5-2005

Acute Physiological Responses and Psychological Perceptions of Various Resistance Training Regimens

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Acute Physiological Responses and Psychological Perceptions of Various Resistance Training Regimens

A Thesis Presented to the School of Health, Physical Education, and Recreation,

and the

Faculty of the Graduate College at the University of Nebraska.

In Partial Fulfillment of the Requirements for the Degree

Master of Science

University of Nebraska at Omaha

By

William J. Vincent

May, 2005

THESIS ACCEPTANCE

Acceptance for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Science in Exercise Science, University of Nebraska at Omaha.

Committee

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Chairperson______________________________

Date 5-3-05

ACUTE PHYSIOLOGICAL RESPONSES AND PHYSIOLOGICAL PERCEPTIONS OF VARIOUS RESISTANCE TRAINING REGIMENS

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University of Nebraska, 2005

Chair: Dr. Kris Berg

The purpose of the current study was to examine the effects of four different resistance training protocols associated with periodization of resistance training on the biological signals that are associated with exercise regimens to increase muscle hypertrophy. A secondary purpose was to compare the ratings of perceived exertion (RPE) in the four weight training regimens.

A total of eight male resistance trainers within the ages of 23-35 served as subjects for this study. On the first visit all had a baseline blood assay drawn to measure human growth hormone (hGH) and testosterone (T) and their 5 repetition maximum (RM) strength assessed using the squat, bench press, and lat pull-down machine. On subsequent visits subjects completed four workouts, each of which incorporated a warm up set followed by three sets of each of the above lifts. Each workout also integrated a 5 or 10 RM and/or a 1 or 3 min interset rest period. For each workout pre, middle, and post blood lactate content (BLC) was assessed along with a post workout blood assay to measure levels of hGH and testosterone T. Middle and post RPE was also measured both locally (in the muscle group just worked) and globally (the entire body). A 2x2 repeated measures factorial analysis of variance (ANOVA) incorporating load and duration of the interset rest period was used for every measure of each dependent variable.

The results demonstrated that workouts which incorporated 10 RM per set produced significantly greater levels of BLC, hGH, T, and RPE values than 5 RM workouts ($P \leq 0.05$). Significant interaction did not occur with the exception of hGH and mid workout local RPE where the 10 RM / 1 min interset rest period regimen produced significantly higher values than both 5 RM workouts ($P \leq 0.05$) but not the 10 RM / 3 min interset rest period workout. In conclusion, based on the results of this study it appears that 10 RM with one minute interset rest periods may provide a more effective stimulus for muscle hypertrophy than 5 RM with 3 min rest periods.

Acknowledgements

This study would have never been possible without the aid of several exceptional people. Therefore, I would like to thank the following:

First, **the subjects**, it has truly been a researchers dream working with you. Your willingness to put up with all of the finger pricks and blood draws and push your body to, and in a couple cases, past muscular exhaustion all while holding a positive attitude has made me immensely appreciative.

Melissa Meisinger, Kenji Narazaki, and Chris Sjoberg – It has been a piece of good fortune working with all of you. Your sense of humor and patient compliance in helping me with so many early morning workouts is deeply valued.

The nurses at Student Health, **Marcia, Suzie, and Julie** – your time, kindness, financial generosity, and proficient phlebotomy skills have played an enormous role in making this research possible.

Dr. Jeffery French – Your gifted intelligence, monetary kindheartedness, and practiced hormonal assay knowledge and skills have contributed massively to the quality of this thesis. It has been a pleasure working with you and having you as part of my committee.

Dr. Richard Latin – I feel blessed to have had your guidance throughout my collegiate years. Your to the point teaching style and cool personality have made learning and working under you an exuberating experience. I feel honored and am beyond sincere in how grateful I am to have had you as not only part of my committee, but a noteworthy element of my academic life.

Dr. Kris Berg – Your caring actions speak wonders and your wisdom is positively extraordinary. Most of all your passion for fitness has shined vividly into my heart and motivated me in numerous ways. It is immeasurable in how much pride I have to have had you as my supervisor, thesis chair, professor, and especially mentor.

My parents, **Jim and Coleen Vincent** – Words can not express the feelings I have for both of you. I feel like the luckiest son in the world. If one day someone admires and respects me as much as I do both of you then my largest lifetime goal has been achieved. Everything positive in my life can be traced back to you two. I am eternally grateful for everything.

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Chapter 1. Introduction

Muscle increases both in size and strength as a result of chronic exercise. A variety of training methods are known to achieve these effects. Strength training is typically done by the use of heavy weight, low repetitions, and relatively long interset rest periods (Keul, Haralambie, Bruder, & Gottstein, 1978; Tesch, Thorsson, & Kaiser, 1984). Bodybuilding, or "hypertrophy" training, on the other hand is most often done with lower weight, higher repetitions, and shorter interset rest periods (Tesch, Colliander, & Kaiser, 1986; Tesch & Larsson, 1982). Modern resistance training often incorporates alternating cycles of bodybuilding and strength training in a process known as periodization. This approach is used to constant acclimatization to different types of resistance training (Baechle & Earle, 1994, p.511).

The chronic effect of hypoxia and hormonal response as a result of resistance training, which are known contributors to muscle hypertrophy and strength gains, remains relatively unstudied. Buresh & Berg (2003) found a greater percentage increase in the 1 repetition maximum (RM) and cross sectional area (CSA) with a muscular strength training protocol as compared to a bodybuilding protocol. However, that same protocol produced less of a hormonal response (testosterone, growth hormone, and cortisol) compared to the bodybuilding protocol ($P \leq 0.05$). Takarada, Takazawa, Sato, Takebayashi, Tanaka, and Ishii (2000) concluded that a local hypoxic and acidic intramuscular environment during a low-intensity and 60 second interset rest period resistance-training protocol (30-50% 1RM) induced hypertrophy. This investigation showed significantly larger gains in CSA of the biceps and triceps and maximal isometric and isokinetic elbow flexor strength in one arm with tourniquet occlusion compared to the opposite arm which performed only light intensity training at the same load ($P<0.05$). Consequently, further research on the chronic effects of training appears warranted.

Several acute responses to resistance exercise appear to be helpful in eliciting muscle hypertrophy. These include muscle damage, skeletal muscle hypoxia, and serum hormone response. Hormone response immediately following resistance training seems to be higher after a bodybuilding or strength/endurance session than a strength training or power lifting session. Buresh and Berg (2003) found that a one minute interset rest period workout exhibited greater overall testosterone (T) and cortisol (C) levels ($P \leq 0.05$) compared to 2.5 minute interset rest period workout. Burger and Burger (2002) in a review of literature also concluded that higher intensity strength training seems to elicit greater acute T, human growth hormone (hGH), and C concentrations. Kraemer et al. (1991) compared one session of a 5 RM based workout with 3 minute interset rest periods while the other session consisted of a 10 RM based workout with one minute interset rest periods. Serum T concentrations were significantly increased in males by both exercise protocols for up to 15 minutes after exercise ($P<0.05$). Mid exercise values were significantly greater in the session with the shorter interset rest periods ($P<0.05$) while 60 minutes post exercise values were significantly greater in the long interset rest session ($P<0.05$). The short rest session showed significantly greater increases in hGH compared to the long rest session for both males and females at all stages with the exception of pre-exercise ($P<0.05$). McCall, Byrns, Fleck, Dickinson, and Kraemer (1999) observed that three sets of 10 RM for eight exercises with a one-minute rest between sets and exercises significantly increased hGH, insulin-like growth factor-1, T, C, and sex hormone-binding globulin concentrations ($P<0.05$). Smilios, Piliamidis, Karamouzis, and Tokmakidis (2003) compared hormonal response differences among three different workouts (maximal strength, muscular hypertrophy, and muscular endurance). In both the hypertrophy and strength endurance workouts a higher number of sets induced higher C concentrations ($P<0.05$). In the muscular strength workouts the number of sets did not affect C concentrations and there were also no differences found in any of the maximum strength exercise sessions compared to the control session ($P>0.05$). Gotshalk et al. (1997) also found that a higher number of sets stimulated a greater hormonal response than a lower number of sets.

Muscle damage is another factor that has been theorized to affect muscular hypertrophy. Evans and Cannon (1991) found that by increasing time under tension a moderate-repetition set (8-10 repetitions) accentuates muscle damage. Conceptually, the longer that myosin cross-bridge attachment to actin is sustained, the larger possibility for muscle tissue damage to occur. This would favor moderate repetition sets over low repetition sets (<5 repetitions) because cross bridge formation is sustained longer (Schoenfeld, 2000). High force eccentric contractions have also been greatly associated with muscle damage response (LaStayo, Woolf, Lewek, Snyder-Mackler, Trude-Reich, & Lindstedt, 2003). However, Folland, Chong, Copeman, and Jones (2001) concluded that after nine weeks of training a single set of eccentric arm flexor exercise did not amplify the response to conventional strength training and considerably compromised strength increases for several weeks. These studies suggest that the duration of each contraction on the intramuscular pH level, as well as the recovery duration all influence development of muscle strength and hypertrophy. However, evidence is needed to compare various work-rest ratios and loads to determine their effects on pH / lactate, muscle hypoxia, serum hormone level, and muscle damage.

There is a need for research to link acute hormonal responses to chronic responses. This may help establish a rationale for designing more effective programs for hypertrophy. Researchers must study more typically used regimens and see how the effects of major stimuli known for the development of hypertrophy respond. Then more training studies based on these results must be carried out. Athletes, children, obese persons, and those with diabetes and coronary artery disease might all benefit from having additional muscle mass.

The purpose of the current study was to examine the effects of four different resistance training protocols associated with periodization of resistance training on the biological signals that are associated with exercise regimens to increase muscle hypertrophy. Little is known about the interactions of various weight training regimens on the acute hormonal and intramuscular/extracellular pH. This information might enhance our understanding of the possible mechanisms involved in hypertrophy. Several studies have examined acute and chronic hormone responses as a result of resistance training. However, there have been very few studies that have compared various resistance-training protocols and their effect on acute hormone responses and acute lactate response, which is a possible indicator of hypoxia. Furthermore, there has been little work on ratings of perceived exertion (RPE) related to various weight training regimens. Knowledge of RPE associated with different weight training regimens may be useful in the prescription of resistance training exercise.

Chapter 2. The Problem

Purpose

The primary purpose of this study was to examine the effects of four different resistance-training protocols on biological signals that are associated with an increase muscle hypertrophy. These signals include blood lactate concentration and hormone levels of T and hGH. A secondary purpose was to compare the ratings of perceived exertion (RPE) in the four weight training regimens.

Hypothesis

The following hypotheses were tested in this study:

1. Lactic Acid: Mid and post blood lactate content for the 10 RM/1 minute interset rest regimen will be higher than all of the other regimens.
2. Hormone: T and hGH levels for 10 RM/1 minute interset rest regimen will be greater than the other regimens.
3. RPE: Subjects' local and global RPE will be greatest at mid and post workout for the 10 RM/1 minute interset rest regimen than the other regimens.

Delimitations

This study's intentions were to examine the effects of four different resistance training protocols. Subjects were eight healthy trained men within the ages of 23-35 years attending the University of Nebraska at Omaha. The exercise sessions were supervised and conducted in the HPER Building at the University of Nebraska at Omaha. The data collection phase of this took place over a period of approximately six weeks.

The acute effects among hormone responses, blood lactate concentration, and RPE were examined and compared among the four protocols.

Limitations

Limitations of this study may have included:

1. Subjects may or may not have not given their best effort in testing.
2. Subjects may have taken certain medications, nutritional supplements, or other substances such as caffeine or over the counter medications for colds that may have had an effect on the results.
3. Other possibly meaningful physiologic data such as intramuscular pH and PO2 were not measured.
4. Diet and state of rest were not controlled.
5. Other hormone(s) affecting protein turnover such as insulin-like growth factor were not measured.

Definition of Terms

For clarity the following functional terms are defined:

Bodybuilding – Resistance training workouts characterized by lower weight and higher repetitions and a major goal of achieving hypertrophy

Hypertrophy – Increased muscle size from resistance training

Interset rest period – The amount of time the subject rests between sets.

Repetitions – The number of consecutive times a lift is performed

Set – A certain number of consecutive repetitions performed followed by a period of rest

RM (Repetition Maximum) – The maximal amount of weight that that can be used in order to complete a set of a given number of repetitions.

Momentary RM – Weight removed following a set to permit doing a 5 or 10 RM for the following set.

Significance of Study

No known published studies have examined the effects on acute hormone responses, acute lactate response, and RPE among different resistance-training protocols. Identification of the optimum training regimen for achieving hypertrophy seems to be an important objective among anyone interested in muscle training. However, little scientific knowledge is actually available to guide exercise professionals in developing exercise programs to optimize this training objective. In comparison, a vast number of studies have been conducted that focus on strength development.

Information from this study may be helpful in assisting those with the goal of gaining muscle. In other words, the current study may be a small step in eventually determining what sort of resistance training program helps best facilitate an individual's resistance training goals. Further, initially studying the acute effects of entities such as hormonal response and lactate response may prompt others to conduct long term studies to examine how much hypertrophy certain resistance training programs produce. This descriptive work, however, appears to be a logical step in the acquisition of knowledge about how training affects the development of skeletal muscle.

Chapter 3. Review of Literature

Introduction

There are several known physiological alterations that occur in skeletal muscle hypertrophy. Individual muscle fiber hypertrophy can be explained by the presence of more myofibrils, actin and myosin filaments, sarcoplasm, connective tissue, or any combination of these (Wilmore & Costill, 1999). These structural changes occur as a result of a net increase in muscle protein synthesis and decrease in protein degradation (Wilmore & Costill, 1999). Hormones, hypoxia, and muscle damage which most likely has to do with the intensity of the resistance training session(s) are widely accepted mechanisms for signaling DNA activity within muscle cells. Tension overload may encourage a production of connective tissue and satellite cells which surround the muscle fiber thus strengthening the muscle's connective tissue through release of growth factors (McArdle et al., 1991). This chapter will review studies that have examined the role of resistance training in hormone response, hypoxia, and muscle damage which are all known mechanisms that contribute to hypertrophy. Also the levels of RPE associated with various types of weight training regimens will be reviewed.

Effects of Hypoxia on Hypertrophy

Takarada et al. (2000) examined the effectiveness of relatively low-intensity weight training combined with vascular occlusion in producing improvements in hypertrophy and muscular strength in older women. Previously the authors studied the acute effects of resistance exercise combined with vascular occlusion on muscular function using five men. The mean integrated electromyocardiogram (iEMG), postexercise blood glucose, and plasma lactate concentration were all significantly raised with increase in occlusion pressure at a low-intensity exercise, while they were unchanged with the increase of occlusion pressure at high intensity exercise ($P<0.05$).

Takarada et al.'s (2000) study was designed to investigate the long term effects of low intensity weight training with occlusion, low intensity weight training without occlusion, and high-to medium-intensity weight training without occlusion. Twenty-four older women participated in a 16 week weight training program for elbow flexor muscles. Five of the subjects participated as controls and were told not to engage in any weight training for the duration of data collection. Eleven subjects participated in occlusive training and eight subjects participated in normal training. The low intensity exercise was performed at an intensity of 30-50% 1RM while the high-to medium-intensity was performed at 50-80% 1RM. In the low intensity with occlusion group one arm was trained with its proximal portion compressed to 110 ± 7.1 mmHg for the entire exercise session. The contralateral arm for each subject in this group was trained without occlusion with high-to medium-intensity that has typically been used for gaining muscle size and strength. The low intensity without occlusion group did the same exercise with similar intensity and quantity as performed with the other group's occluded arms. Each exercise session was performed twice per week and consisted of three sets of exercise with an interset rest period of one minute. In the occlusive group exercise was done to failure with both the low and medium-high intensities while the non-occlusive group was instructed to match the number of repetitions performed by the occlusive group's occluded arms.

Significant increases in the cross sectional area (CSA) of the biceps brachii were found with all three forms of resistance training ($P<0.05$). The CSA of the triceps brachii significantly increased in both arms in the group who performed low intensity with occlusion and high-to medium-intensity exercise ($P<0.05$). The percent increase in CSA of both the biceps brachii and brachialis was significantly higher in the occlusion group's occluded arm than in the group that did low intensity exercise without occlusion with an increase of 20.3 and 17.8% compared to 6.9 and 3.8% ($P<0.05$), respectively. The occluded arm's increase in CSA of the biceps brachii and brachialis was higher than the increase in medium-to high-intensity arms but the increase was not significant. However, the triceps brachii demonstrated significantly greater increase in CSA (13.7%) after 16 weeks of training with occlusion than both the medium-to high-intensity arms (6.6%) and the low intensity without occlusion arms (1.5%) ($P<0.05$).

Both isometric and isokinetic strength significantly increased with all types of resistance exercise training ($P<0.05$) while there was no change in strength with the control group. The low intensity with occlusion group's increase in arm strength (18.4 $\pm$1.5%) was significantly greater than that of the low intensity without occlusion arms (1.04 $\pm$ 1.2%) ($P<0.05$). The strength increase of the arms of the high-to medium – intensity group (22.6 $\pm$ 2.0%) was higher than that of the low intensity with occlusion group arms but was not significant. The authors concluded that weight training at a intensity below 50% 1RM when combined with vascular occlusion is effective in producing hypertrophy and increasing strength.

Hormonal Response to Weight Training

Buresh and Berg (2003) took 13 non-regular weight lifting males between the ages of 19-41 years through one of two 10-week resistance training programs. One group had an interset rest period of one minute while the other group's interset test period was 2.5 minutes. The repetitions and sets were constant for both groups. At the end of the 10 weeks the long rest group's increase in arm CSA was significantly greater ($P \leq 0.05$) with a 12.3% increase compared to the short rest group with only a 5.4% increase. The long rest group also demonstrated a slightly higher strength increase ($P \leq 0.05$) while the short rest group exhibited greater overall T and C levels ($P \leq 0.05$) with an increase (10.5 ng/dl and 32.9 mg/ml, respectively) compared to the long rest group (7.1 ng/dl and 22.8 mg/ml, respectively). This acute hormonal response finding is somewhat related to the studies of Kraemer et al. (1991) and Smilios et al. (2003) in that resistance training using a bodybuilding protocol elicits a higher hormonal response than a strength training protocol.

Similios et al. (2003) had 11 men in their mid twenties who were all moderately active in resistance training (two to three times per week) perform eight resistance training sessions in order to compare the hormonal response difference between three different workouts (maximal strength, muscular hypertrophy, and muscular endurance). In addition, the subjects participated in a control session in order to account for the effects of circadian rhythm on the hormonal concentrations.

The maximum strength and the muscular hypertrophy workouts were performed on three different occasions with two, four, and six sets each exercise, whereas the strength endurance workouts were executed on two separate occasions with two and four sets each exercise. The muscular strength workouts consisted of five repetitions at 80-88% of the 1RM for the first set and an interset rest period of three minutes. The initial intensity for the muscular hypertrophy workouts was 68-75% of the 1RM and 10 repetitions were performed at each set with an interset rest period of two minutes. Fifteen repetitions were performed at each set with a one-minute interset rest period for the strength endurance workouts and the initial intensity was set at 52-60% of the 1RM.

In the strength workouts no differences ($P>0.05$) in T concentrations were observed whether two, four, or six sets were performed or between the exercise sessions and control session. T concentrations also did not differ ($P>0.05$) between the three exercise conditions and the control session at any time and point. This finding somewhat conflicts with the studies of Buresh and Berg (2003) and Kraemer et al. (1991) in that exercise induced T increases were found in pre and post tests (no control groups existed in these studies) with longer interset rest periods, although not to the extent of shorter interset rest periods. Growth hormone (hGH) concentrations were higher immediately after exercise ($P<0.05$) when four sets were performed than two sets and six sets. All maximum strength workouts induced higher hGH levels ($P<0.05$) compared to the control session. The number of sets did not affect C concentrations and there were also no differences found in any of the maximum strength exercise sessions compared to the control session ($P>0.05$).

Like the maximum strength workouts the muscular hypertrophy workouts showed no differences in testosterone concentrations ($P>0.05$) among the performance of two, four or six sets or between exercise sessions and the control session. The concentrations of hGH after the four and six set sessions were higher after the workouts compared to the two set sessions ($P<0.05$). There were no differences in hGH concentrations between the four and six set sessions after the workouts ($P>0.05$). C concentrations were higher after the performance of four and six sets compared with the performance of two sets and the control session ($P<0.05$). No differences ($P>0.05$) were observed between the four and six set sessions as well as between the two sets and control session in C concentrations.

In the strength endurance workouts T concentrations were higher ($P<0.05$) after the workouts compared to the control session. No differences were found between the two and four set workouts ($P>0.05$). Concentrations of hGH were higher ($P<0.05$) after performing four sets than two sets. Both exercise sessions yielded higher hGH concentrations compared with the control session. Higher sets also induced higher C concentrations ($P<0.05$).

Kraemer et al. (1991) conducted a study which examined the acute response patterns of serum testosterone, growth hormone, and somatomedin-C (Sm-C) to heavy resistance exercise, compared between males and females. Sixteen people (eight males and eight females) participated as subjects. All subjects were in their twenties and had recreational experience with resistance training. Each participant went through two different resistance-raining sessions which were spaced 72 hours apart. One session was a five RM based workout with three minute interset rest periods while the other session consisted of a 10 RM based workout with one minute interset rest periods. Blood samples were obtained pre-exercise, mid-exercise, immediately post exercise, and at 5, 15, 30, and 60 minutes post exercise.

There were many significant acute hormonal changes as a result of exercise. Serum T concentrations were increased in males by both exercise protocols for up to 15 minutes after exercise ($P \leq 0.05$). Mid exercise values were significantly greater in the session with the shorter interset rest periods while 60 minutes post exercise values were significantly greater in the long interset rest session ($P \leq 0.05$). The short rest session showed significantly greater increases in hGH compared to the long rest session for both males and females at all stages with the exception of pre-exercise ($P \leq 0.05$). This increase in exercise induced hormonal levels as a result of a short interset rest periods is consistent with the findings of Buresh and Berg (2003) and Smilios et al. (2003). Females demonstrated significantly higher pre-exercise hGH levels than males ($P \leq 0.05$). Sm-C showed significant increases but in no constant pattern in both males and females above rest in both sessions ($P \leq 0.05$).

Guezennec, Leger, Lhoste, Aymonod, and Pesquies (1986) tested 11 male experienced weight-trained athletes who were between the ages of 28-38 years once per month for four months in both a submaximal and a maximal bench press test. Blood samples were obtained prior to the tests after the subjects had been in a lying position for 15 minutes, 3 minutes after the submaximal test, and 3 minutes after the maximal test. The training regimens were of the following type: 10 repetitions per set at 70% maximal load, three to four sets per exercise with 2.5 minute interset rest periods, and three to four sessions per week. Such a training procedure was maintained during the first month of the study. For the last three months, the number of repetitions per set was reduced from 10 to 3 and the relative load increased from 70% to 95% of the subject's 1RM.

The maximal number of repetitions at 70% initial maximal load increased significantly ($P<0.05$) with a 31% increase over the four-month period. There was no significant change in plasma insulin after submaximal and maximal work. Plasma C increased after submaximal and maximal work for the last month only. Norephinephrine increased after submaximal work ($P<0.05$). Epinephrine also increased after submaximal work ($P<0.05$) but was significant ($P<0.05$) for the last two months only after maximal work.

Kraemer et al. (1992) led a study where 28 teenage participants (ages 17.3 ±1.4 yr) in a junior age group national weightlifting camp went through a protocol which consisted of consecutive maximal vertical jumps followed by heavy snatch lifts to failure. The purpose of the investigation was to determine the effects of an acute weightlifting exercise session on hormonal responses in elite adolescent male weightlifters. The authors were also interested in the influence of maximal strength and training experience on the hormonal response patterns. Blood samples were obtained early in the morning to determine baseline values of total T, C, hGH, B-endorphin, and whole blood lactate. Blood samples were taken prior to exercise and again at five and 15 minutes following the exercise session.

The finding that stands out in this study was that the length of resistance training experience appeared to influence the exercise-induced response patterns of T. An exercise-induced increase in serum T was observed consequent to the weightlifting exercise session only in the group with over two years of experience ($P<0.05$). The group of weightlifters with less than two years of training experience did not exhibit a significant exercise-induced increase in serum T concentrations ($P>0.05$). This finding is interesting because exercise induced T concentrations were also increased with somewhat experienced weight-lifters (Guezennec et al. 1986, Smilios et al. 2003) and also in non-experienced weight lifters (Buresh & Berg 2003, Kraemer et al. 1991). All of these studies showed significantly increased T concentrations when utilizing short interset rest periods. Results of the Kraemer et al. (1992) study conflict with the studies conducted by Buresh and Berg (2003) and Kraemer et al. (1991) when it comes to in-experienced weight lifters exercise induced T responses. None of the other hormones assessed or whole blood lactate in this study was influenced by the training status so it was further concluded that maximal strength capabilities did not influence hormonal responses. However, all measured hormones and whole blood lactate significantly increased from pre to post training session in both groups ($P \leq 0.05$).

McCall et al. (1999) investigated the effects of high volume resistance training on the acute-exercise induced hormonal response as well as on resting hormone concentrations. Eleven college men (ages 18-25 years) with recreational resistance training experience completed 12 weeks of training at a frequency of three sessions a week. Each session consisted of three 10 RM sets for eight exercises with a one-minute rest between sets and exercises. Before and after training subjects underwent testing sessions to evaluate the efficacy of the training for increasing strength and muscle cross sectional area (CSA). Blood samples were collected to examine hGH, insulin-like growth factor-1, T, C, and sex hormone-binding globulin. Resting blood samples were collected before and after the 12-week training program and exercise blood samples were collected during the fourth and eighth week of training. To control for factors other than resistance training which could affect hormone concentrations, eight college men not participating in resistance training served as controls.

Training resulted in a 25% increase in 1-RM forearm flexor strength. Magnetic resonance imaging (MRI) scans indicated hypertrophy of biceps brachii muscle CSA from 11.8 +_ 2.7 cm pretraining to 13.3 +_ 2.6 cm postraining. No differences in resting hormone concentrations occurred between groups. However C significantly decreased 16.7% from pretraining ($P \leq 0.05$). Resting hormone concentrations and the patterns of acute exercise hormonal elevations during the fourth and eighth week were not changed by 12 weeks of resistance training. Although the pattern of response varied between hormones, acute exercise increased all hormone concentrations. Unfortunately, a limitation of this study was that obtaining a true pretraining acute exercise response was impossible because subjects could not strictly adhere to the protocol's one-minute interval at the outset.

Effects of Eccentric Training

Folland et al. (2001) investigated the effect of a single acute bout of eccentric work upon strength gains during nine successive weeks of strength training. Twenty-six subjects participated in this study. All participants trained their elbow flexors three days-per-week for the entire nine weeks. One arm was trained using traditional isotonic training only (lifting and lowering) and the other arm began with a single bout of eccentric work followed by identical isotonic training. Both isometric and dynamic 1RM strength were measured every week.

Results showed the mean 1 RM significantly increased from 9.1 +_ 0.5 kg to 12.8 ± 0.7 kg for the eccentric arm and from 8.8 ± 0.5 to 12.8 ± 0.6 kg for the traditional isotonic training only training arm ($P<0.01$). Both arms also significantly increased their isometric strength from pre-to post-training ($P<0.001$). However, there were not any significant differences from pre-to post-training between arms in either 1 RM or isometric strength tests ($P>0.05$). The authors concluded that after nine weeks of training using a single bout of eccentric work did not increase the reaction to traditional strength training and inhibited strength gains for the first few weeks.

Evans and Cannon (1991) conducted a review of literature that focused on the delayed nature of exercise-induced muscle damage and discussed mechanisms that may be involved. Some of the main findings of this review include the fact that eccentric exercise often results in delayed onset muscle soreness (DOMS). However, iEMG of eccentric exercise is smaller than that of concentric exercise and unlike concentric exercise does not increase as force production increases. Eccentric exercise was also found to generate greater tension per muscle fiber than concentric exercise but relatively few fibers were recruited that created these large forces. This review somewhat supports the findings of Folland et al. (2001) which found that a single bout of eccentric work significantly compromised strength gains for several weeks ($P<0.05$).

Davies and White (1981) studied the separate effects of eccentric and concentric work on stimulated and voluntary isometric contraction of the triceps surae. Five males performed chair stepping for one hour with a single leg. Results showed that maximal twitch and tetanic tensions during chair stepping in the eccentric leg were significantly reduced for an extended period, while the contralateral concentric leg was not affected ($P<0.10$). The eccentric leg was also found to be more fatiguable than the concentric leg. The authors pointed out that exercise resulting in muscle damage (such as eccentric training) also has the ability of fabricating hypertrophy, which ultimately lessens the risk of future muscle damage from that specific exercise.

Two studies, Vihko, Salminen, and Rantamaki (1979) & Friden, Seger, Sjostrom and Ekblom, (1983), concluded that exercise training causes a resistance to the damaging effects of exercise which suggests an increase in muscle protein turnover. Vihko et al. (1979) studied the activity of selected lysosome acids which reflect damage to muscle fibers on five groups of mice. The groups consisted of sedentary controls, never trained or exhausted; exhausted controls, exhausted once by running on a treadmill 5, 10, or 20 days before being killed; trained mice, continually exercised but not exhausted before being killed; exhausted trained mice, exercising until exhausted and then living under normal conditions for 5, 10, or 20 days before being killed; and detrained animals, where training was terminated 5, 10, and 20 days before being killed. In the untrained mice exhaustive exercise caused fiber necroses and a significant increase in all lysosome acid markers in red muscle fibers 5 days after exercise ($P<0.05$). The authors concluded that training causes an apparent resistance to the injurious effects of exhaustive exercise in mice.

Friden et al. (1983) took 15 males in their twenties through both a four and eight week eccentric training program which studied the peripheral adaptation in the vastus lateralis as a result of repetitive eccentric training. Exercise was performed on a cycle ergometer modified for eccentric work. The subjects cycled to fatigue 2-3 times per week at an intensity of 6,000-18,000 Nm/min. All participants suffered from definite soreness of the knee extensors during the first 1-2 weeks of exercise. Following the first two weeks soreness progressively decreased and all subjects were free of symptoms after three weeks of exercise. Maximal dynamic concentric muscle strength increased slightly over the eight week period but was not significantly different from the controls ($P<0.05$).

However, eccentric work capacity significantly increased 375% after eight weeks of cycling ($P<0.001$). A significantly increased amount of type IIc fibers was also detected after eight weeks of training ($P<0.01$). Volume density of mitichondria was significantly higher in all fiber types after four weeks of training and type IIa only after eight weeks of training ($P<0.05$). The authors concluded that skeletal muscle adapts to excessive tension demands placed on it and speculate that enhanced coordination and rebuilding of the muscle fibers are the determinants of this adaptation.

Two other studies, Komi and Buskirk (1972) and Pierson and Costill (1988), found that only the eccentric trained limb or group (as opposed to the concentric trained) increased in size as a result of training which suggests the eccentric exercise-induced muscle damage and its later repair may be importaint for increasing muscle fiber size, or producing hypertrophy, in response to resistance training. Komi and Buskirk (1972) studied the effects of seven weeks of concentric and eccentric training on muscle tension and IEMG. Thirty-one college men were randomly placed into one of three groups (control, eccentric, and concentric). Subjects in the eccentric group did a forearm flexion workout on a dynamometer four times per week performing maximal eccentric contractions of the right forearm flexors at an elbow angle of 65-170 degrees six times per day. The concentric group performed maximum concentric contractions of the right forearm flexors on the same dynamometer that the eccentric group used. The velocity of contraction, elbow angles, daily repetitions, and conditioning period were the same as the eccentric group.

Results showed that both groups significantly increased maximal tension while the control group did not ($P<0.05$). However, the eccentric group significantly increased maximal tension more than the concentric group in all three measured forces (concentric, eccentric, and isometric) ($P<0.05$). This opposes the results of Folland et al. (2001) (previously summarized) which showed that eccentric training did not increase the reaction to traditional strength training and inhibited strength gains for the first few weeks of training ($P<0.05$). Komi and Buskirk (1972) also found that the mean increase of the upper arm girth of the trained arm was significant in the eccentric trained group while there was no significant increase in the concentric trained or control groups' ($P<0.01$). During the first week of training, the eccentric group complained of muscle soreness. However, by the second week the eccentric training produced no soreness. This initial soreness as a result of eccentric training was also found in Friden et al.'s (1983) study.

Pearson and Costill (1988) had six male subjects perform an exercise regimen of repetitive knee extension exercises in an effort to induce size and strength changes in the quadriceps muscle. The left thigh was trained using progressive constant external resistance exercise (CERE). This protocol consisted of concentric and eccentric contractions. The right thigh was trained using an isokinetic mechanism. Each subject trained three times per week for eight weeks and took a minimum of 48 hours of rest between training sessions. The entire amount of torque generated by each protocol was constant.

Girth measurements displayed a significant increase in thigh volume after eight weeks of training in the CERE thigh (3300.67 ± 526.67 cc) compared to the same pretrained thigh (3044.19 +_ 448.50 cc) while no significant difference was found between the pre and posttrained isokinetic thigh ($P<0.05$). The isokinetically trained thigh gained significant strength at all testing velocities while the CERE thigh did not ($P<0.05$). However, the CERE thigh did show a significant gain in strength when tested on the CERE device.

LaStayo, Woolf, Lewek, Snyder-Mackler, and Trude-Reich (2003) did a review of literature which explored eccentric muscle contractions and their contribution to injury, prevention, rehabilitation, and sport. The authors agree with Evens and Cannon (1991) in that eccentric exercise can many times result in DOMS. However, they state that the chronic use of the same type of eccentric contractions, such as downhill running, results in a protective acclimatization in the muscle known as the "repeated bout effect." Therefore, an eccentric exercise that would cause muscle damage without adaptation would not cause damage if formerly exposed. A reason for the repeated bout effect may be change in size, strength, and spring quality of the muscle following chronic exposure to eccentric exercise. Studies have also shown that the muscle tendon structure also reacts positively to an eccentric-based resistance training protocol. These muscular changes help in the improvement of sport activities and the prevention and rehabilitation of such activities.

Eccentric exercise can be done with much greater force than isometric or concentric exercise thus providing a greater ability to overload the muscle and increase muscle mass, strength, and power compared to isometric or concentric exercise. In addition to the ability of higher force production, the metabolic cost of eccentric activity is very much reduced making this type of exercise potentially useful for those who are unfit or have limited capacity to expend energy while training. The authors conclude that eccentric exercise is a valuable part of a strengthening and/or rehabilitation program for many populations.

Studies involving Rating of Perceived Exertion (RPE) during Resistance Training

Day, McGuigan, Brice, and Foster (2004) investigated the reliability of the RPE scale on resistance training exercise intensity. Nineteen subjects each completed three different resistance training regimens characterized by intensity level. Each regimen consisted of one set of five exercises (back squat, bench press, overhead press, biceps curl, and triceps pushdown). The rest period between exercises was held constant among all regimens at two minutes and each regimen was executed twice and averaged to confirm reliability. The high intensity workout consisted of 4-5 repetitions at 90% of the participants' 1 RM. The medium intensity workout consisted of 10 repetitions at 70% 1 RM and the low intensity workout consisted of 15 repetitions at 50% 1 RM.

After completion of each set and workout subjects were instructed to rate their perceived exertion based on the Category-Ratio (CR)-10 RPE scale. This is a scale ranging from 0-10 where 0 represents no effort and 10 that the end represented the most stressful exercise ever performed. The authors found end-of-workout RPE was significantly different across all three regimens with the high intensity regimen 6.9 ± 1.4, the medium intensity regimen 5.2 ± 1.5, and low intensity regimen 3.3 ± 1.4 ($P \leq 0.05$). The intraclass correlation coefficient between the two different trials of the same intensity was $R = 0.88$. The authors concluded that the end-of-workout (session) RPE is a reliable technique to measure different intensities of weight training.

Lagally, McCaw, Young, Medama, and Thomas (2004) investigated RPE and electromyography (EMG) during the bench press lift in both novice and recreational lifters. Fourteen novice and 14 recreationally resistance trained women performed the bench press at 60 and 80% of their 1RM. Both active muscle RPE and overall body RPE were reported.

The results showed that both active muscle RPE and overall body RPE increased for both groups as the percentage of weight lifted increased. The total active muscle RPE was significantly increased from 12.3 ± 1.81 to 15.1 ± 1.74 ($P \leq 0.05$). Total EMG for both groups also significantly increased as the percentage of weight increased from 98.62 ± 17.54mV to 127.98 ± 29.02mV ($P \leq 0.05$). There were no significant differences in RPE or EMG that were discovered between the novices and recreationally resistance trained participants. The authors concluded that RPE is related to exercise intensity lifted and muscle activity during weight training for both novice and recreational lifters. This study is similar to the study by Day et al. (2004) in that as the weight lifted increases so does the RPE and both studies support the use of RPE as a gauge of intensity for resistance training.

The American College of Sports Medicine's (ACSM's) <u>Guidelines for Exercise Testing and Prescription Sixth Edition</u> (2000) put fourth the following recommendations for use of the RPE scale.

- The subject should pay close attention to how hard he/she feels the work rate is.
- This feeling ought to mirror the subject's total amount of exertion and fatigue, uniting all sensations and feelings of physical stress, effort, and fatigue.
- Concentration should be on the total, inner feeling of exertion and not with any one factor such as localized muscle pain.

Summary

Across the studies reviewed it appears that less rest time between sets, a higher number of sets, and a higher number of repetitions elicit a higher acute hormonal response than more rest time between sets and a lower number of sets and repetitions. Production of a hypoxic state for the muscle seems to also be a contributor in gaining muscle or an alternative to higher intensity resistance training. Eccentric training seems to produce significant muscle damage and hypertrophy seems to result from this damage. Lastly, RPE seems to be higher in resistance training workouts with a higher intensity. Further research is needed to identify the acute physiological responses to various weight training regimens and to identify training programs that optimize muscle hypertrophy.

Chapter 4. Methods

Subjects

Eight men from the University of Nebraska at Omaha (age 26.3 ± 3.8 years, weight 87.5 ± 9.1 kg, height 177.6 ± 7.7 cm) volunteered to participate in the study. All subjects must have had engaged in weight training a minimum of two times per week for the last four weeks and were required to be free from any known cardiovascular or metabolic diseases and any musculoskeletal injuries (subjects training history is summarized in table 1) . All participants were also asked to refrain from using any nutritional supplements, anabolic agents, or stimulants during the study. A written informed consent approved by the Institutional Review Board as well as a medical questionnaire was administered to each person prior to participation.

Table 1 Summary of Subjects and Subjects Training History (N=8)

	Subject									
Variable:	a	b	c	d	e	f	g	h	M	SD
Age (yr)	24	35	25	27	23	27	24	25	26.3	3.8
Weight (kg)	95.6	82.3	71.0	100.2	88.3	84.5	85.0	93.4	87.5	9.1
Height (cm)	176	176	171	196	175	178	176	173	177.6	7.7
Resistance training frequency (per week)	4-5	4	4-5	4-5	3-4	3	4	5-6	4.2	0.8
Years of resistance training	9	15	10	11	7	10	6	9	9.6	2.7
Aerobic training (per week)	1-2	5	3-4	4-5	3	0	3	2	2.8	1.6
Years of aerobic training	2	15	7.5	4	3	0	7	5.5	5.5	1.6

Design

The sequence in performing the four exercise sessions was randomly assigned. The dependent variables were the mean local muscle and total body RPE, acute hormonal responses (testosterone (T) and growth hormone (hGH)), and acute lactate response. Four workouts were used each with a different recovery interval and or momentary RM. Two levels of load and two levels of interset rest intervals were examined. Loads were either momentary 5 and 10 RM while the interset rest period consisted of either 1 or 3 minutes. These four sessions are typical of training programs used by many athletes and weight trainers in various phases of a periodized regimen (Baechle & Earle, 1994). Consequently, the design closely simulates training used by large numbers of people. The data collection portion of this study was approximately 6 weeks.

Data Collection

All data collection took place at the University of Nebraska at Omaha in the HPER building with all subjects in a fasting state. Measurement of acute hormonal response took place in between 10-15 min after each exercise session in the Student Health Center via blood sample where a maximum of 8.5 ml was drawn from the antecubital vein in either the right or left arm. A baseline sample was administered before the strength assessment and after each workout and was taken by a nurse trained in phlebotomy. Blood was centrifuged at 5 degrees C and plasma was frozen until samples were analyzed. Radioimmunoassays were performed to determine the concentration of T and hGH in each plasma sample. A finger stick was done for blood lactate concentration (BLC) using an Accusport (Boehringer Mannheim Corp., Indianapolis, IN). A lancet was used to puncture the skin. The first drop of blood was wiped away, and the second drop was drawn into a pipette in order to avoid contamination by sweat.

Middle and post workout RPE were also reported for every workout. RPE was assessed locally to measure the status of major muscles used in performing the four lifts as well as globally to assess the overall feeling of effort including muscles, heart, lungs, etc. Both local and overall RPE have been used to differentiate RPE during exercise (Lagally et al., 2004).

Strength Assessment

Strength was measured via a 5 RM prior to the start of data collection. The ACSM protocol for strength testing (2000) was used for 5 RM testing. The subjects performed a light warm-up of five to ten repetitions at 40-60% of perceived maximum. Following a one-minute rest the subjects did five repetitions at 60-80% of perceived maximum. If the lifts were successful, a small amount of weight was added and a rest period of three to five minutes was provided. This process continued until a failed 5 RM attempt occurs. The 5 RM was reported as the weight of the last successful 5 completed repetitions. Five-repetition maximums were tested for the squat using the Smith machine, bench-press using the Smith machine, and lat pull-down machine. A 10 RM was then estimated using a chart from the NSCA (Baechle & Earle, 1994, p.410). The weight on the Smith machine can be adjusted by as little as 5 lb increments and the lat pull-down can be adjusted by as little as 2.5 lb increments.

Training Regimens

Subjects were asked to complete a 5 RM for three sets of each exercise: squat on the Smith machine, bench press on the Smith machine, and lat pull-down machine. During this workout subjects rested for three minutes between sets. Another workout consisted of the same interset rest period but a 10 RM for the same exercises was performed. The other two workouts consisted of the same exercises and repetitions; however, a one minute interset rest period was utilized. Details of these procedures were investigated in pilot work with two weight trainers. Here, the amount of load needed to be removed for the second and third sets to achieve a momentary 5 or 10 RM was examined. If the subject were not able to complete his assigned RM, minimal assistance was given until all repetitions for the set were complete. All one minute interset rest period workouts took about 25 min and all three minute interset rest period workouts took about 35-40 min. Muscle groups were worked from largest to smallest in the following order: Squat, bench press, and lat pull-down machine. All four sets of each lift were performed before moving on to the next lift. Subjects were required to rest at least 48 hours between workouts to allow for adequate muscle recovery. All subjects were led through each training protocol by an ACSM certified health and fitness instructor.

The Smith machine is a machine that allows a straight bar to move in the vertical direction. For the Smith machine squat, subjects started in the standing position, placed the bar behind the neck, and squatted down to the point where the thigh and shank made a 90 degree angle before returning to the standing position. The subject could have racked the weight at anytime throughout the range of motion (ROM) by twisting the bar with their wrists toward the front of their body. The bench press also was done on the same machine. Here, the subject laid down on a bench in the supine position. Each hand was placed on the bar and the distance between the hands was a little wider than the shoulders. The arms were fully extended. The bar was then brought toward the chest until it touched the lower portion of the chest. The bar was then pushed away from the chest until it returned to the starting position. The lat pull-down machine is a machine where the subject started in the seated position with both legs underneath a pad which is meant to hold the body down. The starting position was with the elbows extended overhead and hands gripping the bar a little wider than shoulder width apart. The subject pulled the bar toward the body in the downward direction to the point where the bar touched the upper chest and then returned to the starting postion.

Prior to the start of each workout every subject's BLC was drawn. Prior to the strength assessment a baseline hormonal assay was drawn. Subjects were be taken through a warm up and cool down before and after each resistance training session. For the warm up every subject was asked to do five minutes of light aerobic activity at a self-selected pace (walking, cycling, or stepping). Each participant then performed a set of 5 or 10 repetitions (depending on whether it was a 5 or 10 RM workout) at 40% of their estimated 1 RM for the squat. Subjects were then given the amount of rest corresponding to the interset workout rest period in the workout they were to perform before proceeding into that assigned resistance training protocol. The same intensity warm up set and rest period was followed before each of the two remaining lifts. After completion of the weight training session each subject had a blood test to measure selected hormones (T and hGH) and a finger stick to measure BLC before performing five minutes of light aerobic exercise followed by 5-10 minutes of static stretching. The participants were lead through a stretching routine where every major muscle group used in the training session was stretched. All workouts were done between 7:00-9:00 AM to control for hormonal differences during different times of the day.

Statistical Analysis

Descriptive statistics (mean (M), and standard deviation (SD)) were calculated for each dependent variable (post acute hormonal response; pre, middle, and post BLC; and middle and post local and overall mean RPE). A 2x2 repeated measures factorial analysis of variance (ANOVA) incorporating load and duration of the interset rest period was used for every measure of each dependent variable. A Tukey post-hoc test was used when interaction was significant. The alpha level was set at $P \leq 0.05$.

Chapter 5. Results

Data were analyzed with a 2x2 repeated measures factorial ANOVA. Main effects compared marginal means while cell means were compared to test for interaction between levels of the two independent variables.

Hypothesis 1: Mid and post blood lactate content for the 10 RM/1 minute interset rest regimen will be higher than all of the other regimens.

There was not a significant difference in pre BLC values across the four exercise sessions. The mean ± SD of the four workouts was 1.8±0.5 mmol/L. Consequently, lactate values in the middle and end of exercise were used in data analysis rather than delta values. Blood lactate concentration during and after each session are summarized in Tables 2 and 3.

Table 2. Summary of Mid Lactate Workout Responses (mmol/L) (N=8; Cell Mean ± Standard Deviation and Marginal Mean)

Interset Rest Period (min)	RM: 10	RM: 5	Marginal Mean
1	8.83±2.62	4.66±1.21	6.75
3	9.69±4.03	7.09±3.05	8.39
Marginal Mean	9.26*	5.88	

*Significant at $P \leq 0.05$

There was a significant main effect in mid BLC workout values with the 10 RM sessions producing significantly more lactate than both 5 RM sessions ($P \leq 0.05$). The one versus three minute interset rest period sessions yielded close to but no significant difference ($P \leq 0.07$) with the three minute interset rest period workouts yielding higher values. There was not a significant interaction.

Table 3. Summary of Post Workout Lactate Responses (mmol/L) (N=8; Cell Mean ± Standard Deviation and Marginal Mean)

Interset Rest Period (min)	RM 10	RM 5	Marginal Mean
1	11.71±2.54	7.10±2.26	9.41
3	9.94±2.88	6.60±3.88	8.27
Marginal Mean	10.81*	6.85	

*Significant at $P \leq 0.05$.

The main effect for RM was significant with 10 RM producing greater lactate values than 5 RM ($P \leq 0.05$). The main effect for recovery period duration was not significantly different and there was no significant interaction. Consequently, partial support for the hypothesis dealing with lactate response was found.

Hypothesis 2: Testosterone and growth hormone levels for 10 RM/1 minute interset rest regimen will be greater than the other regimens. Post hormonal concentration is summarized in Tables 4 and 5.

Table 4. Summary of Post Workout hGH Responses (ng/ml) (N=8; Cell Mean ± Standard Deviation and Marginal Mean)

RM

Interset Rest Period (min)		10	5	
	1	37.4±27.4	7.9±5.4	22.7
	3	18.2±14.4	11.4±11.9	14.8
		27.8*	9.7	

*Significant at $P \leq 0.05$.

Interaction was significant with the 10 RM/1 min workout eliciting significantly greater hGH levels than both of the 5 RM workouts but not the 10 RM/3 min workout. There was a significant main effect for RM with 10 RM producing greater hGH levels than 5 RM ($P \leq 0.05$). The main effect for rest period duration approached significance ($P \leq 0.08$) with one minute greater than three minute values.

Table 5. Summary of Post Workout Testosterone Responses (ng/ml) (N=8; Cell Mean ± Standard Deviation and Marginal Mean)

RM

Interset Rest Period (min)		10	5	
	1	10.2±2.4	9.1±3.0	9.7
	3	10.4±2.5	9.2±2.6	9.8
		10.3*	9.2	

Significant at $P \leq 0.05$.

The main effect for RM was significant with 10 RM producing greater testosterone levels than 5 RM ($P \leq 0.05$). The main effect for rest period duration was not significant and there was no significant interaction. Therefore, the hypothesis for hormones was partially supported by the results.

Hypothesis 3: Local and global RPE will be greatest at mid and post workout for the 10 RM/1 minute interset rest regimen than all the other regimens. Tables 6-9 summarize the results dealing with RPE.

Table 6. Summary of Mid Workout Local RPE Responses (N=8; Cell Mean ± Standard Deviation and Marginal Mean)

		RM: 10	RM: 5	
Interset Rest Period (min)	1	16.38±2.13	13.63±1.51	15.01
	3	14.75±1.98	14.00±1.93	14.38
		15.57*	13.82	

*Significant at ($P \leq 0.05$).

Interaction was significant with 10 RM/1 Min producing greater results than both 5 RM workouts but not the 10 RM/3 Min workout. The main effect for RM was significant with 10 RM producing greater results than 5 RM ($P \leq 0.05$) while the main effect for rest period was not. Therefore, data partially support the hypothesis.

Table 7. Summary of Mid Workout Global RPE Responses (N=8; Cell Mean ± Standard Deviation and Marginal Mean)

RM

Interset Rest Period (min)		10	5	
	1	17.00±2.27	14.13±2.36	15.57*
	3	13.75±1.83	12.75±2.19	13.25
		15.38*	13.44	

*Significant at $P \leq 0.05$.

The main effects for both RM and recovery time were significant with 10 RM producing higher middle workout global RPE than 5RM and one minute producing greater results than three minutes ($P \leq 0.05$). Interaction, however, was not significant. Consequently, the hypothesis is partially supported.

Table 8. Summary of Post Workout Local RPE Responses (N=8; Cell Mean ± Standard Deviation and Marginal Mean)

RM

Interset Rest Period (min)		10	5	
	1	16.57±2.23	14.14±1.46	15.36
	3	14.20±1.92	13.00±2.45	13.60
		15.39*	13.57	

*Significant at $P \leq 0.05$.

The main effect for RM was significant with 10 RM producing greater post workout local RPE than 5 RM ($P \leq 0.05$) while the main effect for rest period duration was not significant. Interaction was also not significant. Thus, the hypothesis is partially supported by the results.

Table 9. Summary of Post Global RPE Responses (N=8; Cell Mean ± Standard Deviation and Marginal Mean)

Interset Rest Period (min)	RM: 10	RM: 5	
1	17.29±2.29	14.43±2.07	15.86
3	14.60±1.82	12.17±1.72	13.39
	15.95*	13.30	

Significant at $P \leq 0.05$.

The main effect for RM was significant with 10 RM producing greater post global RPE than 5 RM ($P \leq 0.05$) while the main effect for rest period was not. Interaction was also not significant. As a result, the hypothesis is partially supported.

Overall, across all three variables (blood lactate, hormonal levels, and RPE), the main effect for RM was significant with 10 RM producing significantly greater responses than the 5 RM workouts. The main effect interset rest period duration yielded only one significant difference with one minute resulting in significantly greater mid workout global RPE than three minutes. Therefore, the hypothesis overall was fairly consistently supported by the findings regarding main effects. Significant interaction was limited in these results and therefore most of the hypotheses were only partially supported by the data. Where interaction was significant (hGH and mid workout local RPE) results were highest in the 10 RM/1 min exercise session which supports the related hypotheses.

Chapter 6. Discussion

For all three variables (blood lactate, hormonal levels, and RPE), the main effect for RM was significant with 10 RM producing significantly greater responses than the 5 RM workouts. The main effect interset rest period duration yielded only one significant difference with one minute resulting in significantly greater mid workout global RPE. Therefore, the hypotheses overall were fairly consistently supported by the finding regarding main effect for RM i.e., 10 RM yielding larger responses than 5 RM. Significant interaction was limited in these results and therefore most of the hypotheses were only partially supported by the data. Interaction was significant for hypotheses dealing with hGH and mid workout local RPE highest responses in the 10 RM/1 min exercise session which supports the related hypotheses.

Blood Lactate Content

BLC was used in this study as a marker of hypoxia estimated to occur in each of the training sessions. Production of a hypoxic state in recent studies appears to contribute to hypertrophy. Takarada et al. (2000) examined the effectiveness of relatively low-intensity weight training combined with vascular occlusion in producing improvements in hypertrophy and muscular strength in older women. The low intensity exercise was performed at an intensity of 30-50% 1 RM and it was found that both strength and muscle cross sectional area significantly increased in the biceps brachii and brachialis of the occluded arm compared to the non occluded arm ($P<0.05$). BLC has been shown to significantly increase ($P \leq 0.05$) during resistance training (Kraemer et al., 1992, Kraemer et al., 1991). Kraemer et al. (1991) found that BLC) increased significantly more ($P<0.05$) with a 10 RM 1 min interset rest protocol compared to a 5 RM 3 min interset rest period protocol just like the current study did. BLC values for the current study revealed significant main effects for both mid and post workout with 10 RM producing greater results than 5 RM workouts ($P \leq 0.05$). These findings support the notion that a higher number of repetitions per set may be more conducive in producing muscle hypoxia and lactate, and thus hypertrophy.

One reason that lactate values were significantly higher with the 10 RM workouts compared to the 5 RM workouts may be because glycolysis was activated to a greater extent. The 10 RM sets took longer to perform and also probably produced more mechanical compression of the arteries supplying blood to the involved musculature. Nearly every set that each subject performed was maximal and the intense work without adequate recovery during the one minute recover intervals likely put subjects above lactate threshold consequently producing such high values.

Hormones

Main effect results of the current study also revealed that more repetitions significantly produced more T and hGH ($P \leq 0.05$). Further, the main effect for interset rest period approached significance ($P \leq 0.08$) with one minute producing higher hGH values than three minutes. This is consistent with the results of Kraemer et al. (1991) which showed that a workout with higher repetitions (10 RM) and less rest between sets (1 min) produced significantly more hGH than a workout consisting of less repetitions (5 RM) and longer rest between sets (3 min) ($P \leq 0.05$). Buresh and Berg (2003) and Smilios et al. (2003) also showed less rest between sets produces a higher hormonal response. However, Buresh and Berg's results revealed that workouts incorporating longer interset rest periods produced greater gains in estimated muscle cross-sectional area. The authors speculated that this may likely be a result of the significantly increased cortisol (C) levels that the shorter interset rest period workouts produced compared to the longer interset rest period workouts ($P \leq 0.05$). C has a catabolic effect on muscle tissue (Baechle & Earle, 1994, p.111).

Godshalk et al. (1997) found that three sets per exercise produced a higher hormonal reaction than one set per exercise with the rest period held constant at one minute ($P \leq 0.05$). Here subjects (all male) completed eight different exercises per protocol. The 10 RM 1 min rest protocol elicited a mean hGH response of 16 ng/ml while the current study, which only incorporated three exercises per protocol, found a mean of 37 ng/ml for the 10RM 1 min rest period protocol. Post T levels were a little closer with values of 29 and 35 nmol/L, respectively.

Kraemer et al. (1991) took both males and females through both a 5 RM 3 min interset rest period protocol and a 10 RM 1 min rest period protocol. Like the current study, the short rest session showed significantly greater increases in hGH compared to the long rest session for both males and females at all time periods (pre, mid, and post) with the exception of pre-exercise ($P \leq 0.05$). However, mid exercise T values were significantly greater in the session with the shorter interset rest periods while 60 minutes post exercise values were significantly greater in the long interset rest session ($P \leq 0.05$).

Kraemer et al. (1992) conducted a study where 28 teenage participants in a junior age group national weightlifting camp went through a protocol which consisted of consecutive maximal vertical jumps followed by heavy snatch lifts to failure. The finding that stands out in this study was that the length of resistance training experience appeared to influence the exercise-induced response patterns of testosterone. An exercise-induced increase in serum testosterone was observed consequent to the weightlifting exercise session only in the group with over two years of experience ($P<0.05$). The group with over two years experience exhibited a mean 15 min post exercise T level of 19.1 nmol/L while the current study's 10 RM 1 min interset rest period workout exhibited a mean post (approximately 15 min) T level of 35.4 nmol/L. GH values were similar and non-significant between experienced and non experienced weight lifters with the experienced subjects eliciting a slightly higher 15 post workout mean of 30.1 ng/ml compared to the current study with a mean of 37 ng/ml for the 10 RM 1 min rest period workout.

RPE

The current study's main effect for all RPE ratings revealed consistent significance with 10 RM producing higher ratings than 5 RM ($P \leq 0.05$). Currently the published research on RPE with resistance training (Day et al., 2004; Lagally et al., 2004) reveals that as the weight lifted increases so does the RPE ($P \leq 0.05$). However, these studies do not deal with variations in interset rest periods as the current study does. Because different combinations of load and recovery duration of intensity are used a direct comparison cannot be made between this study and those studies cited previously. A general conclusion from this study would be that more repetitions produce higher RPE values if the repetitions achieved are maximal. This study along with that by Day et al. (2004) and Lagally et al. (2004) support the use of RPE to gage intensity and thus promote it for use in weight training exercise prescription. The American College of Sports Medicine (ACSM) advocates the use of RPE as a gage of intensity for resistance training and in their Guidelines for Exercise Testing and Prescription Sixth Edition (2000) put forth the following recommendations for use of the RPE scale.

- The subject should pay close attention to how hard he/she feels the work rate is.
- This feeling ought to mirror the subject's total amount of exertion and fatigue, uniting all sensations and feelings of physical stress, effort, and fatigue.
- Concentration should be on the total, inner feeling of exertion and not with any one factor such as localized muscle pain.

Limitations

Limitations to the study included:

- Not measuring other relevant hormones such as cortisol or insulin like growth factor. Future research would be more comprehensive by examining additional hormones which exert anabolic as well as catabolic effects on muscle.
- Hormones were only measured once post workout. Kraemer et al. (1991) found that a 10 RM 1 min interset rest period protocol increased mid workout T values significantly more than a 5 RM 3 min interset rest period workout while the opposite became true 60 minutes post exercise ($P \leq 0.05$). Consequently, assessment of hormones should be made immediately post exercise as well as later.
- Subjects' diet and state of rest were not controlled. Although the subjects were told to be in a fasting state for the strength assessment and each workout this and other such factors were not known for sure. RPE is probably affected by state of rest. Consequently, subjects may have had variable amounts of exercise and

weight training in the days prior to performing the four workouts. To counter these potential effects, subjects were requested not to train 48 hours prior to data collection.

- Subjects were not drug tested or queried about their intake of central nervous system stimulants such as caffeine, nicotine, ephedra, and other substances in over the counter medications for allergies and colds. However, subjects were asked not to take any supplements or stimulants and to report any over the counter medications to the primary investigator. Drug screening would substantiate if subjects were taking substances that could influence the results.
- N size. A larger N size would bring more statistical power to a study. Consequently, several comparisons not found to be statically significant here, particularly the main effect rest period for mid BLC (P=0.07) and main effect rest period for post hGH (P=0.08), may have reached significance. There was also considerable variability in hormone levels which may have too reduced the probability of detecting significant differences.

Recommendations

Results of this study may help clarify acute physiologic and perceptional effects of different types of weight training programs. This knowledge may be useful in designing training studies that assess chronic effects of weight training on strength and muscle mass. There have been few studies on hormonal responses to weight training and what happens acutely may not be true of the chronic effect. Buresh et al. (2003) found that at the end of the 10 weeks of weight training the long rest group's (2.5 min) increase in arm muscle cross-sectional area was significantly greater than the group with a short rest period (1 min) ($P \leq 0.05$). The long rest group also demonstrated a slightly higher strength increase ($P \leq 0.05$) while the short rest group exhibited greater overall T and C levels ($P \leq 0.05$). Studies of the acute physiologic effects seem to be a logical step before conducting studies of the chronic effects. Training studies based on the results on the results of the acute physiologic responses to various weight training regimens may provide a framework for comparing the chronic responses including assessment and comparison of change in muscle cross-sectional area.

Chapter 7. Summary and Conclusion

The purpose of the current study was to examine the effects of four different resistance-training protocols associated with periodization of resistance training on the biological signals that are associated with exercise regimens to increase muscle hypertrophy. Eight males between the ages of 23-35 participated as subjects in this study. All had an initial blood draw to determine their baseline hormonal status and a strength assessment to determine the proper weight (i.e., 5 or 10 RM) for all workouts. Each subject subsequently came in four additional mornings and was taken through a randomly assigned different workout, each with a different momentary RM and/or interset rest period. For each of the four workouts pre, middle, and post BLC was assesed along with middle and post local and global RPE and a post blood draw to assess T and hGH levels.

The hypothesis was that the workout which incorporated the highest momentary RM and shortest interset rest period (10 RM/1 min) would significantly produce the highest BLC, hormonal response, and RPE values. Across all three variables (blood lactate, hormonal levels, and RPE), the main effect for RM was significant with 10 RM yielding significantly greater responses than the 5 RM workouts. The main effect interset rest period duration produced only one significant difference with one minute resulting in significantly greater mid workout global RPE than three minutes. Therefore, the hypothesis overall was fairly consistently supported by the findings regarding main effects. Significant interaction was limited in these results and therefore most of the hypotheses were only partially supported by the data. Where interaction was significant (hGH and mid workout local RPE) results were highest in the 10 RM/1 min exercise session which supports the related hypotheses.

In conclusion, workouts which incorporated 10 RM per set produced significantly greater levels of BLC, hGH, T, and RPE values than 5 RM workouts ($P \leq 0.05$). All hypotheses are partially supported because with the exception of hGH and mid workout local RPE interaction did not occur. However, the data still indicate that shorter interset rest duration along with higher repetitions per set leads to a greater hGH response than higher interset rest durations and lower repetitions per set. Based on the results of this study along with information on the mechanisms of hypertrophy found in other investigations, it appears that 10 RM with one minute interset rest periods may provide more effective stimulus for muscle hypertrophy than 5 RM with 3 min rest periods. Further research is needed to confirm the chronic effects on various weight training regimens on muscle hypertrophy.

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Appendix A

Informed Consent Form

Adult Informed Consent Form

ACUTE PHYSIOLOGICAL RESPONSES AND PSYCHOLOGICAL PERCEPTIONS OF VARIOUS RESISTANCE TRAINING REGIMENS

Invitation

You are invited to take part in this research study. The information in this form is meant to help you decide whether or not to take part. If you have any questions, please ask.

Why are you being asked to be in this research study?

You are eligible to participate in this study because you are a male between the age of 19-35 years and have engaged in weight training a minimum of two times per week for the past four months. You may participate if you are free from any known cardiovascular or metabolic diseases and any musculoskeletal injuries. You also will be required to refrain from using any nutritional supplements, anabolic agents, or stimulants during the study.

What is the reason for doing this research study?

The primary purpose of this research study is to examine how effective different weight training programs are in building muscle mass. A secondary purpose will be to examine how difficult each workout is perceived to be.

What will be done during this research study?

You will be asked to make five visits to the Exercise Physiology Lab/weight room at the University of Nebraska at Omaha. You will be asked to perform a strength test for each exercise in this order: squat, bench press, and back row machine. After you have been strength tested, you will be asked to do four workouts using these same exercises. During these workouts you will do each exercise for 3 sets of 5 or 10 repetitions with either a 1 or 3 minute recovery between sets. All three sets of each lift will be performed before moving on to the next lift. You will be required to rest at least 48 hours between workouts to allow for adequate muscle recovery. The total time you will need to allot for participation will be about five hours. A maximum of 20 subjects will participate in this research study.

Initials______________

The first meeting will consist of you filling out a medical history questionnaire and signing an informed consent. Your baseline hormonal level will be assessed via a blood draw from a vein in your arm where about one half teaspoon of blood will be drawn. Lastly, your strength will be measured for each of the three exercises.

Prior to the start of each workout your blood lactate content will be assessed via a finger stick. Then blood will be drawn from a large vein in your arm by a nurse to measure the level of testosterone and growth hormone in your blood. You will be taken through a warm up and cool down before and after each resistance training session. For the warm up you will be required to do five minutes of light aerobic activity at a selected pace (walking, cycling, or stepping). For the second part of the warm up you will perform a set of 10 repetitions at 40% of the heaviest lift previously determined in the strength test for the squat. You will then be given the amount of rest corresponding to the interset workout rest period in the workout you will perform before you proceed into your assigned resistance training protocol. The same intensity warm up set and rest period will be followed before each of the two remaining lifts.

After completion of each weight training session you will have a blood test to measure selected hormones (Testosterone (T) and Growth hormone (hGH)) and a finger stick to measure blood lactate content before performing five minutes of light aerobic exercise followed by 5-10 minutes of static stretching. You will be lead through a stretching routine where every major muscle group used in the training session will be stretched. All workouts will be done between 7:00-9:00 AM to control for hormonal differences during different times of the day.

You will be asked to avoid eating for several hours before each session to minimize stomach upset. You will also be asked to stay well hydrated the day before and the day of the exercise sessions to minimize discomfort and heat illness.

Results of this research study will be provided to you via a phone call from the primary investigator.

What are the possible risks of being in this research study?

Resistance training

Possible risks associated with resistance training include injuries to the muscles, ligaments, tendons, and joints to the body and abnormal blood pressure, fainting, dizziness, disorders of the heart rhythm, and very rare instances of heart attack, stroke, or even death.

Venipuncture/finger stick

Possible risks and discomforts associated with a blood draw include pain, bruising, bleeding, fainting and a slight possibility of infection.

Initials______________

It is possible that other rare side effects could occur which are not described in this consent form. It is also possible that you could have a side effect that has not occurred before.

What are the possible benefits to you?

You will be informed of the level of blood lactate and hormonal response each workout produced. Further, you will be informed on how difficult you and others perceived each workout. This information may be useful in terms of developing an exercise prescription to build strength and muscle mass.

You may not get any benefit from being in this research study.

What are the possible benefits to other people?

Society may benefit by learning more about how various resistance training workouts affect perceived exertion during lifting, as well as the hormonal responses to lifting. Information from this study may be helpful in assisting people who train with weights in gaining muscle strength.

What are the alternatives to being in this research study?

Instead of being in this research study you can choose not to participate.

What will being in this research study cost you?

You will not incur any financial obligations as a result of participation in the study.

Will you be paid for being in this research study?

You will receive no compensation for participating in the study.

What should you do if you are injured or have a medical problem during this research study?

Your safety is the major concern of every member of the research team. If you are injured or have a medical problem as a result of being in this study, you should immediately contact on the people listed at the end of this consent form. Immediate emergency medical treatment for this injury will be available at the Nebraska Medical Center. There will be no charge to you for this care provided you have followed all instructions and medical advice and done nothing to cause or contribute to the injury.

Initials______________

The costs for any other medical problems unrelated to this research study are your responsibility. There are no plans to provide payment for things like lost wages, disability or discomfort. Agreeing to this does not mean you have given up any of your legal rights.

How will information about you be protected?

You have rights regarding the privacy of your medical information collected before and during this research. This medical information, called "protected health information" (PHI), includes demographic information (like your address and birth date), the results of physical exams, blood tests, x-rays and other diagnostic and medical procedures, as well as your medical history. You have the right to limit use and sharing of you PHI, and you have the right to see your medical records and know who else is seeing them.

By signing this consent form, you are allowing the research team to have access to your PHI. The research team includes the investigators listed on the consent form and other personnel involved in this specific study at UNO.

Your PHI will be used only for the purpose(s) described in the section "What is the Purpose of this Study?"

Your PHI will be shared, as necessary, with the Institutional Review Board (IRB) and with any person or agency required by law. You are also allowing the research team to share your PHI with other people or groups specified below. All of these persons or groups are obligated to protect your PHI.

You are authorizing us to use and disclose your PHI for as long as the research study is being conducted.

You may revoke this authorization to use and share you PHI at any time by contacting the principal investigator in writing. If you revoke this authorization, you may no longer participate in this research. If you revoke this authorization, use or sharing of future PHI will be stopped. The PHI that has already been collected may still be used.

The information from this study may be published in scientific journals or presented at scientific meetings but your identity will be kept strictly confidential.

What are your rights as a research subject?

You have rights as a research subject. These rights are explained in "The Rights of Research Subjects" that you have been given. If you have any questions concerning your rights, talk to the investigator or call the Institutional Review Board (IRB), telephone (402) 559-6463.

Initials______________

What will happen if you decide not to be in this research study?

You can decide not to be in this research study. Deciding not to be in this research study will not affect your medical care or your relationship with the investigator, the University of Nebraska Medical Center, the Nebraska Medical Center, or the University of Nebraska at Omaha. Your doctor will still take care of you and you will not lose any benefits to which you are entitled.

What will happen if you decide to stop participating once you start?

You can stop being in this research study ("withdraw") at any time before, during, or after the study begins. Deciding to withdraw will otherwise not affect your care or your relationship with the investigator, the University of Nebraska Medical Center, the University of Nebraska at Omaha, or the Nebraska Medical Center. You will not lose any benefits to which you are entitled.

You may be taken off the study if you don't follow instructions of the investigator or the research team.

If the research team gets any new information during this research study that may affect whether you would want to continue being in the study you will be informed promptly.

Documentation of informed consent

YOU ARE FREELY MAKING A DECISION WHETHER TO BE IN THIS RESEARCH STUDY. SIGNING THIS FORM MEANS THAT (1) YOU HAVE READ AND UNDERSTOOD THIS CONSENT FORM, (2) YOU HAVE HAD THE CONSENT FORM EXPLAINED TO YOU, (3) YOU HAVE HAD YOUR QUESTIONS ANSWERED AND (4) YOU HAVE DECIDED TO BE IN THE RESEARCH STUDY.

IF YOU HAVE ANY QUESTIONS DURING THE STUDY, YOU SHOULD TALK TO ONE OF THE INVESTIGATORS LISTED BELOW. YOU WILL BE GIVEN A COPY OF THIS CONSENT FORM TO KEEP.

______________________________ ________________ ____________

Signature of Subject **Date** **Time**

MY SIGNATURE AS WITNESS CERTIFIES THAT THE SUBJECT SIGNED THIS CONSENT FORM IN MY PRESENCE AS THEIR VOLUNTARY ACT AND DEED.

______________________________ ________________ ____________

Signature of Witness **Date** **Time**

MY SIGNATURE CERTIFIES THAT ALL THE ELEMENTS OF INFORMED CONSENT DESCRIBED ON THIS CONSENT FORM HAVE BEEN EXPLAINED FULLY TO THE SUBJECT. IN MY JUDGMENT, THE PARTICIPANT POSSESSES THE LEGAL CAPACITY TO GIVE INFORMED CONSENT TO PARTICIPATE IN THIS RESEARCH AND IS VOLUNTARILY AND KNOWINGLY GIVING INFORMED CONSENT TO PARTICIPATE.

__________________________ ________________ __________

Signature of Investigator Date Time

MY SIGNATURE CERTIFIES THAT I HAVE AUTHORIZED THE INVESTIGATOR SIGNING ABOVE TO DOCUMENT THE OBTAINMENT OF INFORMED CONSENT, AND HE/SHE HAS THE NECESSARY CLINICAL EXPERTISE AND SUFFICIENT KNOWLEDGE ABOUT THE PROTOCOL AND IRB CONSENT REQUIREMENTS TO DOCUMENT OBTAINMENT OF CONSENT. IN MY JUDGEMENT, VALID INFORMED CONSENT HAS BEEN OBTAINED FROM THE SUBJECT.

____________________ ________________ __________

Signature of Principal Investigator Date Time

AUTHORIZED STUDY PERSONNEL

<u>Principal Investigator</u>

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Initials______________

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Phone: 402-554-3221

Chris Sjoberg, BS
Phone: 402-554-3221

Initials______________

Appendix B

Medical History Form

Medical History Form

Date: ______________________________ **Age:** ______________________

Name: ______________________________ **Sex:** ______________________

Address: ______________________________ **Weight (lbs.):** ________________

Employment: ______________________________ **Height (inch):** ________________

Address: ______________________________

Phone: **Home** ______________________________

Work ______________________________

Name of Personal Physician: ____________________

Address: ______________________________

Have you been hospitalized within the last two years? _________

If yes, please explain:

____

____

____

Check the following which have occurred in your past medical history:

Heart Attack _______ **Epilepsy** _______

High Blood Pressure _______ **Asthma** _______

Chest Discomfort _______ **Emphysema** _______

ECG Abnormality _______ **Bronchitis** _______

Stroke _______ **Shortness of Breath** _______

Obesity _______ **Lightheadedness or Fainting** _______

Unexplained Weight Gain Or loss _______ **Heat Illness** _______

Diabetes _______ **Allergy** _______

Arthritis, Bursitis, Gout Or Joint Inflammation _______ **Other (explain)** __________

List any medication(s) you are presently taking and condition(s) being treated.

____

____

____

List and describe any condition you have which may affect your ability to participate in strenuous physical activity.

____

____

____

Any family history of: (check if yes and indicate age of occurrence)

	Age of Occurrence	Who (mother, father, sibling aunt, uncle, grandparents)
Death before age 60	________	____________________
Heart disease	________	____________________
High blood pressure	________	____________________
Diabetes	________	____________________
Stroke	________	____________________
Obesity	________	____________________
Asthma	________	____________________
Emphysema	________	____________________

Weight History (lb.)

High-school graduation	________
One year ago	________
Now	________
Maximum ever	________
When?	________

Smoking History

Ever? ________

Now? ________

What? ________

How often? ________

How much? ________

Attempted to stop? ________

<u>Physical Activity History</u>

Describe any physical activities that you have participated in during the last 12 months.

Activity	**# of days per week**	**# of minutes per session**	**# of weeks or months of consistent involvement**
________	________	________	________
________	________	________	________
________	________	________	________

Describe any physical activities that you have participated in during the last 6 weeks.

________	________	________	________
________	________	________	________
________	________	________	________

Appendix C

Data Collection Form

Data Collection Form

Name____________________ Age_____ Weight_________ Height___________

Date_______________ Time______________

Pre Hormone Measurement Test_________ hGH_________(write down when results come back)

Pre Lactate Measurement ___________

Squat Warm Up ____________(40% estimated 1 RM 5-10 Reps)

1 or 3 minute rest depending on the workout (load bar to 5 or estimated 10 RM weight)

Set 1 Squat Weight _________ Reps completed (without assistance)_______

1 or 3 minute rest depending on the workout ---Strip weight for 2nd set ____________

Set 2 Squat Weight ___________Reps completed (without assistance)_______

1 or 3 minute rest depending on the workout ---Strip weight for 3rd set ____________

Set 3 Squat Weight _________ Reps completed (without assistance)______________

1 or 3 minute rest depending on the workout --Set Up Bench Press and Load Warm Up Weight ___________ (40% estimated 1 RM 5-10 Reps)

1 or 3 minute rest depending on the workout (load bar to 5 or estimated 10 RM weight)

Set 1 Bench Press Weight ___________Reps completed (without assistance)________

Take Lactate ______________ ---Strip weight for 2nd set______(1 or 3 min rest for subject)

Set 2 Bench Press Weight ___________Reps completed (without assistance)______________

Global RPE _________ Local RPE__________

1 or 3 minute rest depending on the workout ---Strip weight for 3rd set ____________

Set 3 Bench Press Weight___________ Reps completed (without assistance)______________

1 or 3 minute rest depending on the workout –Go to Lat Pulldown and Set Warm Up Weight ________ (40% estimated 1 RM 5-10 Reps)

1 or 3 minute rest depending on the workout (load bar to 5 or estimated 10 RM weight)
Set 1 Lat Pulldown Weight __________Reps completed (without assistance)________

1 or 3 minute rest depending on the workout ---Strip weight for 2nd set ____________

Set 2 Lat Pulldown Weight__________ Reps completed (without assistance)______________

1 or 3 minute rest depending on the workout ---Strip weight for 3rd set ____________

Set 3 Lat Pulldown Weight__________ Reps completed (without assistance)______________

Post Global RPE___________ Post Local RPE______

2-3 min later take post BL in lab_________________(value)

Appendix D

Strength Assessment Form

***Name*____________________**

Squat

-Warm-up of five to ten repetitions at 40-60% of perceived maximum______ - one-minute rest
-five repetitions at 60-80% of perceived maximum___________
-lifts are successful -- a rest period of three to five minutes
-add a small amount of weight and try for 5 RM again_____________
-if 5 reps are completed rest 3-5 minutes
add a small amount of weight and try again_________________
Rest 3-5
Again_____________
Rest 3-5
Again_____________

Bench Press

Warm-up of five to ten repetitions at 40-60% of perceived maximum______ - one-minute rest
-five repetitions at 60-80% of perceived maximum___________
-lifts are successful -- a rest period of three to five minutes
-add a small amount of weight and try for 5 RM again_____________
-if 5 reps are completed rest 3-5 minutes
add a small amount of weight and try again_________________
Rest 3-5
Again_____________
Rest 3-5
Again_____________

Lat Row

Warm-up of five to ten repetitions at 40-60% of perceived maximum______ - one-minute rest
-five repetitions at 60-80% of perceived maximum___________
-lifts are successful -- a rest period of three to five minutes
-add a small amount of weight and try for 5 RM again_____________
-if 5 reps are completed rest 3-5 minutes
add a small amount of weight and try again_________________
Rest 3-5
Again_____________
Rest 3-5
Again_____________

****5 RM is considered the weight of the last completed 5 rep attempt**

Appendix E

Written Instructions

Guidelines for participation:

Please do not eat or drink anything with calories on the morning before your workout. (Water is ok and is encouraged in order to maintain adequate hydration)

Please no caffeine or other stimulants on the morning before your workout.

Please do not use any over the counter supplements during the entire period of participation in the study.

Please let Buddy know about any medications you are currently taking.

Please remember that in order for the results of this study to be as accurate as possible it is a must that you give a maximal effort during your workouts. This includes trying your best to get a good night sleep before your workout.

Please do not weight-train within 48 hours of your scheduled workouts.

Once again, thank you for your participation; you are greatly benefiting me, the university, and society. If you have any questions please call me at 554-3221.

BUDDY