Bench Curls
Triceps	Tricep Pushdown	Tricep Pushdown	1 Arm Tricep Ext.
Hamstrings	Seated Leg Curl	Seated Leg Curl	Back Extension
Sets x Reps	3x8-12 all ex.	3x8-12 all ex.	3x8-12 all ex.

Note. Workouts could be performed on Tuesday, Thursday, and Saturday or any variation with 48 hours rest between each workout and three workouts per week. Dbell=dumbbell, ex=exercises, Ext=extension.

Table 3

Example week Low Frequency Training

Monday	Wednesday	Friday
Pectoralis, Deltoids, Triceps	Upper Back, Biceps	Quadriceps, Hamstrings, Calves
(sets)x8-12	(sets)x8-12	(sets)x8-12
Incline Press (3)	Pulldowns (6)	Hack Squats (3)
Flat Press (6)	Rows (3)	Leg Press (3)
Shoulder Press (3)	Seated Dbell Curls (6)	Lunges/Squats (3)
Lateral Raises (6)	1 Arm Bench Curls (3)	Seated Leg Curl (6)
Pushdowns (6)	Crunches (3)	Back Extension (3)
1 Arm Extensions (3)		Standing Calf Raise (9)

Note. Workouts could be performed on Tuesday, Thursday, and Saturday or any variation with 48 hours rest between each workout and three workouts per week. Dbell=dumbbell, ex=exercises, Ext=extension.

All participants recorded their workouts in a training log (Excel, Microsoft Inc.). Data in training log included date, resistance, number of repetitions performed per set, and total workout duration. Tracking of strength workouts was to ensure participant compliance and increasing workload from week to week.

CHAPTER 4
RESULTS

The purpose of the study was to determine if HFT resulted in greater increases in lean mass and strength than LFT of equal volume during an eight week training phase in active, strength trained adults. Raw data was collected and organized regarding lean mass changes, lower body strength, and upper body strength. Mean differences pre to post was used to determine changes in lean mass and strength as a result of the exercise intervention. Mean values and standard deviation was calculated from each group for lean mass and strength improvements. A two- tailed *t* test was conducted to determine if the difference in mean for lean mass and strength was a result of HFT to a significance of 0.05. The analysis of data in this chapter is presented according to the following topics: 1) participant characteristics; 2) means and standard deviations; 3) *t* test score; and 4) within group comparisons.

Baseline Participant Characteristics

Participants selected for the study were physically active adults with prior strength training experience. The study began with 27 participants and 19 participants completed all eight weeks of training and post testing. Participants were placed in groups in an effort to balance male female ratio, mean training days per week during the three months prior to the study, mean training age, one RM strength for chest press, and hack squat, and age of participants. Table 4 illustrates characteristics of the 19 participants completing the study. No significant differences between groups existed at baseline for data collected ($p > 0.05$) (see Table 4).

Table 4

Initial Subject Characteristics: Group Means and Standard Deviation

Variable	HFT Mean ± SD	LFT Mean ± SD	*t*	*p*
n	10 (3 women, 7 men)	9 (4 women, 5 men)		
Age (y)	34.23 ± 10.99	35.14 ± 6.91	-0.214	0.833*
Training Age (months)	47.50 ± 46.14	55.22 ± 31.56	-0.421	0.679*
Training days per week prior to research	2.7 ± 1.83	3.0 ± 1.87	-0.353	0.728*
Total Mass (kg)	80.27 ± 12.81	81.72 ± 15.95	-0.219	0.829*
Lean Mass (kg)	55.34 ± 11.25	49.11 ± 11.51	1.192	0.250*
Height (cm)	173.58 ± 8.71	167.47 ± 7.44	1.635	0.130*
Hack Squat 1 RM (kg)	96.77 ± 40.31	90.15 ± 41.46	0.329	0.747*
Chest Press 1 RM (kg)	84.82 ± 31.41	78.62 ± 40.78	0.374	0.713*

Note. * No significant differences ($*p > 0.05$)

Changes in Lean Mass

Both HFT and LFT resulted in similar changes in lean mass following eight weeks of training. Mean change in lean mass (kg) ± standard deviation (SD(kg) for HFT was 1.06 kg ± 1.78 kg and .99 kg ± 1.31kg for LFT. Percent improvements in lean mass were 1.9% for HFT and 2.0% for LFT.

There was not a significant effect in lean mass $t\ (17) = 0.09$, $p > .05$, with HFT receiving similar results as LFT. The hypothesis that equal volume HFT would result in greater increases in lean mass than LFT following eight weeks of training was not supported. This *t* statistic supports the null hypothesis that equal volume HFT and LFT results in similar improvements in lean mass (see Table 5).

Table 5.

Changes in Lean Mass Following 8 Weeks of Training; Group Mean kg ± Standard Deviation kg.

Group	Pre Training (kg)	Post Training (kg)	Δ Lean Mass (kg)	% Improvement	*t*	p^a	*t*	p^b
HFT	55.34 ± 11.25	56.40 ± 10.40	1.06 ± 1.78	1.9	0.09	0.93*	-1.89	0.092*
LFT	49.11 ± 11.51	50.10 ± 11.61	.99 ± 1.31	2.0			-2.27	0.053*

Note. [a]HFT vs. LFT. [b]HFT and LFT within group changes.
* No significant difference between groups or within groups (*p>0.05).

There was not a significant effect in lean body mass for HFT following eight weeks of training, $t\ (9) = -1.89$, $p > .05$. There was not a significant effect in lean body mass for LFT following eight weeks of training, $t\ (9) = -2.27$, $p > .05$. Neither group presented a mean gain of lean mass (kg) that was significant at 0.05 (see Table 5).

Strength Assessment

Mean (kg) strength changes ± standard deviation (SD) (kg) for the chest press one RM was 9.07 kg ± 6.33 kg for HFT and 5.8 kg ± 4.26 kg for LFT. Percent improvement for the chest press one RM was 11% for HFT and 7% for LFT. Mean (kg) strength changes ± SD (kg) for the hack squat one RM was 21.83 kg ± 11.17 kg for LFT and

20.16 kg ± 11.59 kg for HFT. Percent improvement for the hack squat one RM was 24% for LFT and 21% for HFT (see Table 6).

There was not a significant effect in chest press one RM t (17) = 1.31, $p > .05$, with HFT receiving similar results as LFT. The hypothesis that equal volume HFT would produce greater gains in strength on the chest press exercise during an eight week training phase was not supported. There was not a significant effect in hack squat one RM t (15) = -0.30, $p > .05$, with HFT receiving similar results as LFT (see Table 6).

Table 6

Strength Measures: Group Means (kg) ± Standard Deviation (kg)

	Pre Training (kg)	Post Training (kg)	Δ Strength (kg)	% Improvement	t	p^a	t	p^b
Chest Press								
HFT	84.82 ± 31.41	93.89 ± 32.01	9.07 ± 6.33	11	1.31	0.21*	-4.54	0.001**
LFT	78.62 ± 40.78	84.42 ± 42.56	5.80 ± 4.26	7			-4.08	0.004**
Hack Squat								
HFT	96.77 ± 41.31	116.93 ± 43.33	20.16 ± 11.59	21	-0.30	0.77*	-5.22	0.001**
LFT	90.15 ± 41.46	111.98 ± 43.10	21.83 ± 11.17	24			-5.53	0.001**

Note. [a]HFT vs. LFT. [b]HFT and LFT within group changes.
* No significant difference between groups (*$p > 0.05$). **Significant improvements in chest press and hack squat strength from pre to post within groups (**$p < 0.05$).

There was a significant effect in chest press one RM for HFT following eight weeks of training, t (9) = -4.54, $p < 0.05$. There was a significant effect in chest press one RM for LFT following eight weeks of training, $t\ (8) = -4.08$, $p < 0.05$. There was a significant effect in hack squat one RM for HFT, $t\ (8) = -5.22$, $p < 0.05$. There was a significant effect in hack squat one RM for LFT, $t\ (7) = -5.53$, $p < 0.05$. Both HFT and LFT received similar improvements in chest press and hack squat strength (see Table 6).

CHAPTER 5
DISCUSSION OF FINDINGS

The purpose of this study was to determine if equal volume high frequency training (HFT) (three sets per muscle group three times per week) would produce greater strength and lean mass gains than lower frequency training (LFT) (nine sets per muscle group one time per week) in healthy, trained men and women. Both HFT and LFT produced similar improvements in strength and lean mass, and these findings are supported by other studies (Candow & Burke, 2007; DiBrezzo, Fort, & Hoyt, 2002; Difrancisco-Donoghue, Werner, & Douris, 2007; Graves, et al., 1988; Izquierdo, et al., 2004) (see Figure 1). Kamandulis, et al. (2010) in a study almost identical to the current study, examined changes in leg strength and cross sectional area (CSA) in active young men, for seven weeks. The authors found no significant difference in improvements in quadriceps strength or CSA between a higher frequency group (three workouts per week) versus a lower frequency group (one workout per week) with total set count being 10 per week for both groups.

McLester, Bishop, and Guilliams (2000) in a study comparing frequencies of once vs. three times per week presents results that differ from the current study. McLester et al. (2000) had participants exercising with three sets once per week vs. one set three times per week for 12 weeks. Their results demonstrated greater gains in strength (62%) for the higher frequency group. It is important to illustrate the differences in spite of similar frequency between the current study and McLester et al. (2000) is the current study had participants exercising with three times as many sets per week (nine vs. three). McLester et al. (2000) training phase was also four weeks longer than the current study.

Perhaps volume of training (number of sets x reps) is more important than frequency per week for increasing lean mass and strength as Candow and Burke (2007) concluded when they compared a frequency of two versus three times per week of equal volume. Several studies have investigated changes in lean mass and strength comparing low volume (1 set) vs. higher volume (3 or more sets per week) resulting in superior improvements in lean mass and strength for higher volume programs (Peterson, Rhea, & Alvar, 2005; Rønnestad, et al., 2007; Kraemer et al., 2000).

Strength improvements for the current study resulted in a percent gain of 11% for HFT and 7% for LFT on the chest press exercise. Hack squat strength resulted in a 21 % improvement for HFT and an increase of 24% for LFT. The *t* statistic did not result in significance however, it is important to mention the 3 % greater increase for LFT in hack squat strength, and these results are similar to Kamandulis, et al. (2010). These investigators demonstrated a 1.5% greater improvement in leg press strength in their LFT group compared to their HFT group. The explanation for this difference in adaptation of upper and lower body is unexplained and needs further study (see Figure 2 and 3).

Lean mass improvements for the current study resulted in almost identical increases with 1.9% for HFT and 2.0% for LFT. The t statistic did not result in significance supporting the null hypothesis that HFT did not produce superior increases in lean mass in these 19 participants. These findings are similar to the results of other studies, that lower frequency training is equally as effective as higher frequency training in improving lean mass during an 8 week training period (Candow & Burke, 2007; DiBrezzo, Fort, & Hoyt, 2002; Difrancisco-Donoghue, Werner, & Douris, 2007; Izquierdo, et al., 2004; Kamandulis, et al., 2010).

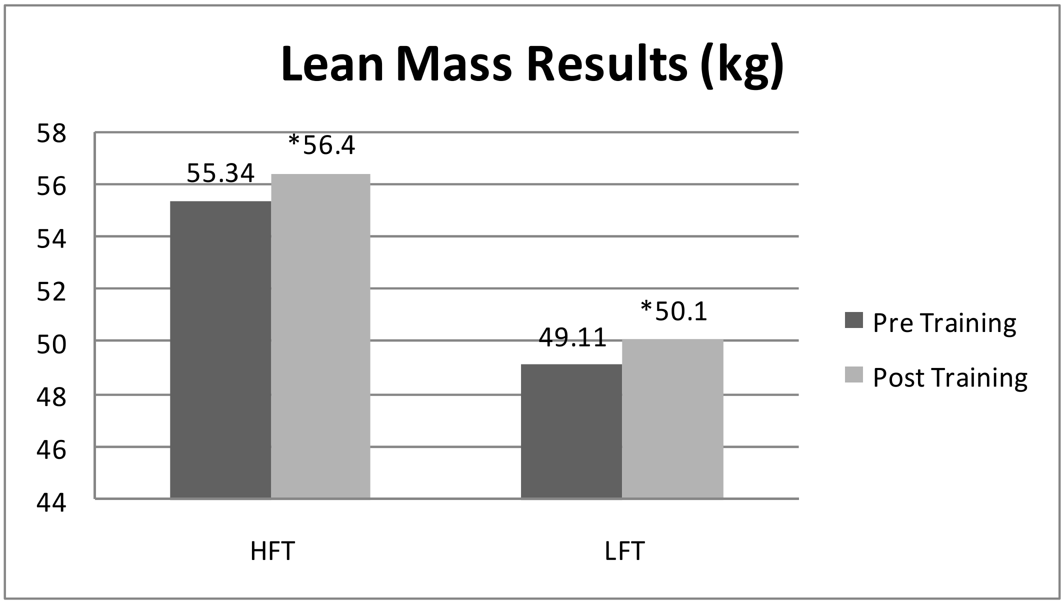

Figure 1. * Not significant from pre training ($p > 0.05$)

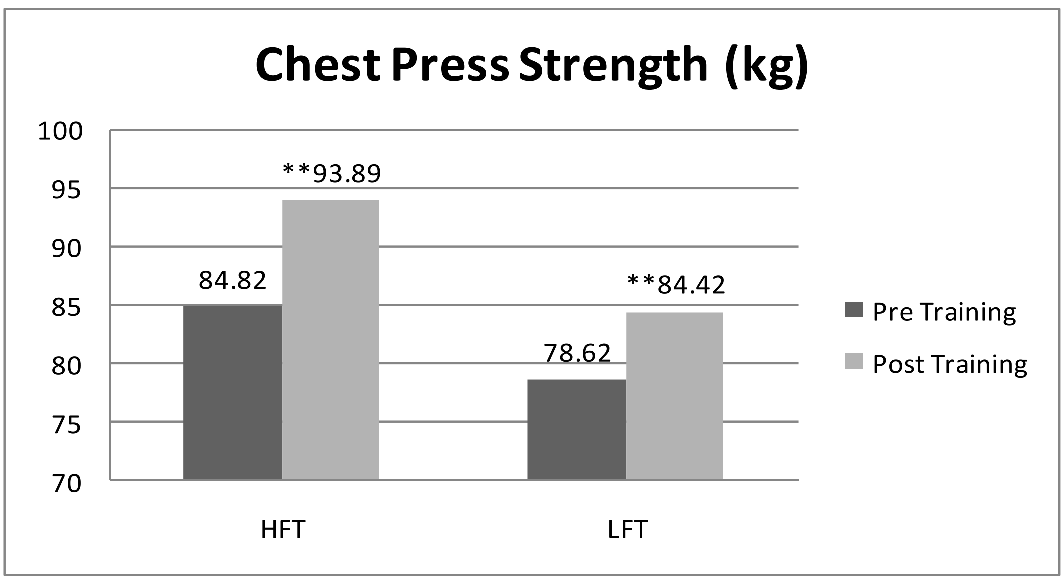

Figure 2. ** Significant from pre training ($p < 0.05$).

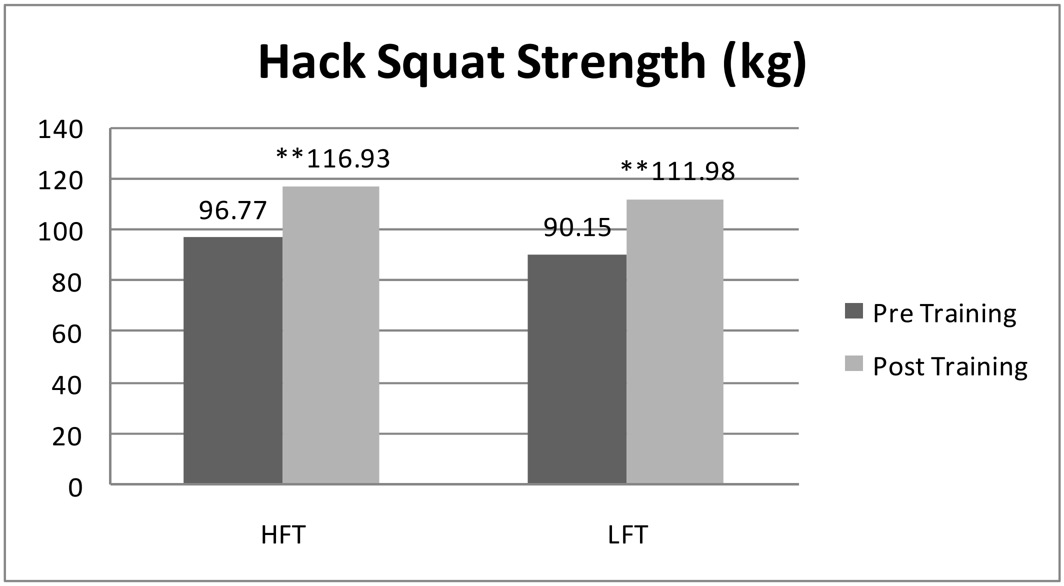

Figure 3. ** Significant from pre training ($p < 0.05$).

Limitations Participant Drop Out Rate

Following collection of all baseline data in the current study the researcher placed participants in one of the two groups. Placing participants was done in an effort to equal baseline data (men to women, current training status, strength, and lean mass) among groups. Initially all baseline data was equal between groups ($p > 0.05$) (see Table 4). However participant drop out was high (8 out of 27) resulting in differing numbers of men and women in each group (HFT three women and seven men, LFT four women and five men) however, this dropout rate did not influence difference between the groups at baseline. Recruitment and participant compliance is perhaps the most difficult part of a training study with human participants. The varying numbers of men and women and total number per group probably did not alter the results as women appear to improve in strength and lean mass similarly to their male counterparts (Buford, Rossi, Smith, & Warren, 2007; Kraemer, et al., 2000).

Nutritional Status of Participants

Nutritional status of participants throughout the study could have had an impact on changes in strength and lean mass. Tarnopolosky (2008) recommends 6-8 grams carbohydrate $\cdot kg^{-1} \cdot day^{-1}$ and protein intake at 1.5 grams $\cdot kg^{-1} \cdot day^{-1}$ for maximum gains in strength and lean mass. It is unlikely all participants were consuming enough nutrition to support training optimally possibly limiting lean mass and strength gains.

Concurrent Training and Adaptations

Participants were encouraged to limit excess activity that might compromise gains in lean mass and strength. Hawley (2009) discuses the molecular response of strength and aerobic exercise and that training with both forms of exercise concurrently may limit the adaptive response of each. Participants in the current study who performed strength exercise outside of the required program, or performed more than three cardio vascular sessions per week (20 min. per session) were dismissed from the study. Limitations of a training study using human participants presents many challenges such as concurrent training, excessive stress, lack of sleep, poor hydration, and many others, which may compromise improvements in lean mass and strength.

Training Period

The current study's results may have been slightly different if the training phase had continued for six months or longer. Both HFT and LFT presented gains in lean mass and strength over eight weeks however it is possible one group would have produced greater gains had participants trained for a longer period. More research is warranted studying long term adaptations to strength training.

Conclusion

Frequency of strength exercise was the focus of this study. The hypothesis was that HFT would produce greater increases in lean mass and strength than LFT of equal volume. The results of this study demonstrate that both HFT (three sets on three occasions per week) and LFT (nine sets, on one occasion per week) produced gains in lean mass and strength in these 19 active, men and women, following an eight week training period. Any difference in lean mass and strength gains among these groups was statistically insignificant.

Future Investigations

Future investigations may focus on number of sets per week that is optimal for improving lean mass and strength. Examining adaptations to strength training programs for a year or more in advanced participants may produce definitive answers. Future investigations may want to examine differing volumes of strength exercise with similar frequency, which is the opposite of the current study. At what point would volume exceed the ability of one to adapt? The current study found that nine sets per week with a frequency of one or three sessions per week produced a similar response. Perhaps 12 or more total sets per muscle group per week would produce a greater response or even slightly fewer sets. Future investigations may investigate less frequent strength exercise (one session per muscle group every 7-10 days) and even higher volumes of exercise (12 or more sets per muscle group).

Future investigations may seek to control some of the limitations of human training studies. Adding nutritional tracking to the training portion could provide useful information. Monitoring participants’ stressors such as sleep patterns, hydration, and general life stress may provide more information into the variables responsible for changes in lean mass and strength. Use of human subjects may always present challenges that compromise improvements in lean mass and strength. A larger subject number along with a longer training period will aid in the reliability of future strength training research.

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APPENDIX A
CONSENT FORM

Identification of Researchers: This research is being done by Michael Thomas, a graduate student, and Steve Burns PhD, a professor. We are with the department of Kinesiology at the University of Central Missouri.
Purpose for the study: The purpose for this study is to compare equal volume, high frequency muscle group strength training to lower frequency training to determine which frequency produces the greatest strength and muscle hypertrophy.
Request for Participation: We are inviting you to participate in a study on strength training. It is up to you if you would like to participate. You can decide to not participate at any time during the study and not be penalized. You can go all the way through the eight-week study and decide to not finish. If you decide not to finish please let us know as soon as you decide.
Exclusions: You must be at least 18 years old and not pregnant to participate in the study. You must have a resting blood pressure of < 140/90, and be free of any cardio vascular disease. You must be free of any major orthopedic condition i.e. (hip replacement, knee replacement).
Description of Research Method: This study involves coming to our initial meeting, which will involve filling out a health questionnaire. This questionnaire will consist of basic health information. After you have filled out the health questionnaire and have determined you are eligible and generally healthy, you will begin with a pretest of measuring body composition by lying in a machine called a DEXA scanner at the University of Central Missouri Exercise Science Lab. This machine involves lying on a table in which the scanner will measure body composition. We will go over the test results with you and give you a copy of the results. You and your body composition results will remain confidential at all times during the study. The following week we will perform the strength testing of a 1-repetition max in the leg press and bench press. This testing is necessary to measure strength improvements during the training phase. Following the initial strength testing you will be given a training routine of either High frequency training or low frequency training. Regardless of the group, you will be required to strength train 3 days per week for about 1 hour at a time. You will be required to either be supervised by Michael Thomas or another professional trainer during your workouts. Constant communication will be encouraged throughout the 8-week study via email or phone to make certain all participants are progressing through their workouts. The final meeting after week 8 will consist of another body composition test via the DEXA scanner followed by post testing for strength gains in the leg press and bench press.

DEXA Information

This study involves exposure to a very small amount of radiation. One DEXA scan will expose you to one thousandth of one rem of radiation, about the same amount of radiation the average American receives in one day from natural background sources. The only part of your body exposed to radiation will be your skin, which is less vulnerable to radiation in comparison to other parts of your body (http://drs.ors.od.nih.gov/services/rsc/forms/RSC-DEXA-Template.pdf).

Time to complete the scan is 5 minutes.
Location: University of Central Missouri, Exercise Science Lab
All participants for this study will be trained on site by Michael at his training center in Springfield, MO or under the direct supervision of a professional trainer approved by Michael. However, there may be times when a subject cannot attend sessions at the training center due to schedule or travel conflicts and may perform their training on their own. Email follow up will be performed in cases such as this.
Privacy: All of your specific information will remain confidential at all times.
Explanation of Risks: Generally, strength-training exercise carries very little risk if you are in good health. You will receive coaching on exercise technique, which will reduce your risk of injury. However, as with any exercise, there exists the possibility of certain changes occurring during the exercise. Risks include; delayed muscle soreness, an abnormal response of blood pressure, fainting, irregular fast or slow heart rhythm, and in rare instances, heart attack, stroke, or death.
Explanation of Benefits: You will receive detailed coaching on strength training technique and fundamentals of training throughout the study. Follow up and coaching throughout the study will allow you to continue strength training after the study is complete. The benefits of strength training are many: from increased lean body mass, which may raise your basal metabolic rate, lower percent body fat, and other positive physiological changes. You will also receive detailed analysis of percent body fat, muscle mass (lean body mass), and bone density from the DEXA scann.
Questions: If you have any questions about this study, please contact Michael Thomas at 417-840-4382 or email at www.mht76890@ucmo.edu or contact Dr. Steve Burns. Dr. Steve Burns can be reached at www.sburns@ucmo.edu or phone 660-543-8894. If you have any questions about your rights as a research participant, please contact the Human Subjects Protection Program at (660) 543-4621.

If you would like to participate, please sign a copy of this letter and return it to Michael Thomas or mail to 1927 South National Suite B Springfield, MO 65804.
I have read this letter and agree to participate.

Signature. ____

Date: _______________________________________

APPENDIX B
PRE PARTICIPATION SCREENING QUESTIONNAIRE

1. The last 3 months how many days per week have you engaged in strength training? (average)

2. The last 3 months how many days per week have you engaged in cardiovascular training? (average)

3. How many months have you participated in strength training over your lifetime? (Cumulative)

4. Briefly describe your strength training program the last three months include exercises, sets, and repetitions.

5. Briefly describe your training program not including the above strength training program include cardiovascular training, running, strenuous work, etc. (time, frequency, mode, etc)

6. Describe any limitations you might have participating in this strength training study?

APPENDIX C
PHYSICAL ACTIVITY READINESS QUESTIONAIRE

Physical Activity Readiness Questionnaire (PAR-Q) and You

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly:

YES	NO		
☐	☐	1.	Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?
☐	☐	2.	Do you feel pain in your chest when you do physical activity?
☐	☐	3.	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	6.	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7.	Do you know of any other reason why you should not do physical activity?

If you answered:

YES to one or more questions

Talk to your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want – as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- Start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- Take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

Delay becoming much more active:

- If you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- If you are or may be pregnant – talk to your doctor before you start becoming more active.

Please note: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

Name ________________________________

Signature ________________________________ Date ________________________________

Signature of Parent ______________________ Witness ______________________________

or Guardian (for participants under the age of majority)

APPENDIX D
HIGH FREQUENCY TRAINING LOG

High Frequency Training Group	Week 1				
Day 1	Monday		Wednesday		Friday
Flat Presses 3 sets					
Pulldowns 3 sets					
Leg Presses 3 sets					
Standing Calf Raises 3 sets					
Shoulder Presses 3 sets					
Seated Dumbbell Curls 3 sets					
Tricep Pushdowns 3 sets					
Seated Leg Curls 3 sets					
Day 2					
Rest					
Day 3					
Flat Presses 3 sets					
Pulldowns 3 sets					
Lunges or squats 3 sets					
Standing Calf Raises 3 sets					
Lateral Raises 3 sets					
Seated Dumbbell Curls 3 sets					
Tricep Pushdowns 3 sets					
Seated Leg Curls 3 sets					
Day 4					
Rest					
Day 5					
Incline Presses 3 sets					
Rows 3 sets					
Leg Presses 3 sets					
Standing Calf Raises 3 sets					
Lateral Raises 3 sets					
1 arm Preacher Dumbbell Curls 3 sets					
Tricep Extensions 3 sets					
Back Extensions 3 sets					
Ab Crunches 3 sets					

APPENDIX E
LOW FREQUENCY TRAINING LOG

Low Frequency Training Group				Week 1				
Day 1				Monday		Wednesday		Friday
Incline Press 3 sets of 10-15								
Flat Press	6 sets of							
Shoulder Press 3 sets								
Lateral Raises 6 sets								
Tricep Pushdowns 6 sets								
Dumbbell Extensions 3 sets								
Day 2								
Rest								
Day 3								
Pulldowns 6 sets								
Rows 3 sets								
Seated Dumbbell Curls 6 sets								
1 arm Curls 3 sets (Preacher)								
Ab Crunches 3 sets								
Day 4 Rest								
Day 5								
Leg Presses 6 sets								
Lunges or squats 3 sets								
Seated Leg Curls 6 sets								
Back Extensions 3 sets								
Standing Calf Raises 9 sets								

APPENDIX F
HUMAN SUBJECTS APPROVAL LETTER

Dear Mr. Michael Thomas,

Your research project, 'Skeletal Muscle Hypertrophy and Strength: A Comparison of High Frequency Strength Training to Low Frequency Strength Training', was approved by the Human Subjects Review Committee on 11/9/2010. This approval is valid through 11/9/2011. Your informed consent is also approved until 11/9/2011.

Please note that you are required to notify the committee in writing of any changes in your research project and that you may not implement changes without prior approval of the committee. You must also notify the committee in writing of any change in the nature or the status of the risks of participating in this research project.

Should any adverse events occur in the course of your research (such as harm to a research participant), you must notify the committee in writing immediately. In the case of any adverse event, you are required to stop the research immediately unless stopping the research would cause more harm to the participants than continuing with it.

At the conclusion of your project, you will need to submit a completed Project Status Form to this office. You must also submit the Project Status Form if you wish to continue your research project beyond its initial expiration date.

If you have any questions, please feel free to contact me at the number above.

Sincerely,

Janice Putnam Ph.D., RN
Associate Dean of The Graduate School
putnam@ucmo.edu
cc: Steve Burns