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The Effects of Resistance Training Frequency On Muscle Hypertrophy And Strength In Healthy Trained Individuals: Literature Review

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THE EFFECTS OF RESISTANCE TRAINING FREQUENCY ON MUSCLE HYPERTROPHY AND STRENGTH IN HEALTHY TRAINED INDIVIDUALS: LITERATURE REVIEW

By

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ABSTRACT

The purpose of this study is to determine the effects of increased resistance training frequency on strength and hypertrophy in trained individuals. Five studies were deemed eligible based on the inclusion exclusion criteria. The inclusion criteria for this review were healthy trained individuals. "Trained" refers to over one year of resistance training experience. Exclusion Criteria were study's that examined either untrained or obese individuals as participants. The evidence indicates a dose-response trend in frequency. Resistance training each muscle group twice a week may be superior compared to once per week. Further more, resistance training each muscle group three times a week may enhance hypertrophy and strength adaptations even more compared to either once or twice a week. Recovery of the muscle may be reached in approximately 72 hours or 3 days. Mechanisms that may correlate to this phenomenon could be related to the more frequent elevations in muscle protein synthesis and physiological anabolic hormones. These results may help develop more specific guidelines in programming for intermediate to advanced athletes as well as lead way to more research on acute training variable manipulation.

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INTRODUCTION

Increasing muscular size (hypertrophy) and strength is a highly sought attribute not only for athletes seeking to improve performance but also for healthy individuals wishing to improve body composition and health. Considerable research has supported the use of resistance training (RT) to increase hypertrophy, strength and athletic performance (Delecluse, 1997). Several studies have found that RT can decrease sprint times, increase vertical jump height and increase muscular strength and power; all important factors strongly correlated with improved performance in sports. (Wisløff, Castagna, Helgerud, Jones, & Hoff, 2004, McBride, Blow, Kirby, Haines, Dayne, & Triplett, 2009). One RT variable used to increase muscle hypertrophy and strength is manipulating how often an individual trains per week. This is defined as training frequency. Previous research conducted on training frequency has studied the effects of resistance training frequency on individuals with little or no RT experience (untrained). However, there is research to support the view that individuals with significant RT experience (trained) may respond differently to increases in training frequency. In trained individuals, increases in the frequency of RT per muscle group per week, may lead to greater increases in muscle hypertrophy and strength than in the untrained. Highly trained (HT) individuals are defined as those who have been consistently resistance training for one year or more. The purpose of this review is to determine the effect of increasing RT frequency on muscle hypertrophy in healthy trained individuals.

The National Strength and Conditioning Association (NSCA) is a world leading membership organization for researchers, strength coaches, personal trainers and educators. They have put forth a set of general guidelines for RT. The NSCA's guidelines for resistance training include recommendations for frequency of RT. Current recommendations for RT frequency from the NSCA are shown in Table 1.The NSCA recommends three workouts per week for many athletes, as the intervening days allow sufficient recovery between sessions. As an athlete adapts to training and becomes better conditioned, it is appropriate to consider increasing the number of training days to four and, with additional training five, six, or seven days. The general guideline is to schedule training sessions so that there is at least one rest recovery day, but not more than three, between sessions that stress the same muscle group (Baechle & Earle, 2008).

Table 1: Example of Classifying Resistance Training Status (NSCA)

Resisitance training Status	Current program	Training age	Frequency (per week)	Training Stress	Technique expereince and skill
Begginer (untrained)	Not training or just began training	<2 months	<1-2	None or low	None or minimal
Intermediate (Moderately trained)	currently training	2-6 months	<2-3	Medium	Basic
Adavanced (well trained)	currently trainign	>1 years	>3-4	High	High

Table 1. Baechle & Earle (2008), pg.384

The American College of Sports Medicine (ACSM) is the largest sports medicine and exercise science organization in the world. The ACSM also make recommendations for RT frequency. For novice participants, ACSM recommends to train the entire body two-three times per week, intermediate participants should train three days per week if doing whole body, or four days per week if doing an upper/lower split, and advanced participants should training four-six days per week, training each muscle group once to twice per week (Esco, 2013).

The NSCA & ACSM recommendations fail to address if there is a relationship between training frequency and muscle size and strength. They do not say whether or not advanced level athletes will benefit from increasing or decreasing RT frequency.limitations of the research on RT is that studies often use untrained individuals to evaluate muscular adaptations and improvements. However, it is well established that highly trained individuals may respond differently than those who lack training experience (Peterson, Rhea, & Alvar, 2005). It is possible that training more frequently may allow greater adaptations in trained healthy athletes as compared to the novice or untrained individuals.

Purpose of the Review

The purpose of this review is to determine if manipulating RT frequency can affect hypertrophy and strength adaptations in individuals who are resistance trained. Determining whether or not there is a dose response present between increasing resistance training frequency and muscle growth can help strength coaches and trainers program routines for their athletes. Will increases in resistance training have a positive or negative affect on muscle size and strength? Are there any important mechanisms responsible for muscle adaptations to RT that frequency influences? If there is a trend for a higher frequency of RT and muscle growth, what would the new guidelines be? These are questions this review set off to attempt to answer.

Operational Definitions

Advanced- 1 year or more of training

Anabolic- Biological state of building up complex molecules from simpler ones

The effect size- Statistical measurement to compare differences between groups

Resistance Training Frequency- How many times per week a muscle is trained.

Hypertrophy- Increase in muscle size

Intensity- Load, or weight

Intermmediate- Between beginner and advanced, 2-6 months of training

L-[1,2^{-13}C$_2$] leucine- Amino acid tracer, for measurement of MPS

Load- Weight

Micro cycle- Training week or weeks

Macro cycle- A group of meso cycles, which may last several months to years

Micro cycle- A training week or weeks

Mechanistic target of rapamycin (MTOR) pathway- key biological regulator of cell growth

Meso cycle- A group of micro cycles, typically lasting a month or more

Muscle Protein Synthesis- Increase in the number or size of protein in muscle tissue

Novice- Beginner, <2 months of training

Over reaching- Short term increase in intensity, volume or frequency

Resistanced trained- 1 year or more of resistance training

Volume- Repeitions x sets x load

LITERATURE REVIEW

Resistance training Principles

In order for hypertrophy to occur through RT, proteins inside the muscle must increase in size or number (Schoenfeld, 2010). RT has been shown to stimulate Muscle protein synthesis (MPS). MPS is the state of adding proteins inside the muscle, which is ultimately how the muscle grows (Schoenfeld, 2010). MPS has been termed the driving force behind adaptive responses in exercise (Atherton & Smith, 2012). Thus, MPS is an important adaptation in RT exercise. It has been demonstrated that the process by which RT stimulates MPS, includes activating the mechanistic target of rapamycin (MTOR) pathway (Dreyer, Drummond, Dhanani, Fry, Glynn, Rasmussen & Timmerman, 2009). The MTOR pathway is a key biological regulator of cell growth In this case, growth of muscle tissue. Possibly training the muscle group in a more frequent manner may stimulate MPS more often, thereby putting the individual in a greater anabolic environment over time. This may encourage greater skeletal muscle hypertrophy, and strength gains. Anabolic refers to the state of building muscle tissue. On the other hand, those who RT with a low frequency maybe missing opportunities to increase MPS and therefore decrease adaptations to RT.

Review of the literature on MTOR can be explained by the logic model depicted in Figure 1. It begins with RT stimulating the MTOR pathway. MTOR then elevates MPS which increases muscle growth. Hypertrophy will allow increases in force production (strength). The larger a muscle is, the more force is can produce (Seynnes, de Boer, & Narici, 2007). This indicates the relationship with hypertrophy and strength.

Figure 1: Muscle Protein Synthesis Theory

Figure 1

Motor Development and Frequency

Motor control is also an important factor to consider. Motor control refers to the nervous system's control of the muscles to permit skilled and coordinated movements (Haywood & Getchell, 2009). Many exercises require a great amount of motor control that must be practiced. Some exercises include the clean and jerk, the snatch, hang cleans, the squat, and the deadlift. Doing a movement more often can help an individual master that movement and refine technique (Ericsson, & Charness, 1994). Some researchers believe that it takes about ten years to reach an elite level Ericsson, Krampe, & Tesch-Römer, 1993). Increasing RT frequency can allow more time for an individual to practice technique and develop motor control. Once exceptional form and technique is obtained, the individual may allow greater progressive overload. Thus, allowing muscle growth and strength development to occur (Antonio & Gonyea,1993).

Volume and Training Frequency

RT volume refers to the total amount of work in a training routine (Baechle & Earle, 2008). It can be calculated by number of sets x number of repetitions x the load (Baechle & Earle, 2008). RT volume has been identified as a key driver for not only hypertrophy of the skeletal muscle, but strength increases as well (Krieger, 2010). When comparing multiple sets of resistance training, multiple sets are associated with 40% greater hypertrophy than a single set in both trained and untrained individuals (Krieger, 2010). Increases in training frequency may allow an individual to simply add more volume in a routine. For example, if an athlete wishes to increase their RT volume, they may expand one large training bout into two or more training bouts allowing for more volume per muscle group at the end of the week.

Frequency and Periodization

While RT protocols significantly improves strength and size, these adaptations will eventually plateau. Over use injuries and overtraining symptoms may also occur as a result of prolonged RT routines (Baechle & Earle, 2008). Over training typically results from extreme levels of RT frequency, volume, and intensity without sufficient rest or recovery. Which can result in drastic decreases in performace (Baechle & Earle, 2008). Current recommendations are that individuals vary their resistance training throughout a training year by manipulating RT design training variables.to avoid over training symptoms, injuries and to promote longer adaptaions (Baechle & Earle, 2008). This concept is known as periodization. Design training variables include exercise selection, training frequency, exercise order, training load and repetitions, volume and rest periods (Baechle & Earle, 2008). These can all be manipulated within a periodization, which is split up into different phases. These phases include a micro cycle, macro cycle and a meso cycle. A micro cycle is a training week or weeks. A group of micro cycles with a specific goal is referred to as a block or macro cycle. A cluster of these blocks is a meso cycle (Baechle & Earle, 2008). Typically Volume is high at the beginning of a block, with intensity low. Gradually these inverse variables change over time with intensity rising, and volume decreasing (Baechle, Earle, 2008). Frequency of resistance training is not clearly mentioned in literature and usually left unaltered through out an entire macro cycle in many periodization programs. The variable of resistance training frequency may be a limiting factor in many programs if it has potential to positively affect performance, yet left unchanged. Information on the efficacy of manipulating resistance exercise frequency is largely unexplored (Wernbom, Augustsson, & Thomeé, 2007).

Rationale

Review of the current guidelines for RT show little mention of the effects of increasing RT frequency in individuals that are highly trained (HT). A literature review was conducted to compare the effect of increased resistance training frequency on skeletal muscle growth and neuromuscular adaptations (i.e., strength gains) in HT indviduals. It is possible that there is a dose-response effect, and that by increasing the number of times per week a single muscle is trained and hypertrophy.

METHODS

To gain better understanding on the manipulation of training frequency on muscle hypertrophy and strength gains, text books, web journals, and specific articles from peer reviewed search engines such as Google Scholar, UCF Library, and PubMed, relating to the topic have been searched and reviewed in depth. Searching and cross-referencing were performed from the bibliographies of previously retrieved studies and from review articles. The following terms: “Frequency”, “Resistance training”, “Equated volume periodization”, and “Hypertrophy” were searched. Research on acute training variables including resistance training frequency is scarce. Research that has been done is limited by the participants that skew the results (i.e., sedentary, overweight, obese, not active).

The inclusion criteria for this review were healthy trained individuals. The termed “Trained” refers to over one year of resistance training experience. Exclusion criteria were study’s that examined either untrained or obese individuals as participants. Although these populations have their contributions to research, they are not the aim of this review. Untrained individuals respond to a large variety of stimulus (Peterson, Rhea, & Alvar, 2005). Using data from untrained individuals can distort how we think to train advanced athletes. Based upon the inclusion, and exclusion criteria only five studies were found to be relevant for this review. Five studies is not large enough to be referred to as a “meta-analysis” or to meet statistical significance. Statistical significance refers to the probability of an outcome being random. However, the evidence presented may elicit further research on the subject.

RESULTS

The results of the five studies that were deemed eligible are found on Table 2. One study by Schoenfeld et al., (2014) found that RT frequency did not have a greater influence on hypertrophy. However, there the groups in the study trained slightly differently. Group one lifted lighter weight while group two lifted heavier. Group two got significantly stronger. The four other studies found similar conclusions. That is that higher RT frequency corresponds with greater increases in size and strength with equated volume.

Table 2: Summary of RT frequency studies

Author	Study purpose	Results	Limitations
Schoenfeld et al., (2014)	To compare hypertrophic and strength responses in two groups performing different routines.	No difference in muscle size between training 3x per week and once.	Each group had a different routine.
Schoenfeld et al., (2015)	To examine the influence of resistance training frequency on muscular adaptations in well-trained men	Training three days per week was superior to once. Group that trained three x a week gained more muscle and got stronger.	The type of routine the participants did before.
Ratamess et al., (2003)	Examined high resistance training with planned over reaching with and with -out supplementation of amino acids	The group that over reached by increasing RT frequency got bigger and stronger than the group that trained only one muscle per day a week.	Supplemented with amino acids.
Hoffman et al., (1990)	To see how training frequency would affect strength.	Four and five days per week were superior to three.	Endurance was trained and tested, which can interfere

			with strength.
McLester et al. (2000)	To compare weight lifters training at different frequencies with matched volume	Training a muscle three x per week was superior to once per week.	Very low total RT volume.

Split vs. total body training

There are many different ways in which an individual can program their training. Some people swear by a "split" routines, where the muscle are split up into certain days. For example, one might train the chest on Monday, and back on Tuesday etc. Others prefer "total body" work outs where they train the upper and lower body on the same day, several times a week. I am going to review a few studies that compare both of these styles. Typically total body routines have a higher frequency of training which might make them a better choice for highly trained athletes. Most individuals train using a split routine, training one muscle group in isolation a week. In fact, a web-based survey revealed that 127 out of 127 bodybuilders said that they train in this fashion (Hackett, Johnson, & Chow, 2013). Not many individuals train full body, or train each muscle group multiple times a week. If increases in RT frequency relate to greater gains in strength and size, these individuals may be missing out on muscular development.

Schoenfeld (2014), examined two different training protocols to compare hypertrophic and strength responses in two groups performing different routines. Since volume is a key driver in strength and hypertrophy responses, it was equated in both groups. (Krieger, 2010, Wernbom et al., 2007). This will assure that insufficient volume in one group would not annul a hypertrophic stimuli skewing the results. Participants in this study were between 18-35 years old, and were considered resistance trained experienced with the average being 4.2 years. This is optimal that the participants were trained. Other studies have used untrained individuals, which can elicit results that resistance trained individuals would not experience (Peterson, Rhea, & Alvar, 2005). One group completed a powerlifting style (ST) routine performing three repetitions per set with three-minute breaks in between. The other group trained in a typical bodybuilding fashion (HT), performing ten repetitions per set with one point five minutes to rest in between sets. Common exercises seen in many body building style routines were selected. Exercises targeting the anterior torso, like the incline bar bell press, flat barbell press, and hammer strength chest press. Exercises targeting the posterior torso were the wide grip lat pull down, close grip lat pull down, and seated cable row. Exercises for the thigh included the barbell back squat, machine leg press, and machine leg extension.

Table 3 Exercise, sets, repetitions, and rest intervals per week

TABLE 2. Exercises, sets, repetitions, and rest intervals for each weekly session in ST and HT.

Protocol	Session 1	Session 2	Session 3
ST	Exercises: Incline barbell press, machine leg press, and wide-grip lat pull-down Sets: 7 Repetitions: 3 Rest interval: 3 min	Exercises: Flat barbell press, barbell back squat, and close-grip lat pull-down Sets: 7 Repetitions: 3 Rest interval: 3 min	Exercises: Hammer Strength chest press, machine leg extension, and cable seated row Sets: 7 Repetitions: 3 Rest interval: 3 min
HT	Exercises: Incline barbell press, flat barbell press, and Hammer Strength chest press Sets: 3 Repetitions: 10 Rest interval: 90 s	Exercises: Wide-grip lat pull-down, close-grip lat pull-down, cable seated row Sets: 3 Repetitions: 10 Rest interval: 90 s	Exercises: Barbell back squat, machine leg press, and machine leg extension Sets: 3 Repetitions: 10 Rest interval: 90 s

Table 2 (Schoenfeld, Ratamess, Peterson, Contreras, Sonmez, & Alvar, 2014).

The ST group as shown, completed seven sets with three reps, total body three times per week. This method minimizes metabolic stress and accumulation, which may be another stimuli for muscle hypertrophy (Rooney, Herbert, & Balnave, 1994, Schoenfeld, 2013). Metabolic stress pertains to metabolic by products and substrates such as hydrogen ions and lactate that accumulate in the muscle (Cryer, 1991, Goto, Ishii, Kizuka, & Takamatsu, 2005). The HT group trained how most bodybuilders do, performing three sets of ten of one muscle group. The higher volume per session accompanied large metabolic stress. Muscle thickness of the bicep brachii measured by ultrasound imaging, was almost exactly the same with a 12.6% increase in the HT group, and 12.7% increase in the ST group. Muscular strength favored the ST group with a 10.9% increase compared to the HT group's 8.1 % in the bench press, and again in the back squat, 22.2%, 18.9% respectively. There was a significant difference noted in change in 1RM bench press favoring ST vs. HT. A trend for greater increases in one repetition maximum (1RM) was noted in favor of ST vs. HT (Schoenfeld, Ratamess, Peterson, Contreras, Sonmez, & Alvar, 2014).

This is interesting because the power lifting style program with lower reps and higher intensities, and the body building style with lower intensities and higher reps both gained almost the exact same amount of muscle, even with the higher frequency in the powerlifting cohort. This finding allows us to see that the "hypertrophy range" of 8-12 repetition preached by so many is not entirely true. Although volume was equated, the lower rep higher intensity rep scheme gained significantly more strength than the body building routine, which corresponds with a similar study by Campos et al. (2002). This indicated a dose-response relating to strength athletes. To get strong, athletes have to lift specifically to get strong (i.e., Lower rep, Higher intensity). There seems to be a wide range of reps, sets and intensities that stimulate hypertrophy. However strength is a skill, and needs to be specifically practiced if getting stronger is desirable.

A study conducted by Schoenfeld et al., (2015) examined the influence of resistance training frequency on muscular adaptations in well-trained men. In this study the subjects were 20 males that volunteered from 19 to 29 years old. All volunteers were well trained, and were divided into two groups. One group followed a SPLIT training program while the other followed a three-day per week routine. The SPLIT incorporated a typical "bodybuilding routine" of training a muscle with higher volume once per week. The hypothesis was that this type of routine created more "metabolic stress" which would elicit more hypertrophy than a lower volume per session program that would create little metabolic stress. Group number two followed a TOTAL protocol where they trained all major muscle groups three times a week. Resistance training variables such as exercises performed, weekly training volume and rest intervals were held constant in both cohorts. Training sessions included two-three sets, eight-twelve reps, with 90 seconds rest in between sets for each exercise. Before training, the subject's 10RM was assessed to determine appropriate training loads. The load was adjusted as needed to obtain momentary concentric muscular failure. All subject's diets were watched and adjusted to make sure they had enough nutrients to obtain muscle hypertrophy. Whey protein supplements were given post training to enhance the anabolic effect by increasing MPS (which is well supported by many studies). Ultra sound was used to evaluate muscle thickness (MT) at three sites forearm flexors, forearm extensors, and vastus lateralis (thigh muscle). Muscle strength was assessed by 1RM testing using the parallel back squat and bench press. After analyzing the data they found that when adjusting for baseline, a significant difference was noted such that TOTAL produced superior results compared with SPLIT. Muscle thickness measured by ultra sound of the forearm flexors were greater in the TOTAL than the SPLIT, (6.5 vs. 4.4%, respectively). Muscle thickness of the quadriceps followed a similar pattern favoring the higher frequency protocol as well (0.70 vs. 0.18, respectively). 1 RM testing was higher in the TOTAL group for BENCH and SQUAT. The effect size for TOTAL was 96% greater than the SPLIT group. Well-trained athletes may benefit from periodically training a muscle three times a week to maximize muscle hypertrophy. Results are consistent with the time course of MPS, which has been shown to last approximately 48-hour post-resistance training (Peterson, Rhea, & Alvar, 2005). "Theoretically, keeping MPS consistently elevated over the course of each week would heighten myofibrillar protein accretion and thus have a positive effect on muscle size" (Schoenfeld Peterson, Ratamess, & Tiryaki-Sonmez, 2015, pg1826). Total body seems to be superior when compared to split routine. While maintaining the same amount of work between groups, training a muscle more often resulted in larger gains muscle size and strength.

Muscle protein synthesis

The previous study brought to light the time course of MPS. The time course of MPS elevation and its return to baseline will be discussed to support the theory on RT frequency. MPS has been theorized to indicate and predict skeletal muscle hypertrophy. A recent study by Damas et al. (2016), concluded that MPS is accurate at indicating hypertrophy in trained individuals after muscle damage is attenuated. Meaning, while muscle damage is increased MPS has no correlation with hypertrophy. However, when muscle damage is decreased after repeated bouts of resistance training, correlation is high. Therefore, MPS is an excellent proxy at determining hypertrophy given these conditions.

MPS has been shown in numerous studies to increase post resistance training. MacDougall, (1995) examined Muscle Protein Synthesis (MPS) 36 hours after training in healthy young men. Six subjects performed twelve sets of six to twelve RM elbow flexion exercises with one arm, while the opposite arm did no exercise to serve as a control. MPS was measured from the incorporation of an amino acid that can be traced called L-[1,$2^{-13}C_2$] leucine into biceps brachii of both arms using the primed constant infusion technique over 11hrs (Interisano, & Yarasheski, 1995). Four hours post training MPS increased 50% above baseline, and increased to 109% (nearly double) at 24 hours. At approximately 36 hours, MPS had returned to 14% of baseline (i.e., the control arm). This study suggest that following a heavy bout of resistance exercise MPS more than doubles by 24 hours, then rapidly declines to baseline around the 36 hour mark. MPS will be elevated for a maximum of only 36 hours. This begins to question the recovery time line, and the old school mentality of waiting seven days to train the same muscle again. Elevating MPS synthesis over time, makes an acute adaptation chronic. This may benefit any athlete or individual wishing to stay anabolic. Missed opportunities to elevate MPS with low RT frequency may be a detriment for athletes looking for hypertrophy adaptations.

Furthermore, a literature review by Damas et al. (2015) concluded that as an individual becomes more trained, MPS becomes short-lived compared to an individual in an un-trained state. Myofibril protein synthesis was shown to be two-fold higher, in some instances. Trained athletes may have a larger acute MPS, however MPS in un-trained individuals last longer and peak later. If Muscle Protein Synthesis has a weaker response in the highly trained due to adaptations to resistance training, it would make intuitive sense to increase this response as much as possible to obtain a hypertrophic response. Those who are RT individuals have two reasons two increase RT frequency from these articles. For one MPS peaks 24 hours after exercise and returns to baseline in 36 hours. Secondly the MPS response becomes weaker as an individual becomes for trained. More reason to increase how often a muscle is trained.

Over reaching with high frequency

Rapid increases n RT frequency can result in an individual over reaching (Baechle & Earle, 2008). Overreaching is the process of performing at a higher volume, intensity, or frequnecy for only a short period of time, which can be recovered from in a matter of days (Fry & Kraemer, 1997). Over reaching on a short-term basis, approximately one-two weeks can result in significant increases in muscle size and strength (Ratamess, 2003).

Ratamess, (2003) examined high resistance training with planned over reaching with and with -out supplementation of Amino Acids. Subjects were all trained men with an average of five years of previous training experience. In this study they had the subjects overreach, training total body for four weeks, following a two-week low volume high intensity de-load. Prior to the over-reaching phase, the participants completed four weeks of base resistance training to assure they were in a trained state. The base training included five exercises per work out, 2 days per week. After the four-week base training phase, the participants completed the overreaching phase. This was achieved by training each major muscle group five days a week consecutively. The over-reaching phase had a substantial increase in frequency and volume compared to the previous training phases. Initially strength and power were reduced, however the moderate-volume high intensity phase that followed enhanced muscular strength and power. Significant increases in 1RM bench and squat were observed in the second, third and fourth weeks of training. Even after a two-week de-loads, where the frequency and volume were decreased, strength still increased.

These results supported the concept of overreaching and indicated that a large short-term increase in training volume and frequency can produce significant increases in performance. (Ratamess, Kraemer, Volek, Rubin, Gomez, French, & Newton, 2003). Planned over reaching is warranted if adaptations of increased muscular strength and power are the goal. Over reaching can be achieved by increasing the rate of RT.

Efficacy of split routines

Although split routine can refer to training a muscle only once per week, they also commonly encompass training a muscle two times a week. Here I am going to review a study examining the efficacy of training a muscle twice per week. Training a muscle twice per week is sometimes characterized as bad, for the ignorant reasoning that one cannot recovery that quickly.

Classic Bodybuilding routines or “Bro-splits” more commonly referred to as a split routine as mentioned in the previous study by Schoenfeld et al., (2015) are characterized of training a muscle one-two times a week. Which has been considered optimal for muscle hypertrophy (Schoenfeld et al., 2015). SPLIT routines allow an individual to train at a higher volume per work out compared to total body work outs due to the fact that they are less energetically taxing and provide adequate recovery of about 72 hours or more in between training the same muscle (Kerksick et. al., 2009).

Kerksick et al., (2009) compared how college aged men (CA) and middle-aged men (MA) would respond to a SPLIT training routine. Each group followed a Linear Periodization protocol for eight to ten weeks, which although is short term is ample to elicit adaptations

(Buford et al. 2007, Kerksick, et. al. 2006, Kraemer et al. 1999). The training regimen consisted of an upper and lower body workout twice a week. Weeks one-four were three sets of ten, while weeks five-eight were three sets of eight targeting all major muscle groups.

Dual x-ray absorptiometry (DXA) revealed that after the 8 weeks, both groups increased body mass. Increased lean mass, and fat-free mass were similar in both groups. Not very surprising, the CA group reported overall greater increases in lean body mass, Fat-free mass, and maximal strength.

Although this study showed us that college age men had a greater hypertrophic and strength gain response to training than the middle age men, the interesting thing is that they both increased muscle and strength using a split routine training the muscle twice per week. Going back to the survey by Hackett et al. (2013), 100% of the bodybuilders that took the survey said that they only train a muscle group once per week in a "split routine" fashion. Perhaps even slight increases in frequency will lead to a greater response in those who are still training a muscle only once per week.

Self-selected resistance training frequency

In the world of athletics, athletes such as football players have special periods of times to emphasize and train for a particular goal. An "offseason" refers to a period of time a player has to focus on more strength and conditioning than sport skill (Baechle & Earle, 2008).

A study by Hoffman et al., (1990) observed athletes self-selecting a training frequency program for a winter conditioning program. Subjects were recruited from a division IAA football team for a ten-week winter conditioning program. The purpose was to see how training frequency would affect their strength. They could pick a three-day, four-day, five-day or six-day a week resistance training routine. To evaluate improvements, common offseason football field test were used before and after the program. These included the 1RM bench press, 1RM back squat, vertical jump, 40 yard sprints, and a two-mile run. Anthropometrics were measured as well to see if there were any changes in body composition.

All programs revealed in increase in performance. However, of all the variables, four and five days appeared to be superior in developing strength, endurance and muscle mass (Hoffman, Kraemer, Fry, Deschenes, Kemp, 1990). Since football players are judged based off a wide variety of assessments I believe that training six days a week may have been even more beneficial if looking solely at strength and muscle mass development. When endurance is a component, training for just strength and hypertrophy can take away from that skill. Football players are very advanced in the realm of resistance training. Even at their advanced level, the for group that trained more frequently gained superior size and strength, showing a relationship between RT frequency, muscular size and strength.

Frequency in weight lifting

Mclester, et al. (2000) compared recreational weight lifters training at different frequencies with matched volume. Group One trained once a week performing three sets to failure. Group Two trained three times a week performing one set to failure. The intensities were prescribed by each participant's 1RM. Each training set consisted of a rep range of three-ten in a periodized fashion. The results were pretty interesting. Although Group One only trained once per week, they significantly improved their 1rm with a 62% increase. However, Group Two which trained three times a week gained a noticeable amount of lean body mass and a further increase in strength than group one. Although the group who trained once per week saw increases in strength, the higher frequency group with matched volume saw an even larger increase in strength and lean body mass. From a dose-response perspective, with the total volume of exercise held constant, spreading the training frequency to three doses per week produced superior results (Mclester, Bishop, & Guilliams, 2000). Even though training once a week can increase strength, a higher frequency of two and three may elicit further gains in not only strength but also hypertrophy of the skeletal muscle, even with equal volume in experienced weight lifters. In this review, four out of five studies using trained individuals gained more muscle and strength with higher frequency of training than the groups used a lower frequency.

DISCUSSION

From reviewing the literature, evidence shows a relationship between increasing the frequency in which a trained individual resistance trains, and increases in muscle mass and strength. This may be correlated with MPS; however, other factors must be considered besides the time course of MPS when programming or manipulating the frequency of resistance training. Recovery from resistance training and elevation of anabolic hormones may be of great importance.

Recovery

Training frequency is related to the necessary amount of time to recover. Skeletal muscle must recover in between workouts in order to repair, adapt and avoid overtraining. Therefore, frequency must fall under the time frame of muscle recovery if hypertrophy or strength is the objective. Recovery of skeletal muscle is extremely elaborate. One can observe how long it takes on average for the immune system to return to baseline, sarcolemma repair, myofibrillar repair, and so on. For a very general idea, two studies with trained individuals using resistance training as the mode of exercise where chosen to get a sense of how long it may take to recover from their given exercise bout. Training experience, age and genetics all play a role in recovery, so these will only give a very general idea of the recovery timeline to take in to consideration.

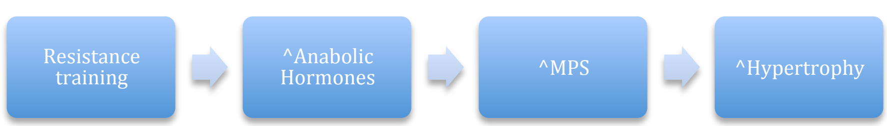
After a resistance training session, if intensity is high enough, and micro-trauma occurs an individual will feel pain in the trained muscle group. This pain is most commonly referred to as Delayed On Set Muscle Soreness (DOMS). DOMS can be felt in the muscle several hours to days after resistance training. DOMS is thought to be caused by eccentric lengthening, which causes micro-trauma to the muscle fiber (Yu, Fürst, & Thornell, 2003). Many researchers relate DOMS to Muscle damage and recovery for this reason. Soares et al., (2015) examined the dissociation of muscle damage recovery between single- and multi-joint exercises in highly resistance-trained men. More specifically the time course of elbow flexor recovery. Sixteen men with the average age of 24, performed eight sets of 10RM with the unilateral seated row exercise, and eight sets of ten with unilateral bicep preacher curls, with the contralateral arm. DOMS, and maximum isometric peak torque (PT) measured at baseline pre workout using an isokinetic dynamometer (biodex), 10 minutes after workout, then 24h, 48h, 72h, and 96 hours post training. Results indicate that DOMS in the multi-joint group returned to baseline levels after 72 hours post work out. DOMS was greater in the single-joint group increasing at 24, 48, and 72 hours. In single-joint exercises, PT was lower than baseline at 24 hours. In multi-joint group, PT returned to baseline at 24 hours. DOMS soreness can last up to 72 hours, however Peak Torque returned to baseline within 24 hours post heavy resistance training bout. Depending on whether or not an athlete uses multi-joint or single-joint exercises, they may not be able to perform strength or power activities at their best until 24-48 hours after the previous bout (Soares et al., 2015). Never the less, if peak torque returns to baseline approximately 24 hours post training, theoretically recovery of that particular muscle is complete, or near completion. This indicates reason to train more frequently through out the week or micro cycle. Decreases in strength immediately post-heavy resistance training has been observed in more advanced trained lifters. A complete recovery of MVC and 1RM can take approximately three days for this population. Although three days may seem desirable, it is not completely necessary. Increases in strength have been observed in shorter intervals in between training sessions (Tan, 1999).

If intensity is high enough, resistance training can cause micro trauma that will ultimately repair itself to a bigger, stronger muscle. This micro trauma occurs in the myofibrils. Recovery of myofibril damage is different between trained and untrained individuals. Further more, eccentric muscle actions causes more damage than concentric action. Gibala et al., (2000) observed the recovery time line of trained individuals performing concentric only and eccentric only training. Subjects performed unilateral bicep curls; one arm performed the concentric action while the other performed eccentric for a total of 8 sets of 8 repetitions each. Needle biopsy samples revealed a greater disruption of fibers in the eccentric only arm. The amount of damage quantified by electron microscopy was considerably less than untrained individuals in previous studies. They also concluded that the muscle recovery took about 5 days of inactivity following resistance training. Since strength and conditioning programs and body composition routines incorporate eccentric movements, it is an important take away that it may take up to 5 days of recovery. However, this study only took samples at 21 hours, and 5 days, which means that the recovery could be much less than 5 days. Regardless, waiting 7 days to train the muscle again may be pointless if recovery has been reached. The more trained the athlete is, less damage occurs to the muscle fiber which ultimately leads to less recovery time needed. This has also been termed the repeated bout affect (McHugh, Connolly, Eston, & Gleim, 1999).

Endocrine Responses

Resistance training can stimulate hormones in our bodies that may have an important role in muscle growth and recovery (McCaulley et al., 2008). Hormones such as Growth Hormone (GH), Testosterone (T), Insulin, and IGF are anabolic in nature and have shown to have positive effects with Hypertrophy, and MPS. (Griggs et. al. 1989, Gelfand et. al., 1987, Kupfer et. al., 1993, Mulligan et. al., 1993) Anabolic refers to the state in which a muscle is building large molecules like protein out of smaller ones like amino acids. Below is a logic model that illustrates the anabolic hormone theory developed through investigating the literature. Resistance training simulates an acute increase in anabolic horomones. Anabolic hormones elevate MPS, which increases muscle hypertrophy.

Figure 2 Anabolic Hormone Theory



A study by McCaulley et al. (2008), conducted a study to determine the acute neuroendocrine response to hypertrophy (H), Strength (S), and Power (P) style resistance training with equated volume. Recruited subjects for the study included ten healthy trained (>2 years) men. They completed an H phase, which included four sets of ten at 75% of 1RM, with

90 second rest intervals. For each phase the parallel back squat (with at least 90 degree knee flexion) was executed. Then an S phase followed, which included eleven sets of three at 90% of 1RM with five min rest intervals. Lastly was the P phase that included, eight sets of six jump squats at 0% of 1RM with three minutes of rest.

Blood samples were collected to measure the hormones testosterone, cortisol and total serum steroid hormone binding globulin (SHBG). SHBG is a protein that binds to the hormone T and other hormones. While bounded, SHBG transports these hormones in the blood as biologically inactive forms. Changes in SHBG levels can affect the amount of hormone that is available to be used by the body's tissues.

Blood samples were collected 20 minutes before exercise, immediately following the protocol, 1-hour post, 24 hours post, and 48 hours post. We will look at T and SHBG only, as they are anabolic hormones that may contribute to increases in skeletal muscle and strength (Griggs, Kingston, Jozefowicz, Herr, Forbes, & Halliday, 1989). T acutely elevated in all protocols from baseline. The H protocol reached a significant different percent change from pre to post ($p < 0.05$) for all three hormones, approximately 18nmol/L to 24 nmol/L. Across the board, T and SBHB returned to baseline 60 minutes post work out.

Table 4 Comparison of Testosterone and SHBG at rest and immediately post exercise

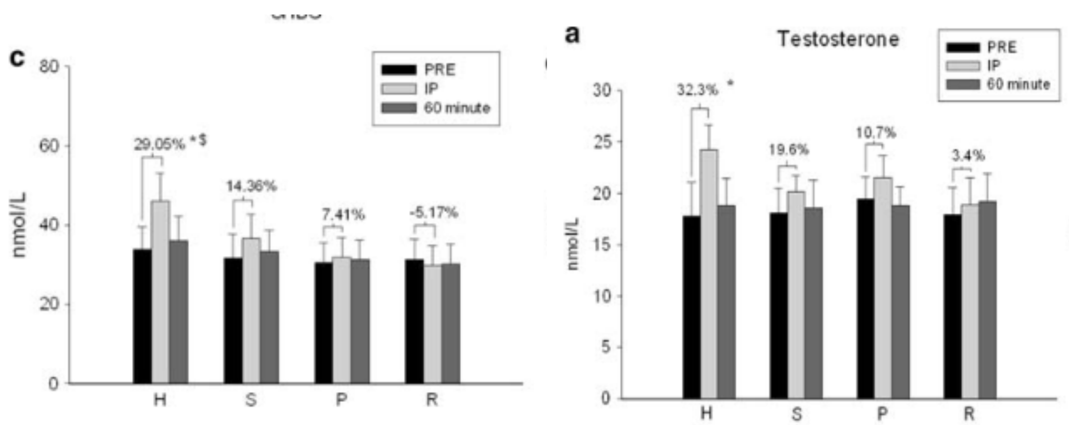


Table 3 (McCaulley, McBride, Cormie, Hudson, Nuzzo, Quindry, & Triplett, 2009).

Although the hypertrophy protocol with shorter rest intervals showed the highest acute elevation in testosterone and SHBG, both hormones returned to baseline just 60 minutes post exercise bout. This reinforces the idea that if T is anabolic and nature and elevation is an acute response, then resistance training more frequently may expose an individual to a more chronic elevation in testosterone thus creating a more anabolic state over time further increasing muscle hypertrophy, and strength.

Gotshalk et al., (1997), compared the anabolic hormones serum growth hormone (GH), testosterone (T), corstisol (C) in responses to single sets vs multiple sets of heavy resistance training routines. The study used eight recreationally weight-trained men, who completed two identical work out routines. Blood samples revealed that multiple sets showed significantly greater increases than single set at 5 minutes, 15 minutes, and 30 minutes post exercise (Gotshalk et. al 1997). Higher volumes of work produced greater increases in anabolic hormones post work out (Gotshalk, Kraemer, Loebel, Newton, Nindl, Putukian &Sebastianelli, 1997).

If training frequency is increased, then the muscles being trained can receive more volume, in which case may stimulate the increase in circulating anabolic hormones GH, T, observed in Lincolns's study which may have a positive effect of hypertrophy and strength.

Increasing resistance training stimulates increases in MPS and anabolic hormones. Both of which have been shown as necessary for optimal muscle growth (Damas et al., 2016, Griggs et. al. 1989, Gelfand et. al., 1987, Kupfer et. al., 1993, Mulligan et. al., 1993). Perhaps increasing this response more often has positive effects for trained individuals looking to get bigger and stronger. When designing a periodization for an athlete or individual who's goals are to gain size and strength, a higher frequency of training may be warranted. Like most design variables, this should be implemented in a periodized fashion. Training a muscle once a week may be beneficial for beginners, but may not be optimal for more advanced athletes. The survey that revealed that 127 out of 127 bodybuilders train only one muscle group per week is rather alarming. Given the evidence found for the time course of MPS, recovery, and anabolic hormones. (Hackett, Johnson, & Chow, 2013). Individuals with low RT frequencies may be missing out on opportunities to improve strength, power, and hypertrophy. The readiness of the trainee for increases frequency should be determined based off past training experience and training age. Higher volumes in one's offseason may incorporate higher frequencies to accommodate the higher volume of training each week. In other words, to manage a higher volume of training, you can spread the volume into several sessions.

Every few micro cycles the coach may increase the training frequency and intensities in an attempt to over-reach the athlete. Followed by a deload to manage fatigue and to stay away from over-training. This may elicit super compensation for further gains in muscle mass and strength (Ratamess, 2003). Incorporation of active recovery days may be implemented as well. Active recovery is the process of using submaximal exercise using the same muscles to promote recovery (Bogdanis, Nevill, Lakomy, Graham, & Louis, 1996). This may be prudent to maintain motor learning of exercises, and to promote faster recovery (Corder, Potteiger, Nau, Figoni & Hershberger, 2000). Increases in frequency throughout the week can incorporate different reps and sets to avoid boredom and possibly further increase strength, such as Daily Undulating Periodization (DUP) protocols (Rhea et.al, 2000).

Further research and limitations

Schoenfeld, (2016) has a meta-analysis under review that examined resistance-training frequency with untrained subjects. His conclusion was that training a muscle three times per week was superior to one. However, his review included untrained participants. The lack of studies on resistance-trained individuals warrants further research in this area to better our understanding on the mechanisms at play. Future research should focus on longitudinal studies on highly trained individuals to see if there are benefits in increased frequency, and what the dose-response is. Frequency of resistance training is a piece of the puzzle under utilized when it comes to increases in performance. Perhaps further research will elucidate this concept which will help guide coaches and trainers with conditioning top level athletes every where.

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