ABSTRACT

EFFECT OF 8 WEEKS OF CHRONIC L-ARGININE SUPPLEMENTATION ON UPPER BODY MUSCULAR STRENGTH IN RECREATIONAL BODY BUILDERS

L-arginine has been advertised as a potential ergogenic aid for resistance training. However, scientific studies that have been conducted have not supported manufacturer claims. The purpose of this study was to examine the effects of L-arginine supplementation on upper body muscular strength in the bench press in healthy, male, recreationally trained body builders. Twenty male college-age volunteers were randomly assigned to one of two groups in a double-blind design: L-arginine supplementation (8 weeks at 12 grams/day) or placebo (cornstarch at 12 grams/day). During the course of the investigation, subjects participated in 6 separate testing sessions. Subjects’ 1 repetition max (1RM) was measured on visits 1, 3 and 5 (V1, V3, V5). On visit 2 (V2), a strength test was performed that assessed the maximum number of repetitions that can be performed at 87.5% of their previously established 1RM. Following visit 2, Subjects loaded with either L-arginine or placebo for 4 weeks and were tested again, both for a newly established 1RM (V3) and an additional muscular strength test (V4). Subjects then loaded for an additional 4 weeks after which the same two measurements were determined (V5 & V6). 1RM was not significantly increased compared with the placebo group (p>.05) following the 4 and 8 weeks of L-arginine supplementation. Significance was found (p<.05) in the maximum number of repetitions that a subject could perform at 87.5% of their previously established 1RM in the L-arginine group at 8 weeks compared to baseline and in the amount of volume lifted at 8 weeks compared to placebo.

Andrew Quesada
December 2010
EFFECT OF 8 WEEKS OF CHRONIC L-ARGININE SUPPLEMENTATION ON UPPER BODY MUSCULAR STRENGTH IN RECREATIONAL BODY BUILDERS

by

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A thesis
submitted in partial fulfillment of the requirements for the degree of Master of Arts in Kinesiology in the College of Health and Human Services California State University, Fresno December 2010
APPROVED

For the Department of Kinesiology

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ACKNOWLEDGMENTS

On a cold winter night, a grandma asked her grandson: “If you can ask God for one thing, what would you ask for?” The grandson smiled at his grandma and said the first thing that came to his mind, “I would ask God to keep my grandma with me forever and always.” The grandma, looking to her grandbaby with tears in her eyes said, “I will be with you forever and love you always.”

A grandfather prays with his grandson every night, “Dear God, if you can make my grandson one thing, make him a man in all of his ways.” Of all of the people that surround my life, there is nobody nobler, more selfless, kinder, or godlier then my grandpa. His life reflects everything that I want to be, and because of that, I cannot thank him enough for everything he has done for me. I will never stop striving to be a man in all of my ways, for as long as I live.

My acknowledgments go out to my grandparents, Dan and Lupe Quesada. Although my grandma is no longer with me on earth, I know she is with God in heaven and with me always in my heart and in my mind. She is forever missed and forever loved. When I asked God on that cold night to never take my grandma away from me, he listened. God put my grandma in my thoughts and in my life forever and always. Until that day where I see her again in heaven, I thank God every day that he put her in my life.

I would next like to thank my friends and family for always being there for me no matter what. Your prayers and encouragement have gotten me through every hardship in my life and I would not be here today if it were not for you. You believed in me in times that I did not believe in myself. I love you all.

-Andrew
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CHAPTER 1: INTRODUCTION

Today’s athletes constantly reach for a pill or new supplement which would give them an edge over their opponent. In the mind of an athlete, winning is winning no matter if you win by an inch or a mile. Amino acids are the most widely used potential ergogenic aids in athletes today (Martin, Faulhaber, Hotter, & Likar, 2005). Athletes desiring anabolic effects have targeted the amino acid L-arginine as an ergogenic aid. The semi-essential amino acid L-arginine AKG is a popular supplement currently on the market and commonly used by athletes as a potential ergogenic aid for resistance training. Advertisements for this amino acid target college age males with claims that it is a good “pre-workout” product to enhance strength, power, and vasodilation thus increasing nutrient delivery and enhancing endurance during resistance training. However, according to many nutritional researchers, scientific studies that have been conducted using L-arginine have not supported manufacturers’ claims (Robinson, Sewell, & Greenhaff, 2003; Wolinsky, Guest, Lewis, & Guest, 2004).

L-arginine is a semi-essential amino acid. In healthy children and adults L-arginine may be considered a nonessential amino acid as it can be biologically manufactured in the body and used when needed. In individuals experiencing a catabolic stress such as exercise arginine becomes a conditionally essential amino acid (Nakagawa, Takahashi, Suxuki, & Kobayashi, 1963). L-arginine activity is high in the liver; it facilitates detoxification functions, specifically filtering the ammonia out of the cell that is produced during exercise. This removal of ammonia is an important physiological function pertaining to muscle recovery as it promotes faster recovery time postexercise allowing for an increase in protein metabolism to repair muscle tissue and decrease muscle soreness (Moncada,
Palmer, & Higgs, 1989). L-arginine is also the precursor for the gas Nitric Oxide (NO) that is produced in the body which facilitates smooth muscle relaxation. NO is also important in neurotransmission, gastrointestinal activity, respiratory function, genitourinary function and host defense functions (Palmer, 1993).

Most of the studies that have been conducted on L-arginine have used special populations. Supplemental L-arginine has been demonstrated to have positive effects on immune responses in patients experiencing burns, surgery, and trauma (Daly et al., 1988; Saffle, Wiebke, Jennings, Morris, & Barton, 1997). These studies have shown reduced length of hospital stay and infection rate. Also reported were increased lymphocytes, CD3+ and Cd4+ helper cell activity in patients provided supplemental arginine (Kirk et al., 1993).

The very few studies that have been conducted using healthy, resistance-trained adults have shown either inconclusive results or have demonstrated that further research is needed. Siani et al. (2000) concluded that when a moderate, 3 gram a day increase in L-arginine was given to subjects, they had a significant decrease in blood pressure. However, Robinson et al. (2003) reported that L-arginine supplementation did not lower systolic or diastolic blood pressure in healthy adults when ingested pre and postexercise.

**Purpose**

The purpose of this study was to examine the effects of L-arginine supplementation on upper body muscular strength as measured by bench press in healthy, male, recreationally trained body builders.

**Research Questions**

1. Does L-arginine supplementation increase upper body strength in the bench press in resistance trained males at 4 weeks in comparison to baseline?
2. Does L-arginine supplementation increase upper body strength in the bench press in resistance-trained males at 8 weeks in comparison to baseline?

3. Does L-arginine supplementation increase upper body strength in the bench press in resistance-trained males at 8 weeks to a greater extent when compared to 4 weeks?

**Hypotheses**

1. L-Arginine supplementation will increase upper body strength in the bench press at 4 weeks in comparison to baseline.

2. L-arginine supplementation will increase upper body strength in the bench press in resistance trained males at 8 weeks in comparison to baseline.

3. L-arginine supplementation will increase upper body strength to a greater extent in the bench press at 8 weeks in comparison to strength gains at 4 weeks.

**Delimitations**

1. Subjects were self-directed recreational resistance-trained males (body builders) with max bench press performance that varied on muscular fitness and strength variables.

2. This study evaluated only males who were resistance-trained and who had been on a consistent weight training program for a minimum of 2 years.

3. Subjects’ upper body muscular strength was determined by testing subjects’ 1RM and from the maximum number of repetitions subjects could complete at 87.5% of their 1 repetition maximum (1RM) bench press.

4. Subjects kept a training log throughout the entire duration of the study and kept a diet log for 48 hours prior to each testing period.
Limitations

1. Female subjects were not tested due to the hormonal cycle in females that may have an impact on the metabolism of L-Arginine and its bioavailability that is affected during a females’ menstrual cycle (Lane, Steege, Rupp, & Kuhn, 1992).

2. Diets consisting of protein/nitrogen/L-arginine rich foods, which can also increase Nitric Oxide levels in the body, were not controlled for in this study.

3. Each subject’s individualized training regimen and individualized nutritional regimen throughout the study was consistent from test to test but not controlled.

Definition of Terms

1. Ergogenic Aid: dietary supplements intended to enhance athletic performance.

2. L-arginine AKG: an essential/ nonessential amino acid occurring in proteins and involved in the urea cycle, which converts ammonia to urea, and in the synthesis of creatine (Pasquale et al., 1997).

3. Nitric Oxide (NO): a molecule consisting of one atom of nitrogen and one atom of oxygen. The production of Nitric Oxide occurs when the amino acid L-arginine is converted into L-citruline through an enzyme group known as Nitric Oxide Synthase (NOS) (Bode-Böger et al., 1998).

4. Recreational body builder: an individual who has participated in a 4-5 day a week resistance training program year round, for a minimum of 2 years. One who splits up his workout by individual body parts, striving for muscular strength, size, and a body builder’s physique.

5. Vasodilation: dilation of a blood vessel, as by the action of a nerve or drug.
CHAPTER 2: REVIEW OF LITERATURE

This chapter examines the relevant literature pertaining to the effects of L-arginine supplementation. The review of literature discusses the physiological role that L-arginine plays in the body, the effects that L-arginine has in different special populations and the ergogenic effects of L-arginine that have been found in the healthy, resistance-trained population.

L-Arginine and Its Physiological Role in the Body

L-arginine is considered a semi-essential amino acid, although in some cases such as postsurgery inflammation, those with high blood pressure, and those who are lacking blood flow in certain areas, L-arginine becomes an essential amino acid. L-arginine is used during times of physiological stress, such as during exercise in healthy adults. In addition, L-arginine plays an important role in children with an inborn error of compromised urea cycle metabolism in the liver; in this case L-arginine may become an indispensable amino acid. Supplemental L-arginine is also used to spare L-arginine reserves that are stored in the body that have not been used during stress, thus sparing L-arginine in the body that may be needed for use when intake becomes low. This process of L-arginine sparing and utilization varies by individual but may be required by a person’s metabolism at any time during times of catabolic stress (Wolinsky et al., 2004).

L-arginine in certain doses, even as low as 2 grams, has been shown to stimulate the secretion of growth hormone, even more than intense, anaerobic exercise alone (Pasquale et al., 1997). According to Chromiak and Antonio (2002), specific amino acids such as L-arginine can stimulate growth hormone (GH) release. When infused intravenously or administered orally, arginine has been shown to release growth hormone (Chromiak & Antonio, 2002). Wolinsky
et al. (2004) have shown that exercise alone has a greater impact on growth hormone release than L-arginine supplementation or any physiological effects it may have in the body (Bode-Böger et al., 1998).

L-arginine is also known to be a precursor to creatine phosphate. Creatine is stored in skeletal muscle and is used in short bouts of high-intensity exercise. Higher intramuscular creatine phosphate (CrP) levels in skeletal muscle helps regenerate ATP faster. Given that L-arginine helps increase phosphate levels in the muscle by increasing creatine stores that are used during short, high bouts of anaerobic performance, it is conceivable that during the bench press exercises more repetitions should be able to be done (Stead, Au, Jacobs, Brosnan, & Brosnan, 2001). Thus L-arginine could be utilized to create more creatine phosphate when weightlifting, delaying the depletion of creatine stores during the duration of a workout (Pasquale et al., 1997).

Nitric Oxide (NO) is produced in the body from the conversion of L-arginine using the enzyme nitric oxide synthase (NOS). NOS oxygenates the guanidine group of L-arginine that converts L-arginine into Nitric oxide and L-citrulline that is circulated in the blood that increases vasodilation (Boudko, 2007). Nitric oxide (NO) is synthesized by the L-arginine/NO pathway. Nitric oxide is needed in the body to regulate vascular smooth muscle tone and transfer blood and nutrients more effectively in muscle cells. NO also causes relaxation of the smooth muscle by activating soluble guanylate cyclase to increase cyclic guanosine monophosphate (GMP) levels. GMP is a cyclic nucleotide derived from guanosine triphosphate (GTP). In addition, cyclic AMP activity is increased and acts as a second messenger much like GMP, most notably by activating and increasing intracellular protein kinase threefold in response to the binding of membrane impermeable peptide hormones on the external cell surface. L-arginine
supplementation may have an anabolic effect during resistance training and slow catabolism postexercise. This may result in a fast recovery period postexercise and significant strength gains due to L-arginine supplementation (Francis & Corbin, 1999).

**L-Arginine in Special Populations**

Special populations, especially people with heart failure, have been the primary population used when examining L-arginine supplementation. Acute supplementation may provide a favorable outcome through a mechanism where L-arginine provides the substrate for Nitric Oxide, especially in patients with elevated levels of the endogenous NO synthase inhibitor asymmetric dimethylarginine. Short-term endocrine effects and reactions may contribute to L-arginine induced vasodilation after higher doses that help with smooth muscle relaxation and increased blood flow to organs. In addition, long-term studies have been performed that show that chronic oral administration or intermittent infusion therapy with L-arginine can also improve clinical symptoms of cardiovascular disease (Bode-Böger et al., 1998).

A study by Dumont, D’Amours, Lebel, and Lariviere (2001) demonstrated that when L-arginine was supplemented in rats with hypertension, an increase in tissue weight and capillary density was created. This could have a beneficial effect in anaerobic exercise. Allowing for a decreased diffusion distance during muscular hypertrophy by an increase in capillary density may increase the amount of nutrients in the cells of skeletal muscle, in addition to increasing ATP production in the mitochondria that may lead to an increase in strength. In contrast, with acute L-arginine supplementation, improvement of NO release has been shown to have the greatest effect on increasing vasodilation but did not have
any effect on improving high systolic blood pressure. However, Siani et al. (2000) demonstrated that 3 grams a day of supplemental L-arginine significantly lowered blood pressure and improved renal function and carbohydrate metabolism in healthy, male volunteers.

L-arginine supplementation has also been studied in elderly individuals with insulin resistance. In people with diabetes, infection is more common because wound healing is severely compromised. Witte, Thornton, Tantry, and Barbul (2002) researched L-arginine supplementation in subjects with diabetes and found that wound healing is directly related to the amount of NO that is produced in the body. They suggested that L-arginine supplementation restores impaired healing by normalizing the NO pathway without affecting arginase activity.

L-arginine supplementation has also been showed to increase insulin response in individuals with cardiovascular disease. Thirty-two nondiabetic patients with cardiovascular disease received L-arginine (6.4 g/d) or placebo for 6 months. An evaluation of insulin sensitivity index during the oral glucose load, markers of systemic nitric oxide bioavailability and inflammation, and blood flow was performed before and at the end of the treatment in both groups. It was concluded that L-arginine increased the insulin sensitivity index. In conclusion, insulin resistance, endothelial dysfunction, and inflammation are important cardiovascular risk factors in coronary artery disease patients and L-arginine seems to have anti-inflammatory and metabolic advantages in these patients (Lucotti et al., 2009).
L-Arginine in a Healthy Resistance Trained Population

Campbell et al. (2006) examined the effects of L-arginine α-Ketoglutarate (AAKG) in resistance-trained males. Subjects received 12g a day of L-arginine (4g/3 times daily) for 8 weeks. Given that the subjects were strictly resistance-trained, results showed only a significant increase in 1 RM bench press and Wingate peak power, but showed no effect on lean body mass or isokinetic endurance performance in the supplemented group compared to the placebo group.

Campbell et al.’s (2006) is the only study that has been conducted on L-arginine supplementation in resistance-trained males and its potential ergogenic effects. Examining the inconclusive results the study provided, the current study examined the potential ergogenic effects of chronic supplementation of L-arginine on strength training variables.
CHAPTER 3: METHODS

The following chapter outlines the methodology for this investigation. Descriptions of the subjects, research design, and statistics are presented.

Participants

Twenty male, college-age, resistance-trained individuals were recruited for this randomized, double blind study. The demographic data for the subjects were (mean ± SD): age, 24.2 ± 3.1; weight, 182.4 ± 30.2, height, 70.5 ± 3.5 in., body fat, 13.5 ± 6.2%. All subjects were informed of the risks and benefits and signed an informed consent form (Appendix) in adherence with the ethics committee of California State University, Fresno prior to their participation. To participate in the study, subjects could not have taken any anabolic performance enhancing supplements for 6 months prior to start of the test. Subjects adhered to a 3-5 day a week resistance training schedule and were asked to maintain a training log throughout the duration of the study.

Procedures

Research Timeline

During the course of the investigation, all subjects reported to the Human Performance Laboratory (HPL) located on the California State University, Fresno campus, on six separate occasions. At the initial visit of the study, subjects age, weight, height, and percent body fat were determined. These measurements were taken again at 8 weeks to determine any changes in body composition. During the first visit, subjects were informed of risks and benefits involved in the study. Subjects’ 1RM for the bench press was measured on visits 1, 3, and 5 (V1,V3, V5). Following a 3-day rest (V2), the number of repetitions the subject could
perform at 87.5% of their established 1RM was determined and used for an additional strength assessment for the duration of the study. Subjects were then randomized into either the placebo group or the L-arginine group (n=20), and followed a 4-week period of either taking cornstarch or L-arginine, respectively. After 4 weeks, subjects then returned to the lab for another 1RM test (V3), and 3 days later another additional strength assessment was done (V4). Following an additional 4 weeks of L-arginine or placebo (cornstarch) loading, subjects underwent the same measurements (V5, V6) (see Figure 1).

Since there was no control over the amount of L-arginine that could be obtained from food, subjects were asked to adhere to their same eating habits 48 hours prior to testing to allow for uniformity between experimental trials. In addition, a nutrition log was kept 48 hours prior to testing to ensure that they did adhere to the given procedures. Subjects were also asked to abstain from all alcohol and strenuous resistance training 48 hours prior to testing.

Pretrial Warm-up

Subjects were asked to maintain the same resistance training schedule throughout the duration of the study. During the investigation, no training intervention took place. During each visit, the following standardized American
College of Sports Medicine warm up was used: set 1: 25% max for 10-12 reps, set 2: 50% max for 10-12 reps, set 3: 75% max 8-10. After warm-up was completed, on the fourth set, either a 1RM was established or the number of repetitions completed at 87.5% of 1RM was determined. All bench press exercises were on a Smith machine to ensure that the bar came down on the chest the same place every time, and that the subjects kept their back straight on the bench at all times, with no arching of the back.

Supplementation Protocol

There were two treatment possibilities that subjects received during the 8 weeks of testing. Subjects were randomly assigned to take either L-Arginine AKG or placebo (cornstarch) at a dose of 3 grams/4 times daily for the duration of the study. Subjects participating in the study took either L-arginine or cornstarch at the following times: 30 min before breakfast, 30 min before lunch, 30 min before workout and 30 min before bed. At least a 4-hour gap between dosages was desired, so the L-Arginine or placebo (cornstarch) loading effect constantly took place throughout the day. This loading protocol was consistent with the only L-arginine study previously conducted on strength trained individuals (Campbell et al., 2006).

Upper Body Muscular Strength Assessments

To assess if there was a change in subjects’ upper body muscular strength, subjects’ 1RM and maximum number of repetitions were done on visits 1, 3, and 5 to see if there were any changes in the bench press over the duration of the study. On visits 2, 4, and 6, no less than 2 hours after a light meal, subjects warmed up and performed the maximum number of repetitions that they could at 87.5% of
their 1 repetition max (1RM) in the bench press (BP) (Peterson, Rhea, & Alvar, 2005). Full and partial repetitions were counted using a yardstick that was placed on the Smith Machine perpendicular to the bar and video was used to review repetitions done to establish the exact number of repetitions completed in a given bout. All subjects agreed to and complied with the given testing expectations and performed as many repetitions as they could in accordance with their previously predicted 1 repetition max (1RM). Both the subjects’ 1RM and the subject’s 87.5% of max repetition tests were used for strength assessment. All weight or repetition increases or decreases were recorded in direct correlation with subjects’ total mean volume lifted (weight lifted x max repetitions done at 87.5%) at 8 weeks of supplementation.

**Statistical Analysis**

In order to test for differences in upper body strength changes over the course of the investigation, a one-way ANOVA with repeated measures over time was conducted. The dependent measures were muscular strength at baseline, 4 weeks and 8 weeks. The experimental factors were placebo and L-arginine. A Bonferroni adjustment was used to probe differences between means. In the case of a significant main effect significance between groups was accepted at p ≤ .05 and data were reported as means ±SD.
CHAPTER 4: RESULTS

This chapter represents the results of the collected data as described by the methodology of this research effort. It is organized into the baseline measures of subjects and the effect of supplement on upper body muscular strength.

**Baseline Measures**

Initial 1RM values for the subjects in the L-arginine supplementation group (ARG) were 228.5 ± 34.1 lb compared to placebo (PLA) group (232.0 ± 38.8 lb). There was no statistically significant difference between the groups for this variable (Figure 2).

Initial average number of repetitions performed at 87.5% of the subjects’ bench press 1RM in the L-arginine supplementation group (ARG) were 6.0 ± 1.0 reps compared to placebo (PLA) group (4.1 ± 1.6 reps). There was no statistically significant difference between the groups for this variable (Figure 3).

**Effect of Supplement on Upper Body Muscular Strength**

The most important findings of this study was a significant increase in the number of repetitions performed at 87.5% of subjects’ 1RM in the ARG group compared to the placebo group after 8 weeks of supplementation. Furthermore, the ARG group also showed an increase in total volume lifted (weight lifted x max repetitions done at 87.5%) compared to placebo group at 8 weeks of supplementation (Figure 4).

1RM measures were not different between groups after 4 weeks of supplementation (PLA 235.0 ± 33.9 lb, ARG 242.5 ± 33.9 lb) compared to baseline measures (PLA 232.0 ± 38.8 lb, ARG 228.5 ± 34.1 lb). Furthermore, an additional 4 weeks of supplementation (PLA 238.0 ± 38.3 lb, ARG 254.5 ± 33.9 lb).
lb) also did not result in any significant increase in 1RM between groups compared to baseline (PLA 232.0 ± 38.8 lb, ARG 228.5 ± 34.1 lb). PLA and ARG groups were not significant from each other at (p>.05) (Figure 2).

Following 4 weeks of supplementation, the number of repetitions completed at 87.5% of subjects’ 1RM was not significantly different from each other. The average numbers of repetitions at 87.5% of subjects’ 1RM for the ARG group were 5.3 ± 1.6 reps vs. 5.7 ± 1.7 reps in the PLA group. However, following 8 weeks of supplementation, the average number of repetitions at 87.5% of subjects’ 1RM for the ARG group was 5.4 ± 1.4 reps vs. 4.9 ± 1.1 reps in the PLA group. Significance was found after 8 weeks of L-arginine supplementation at (p<.05) compared to placebo (Figure 3).

The findings of this study demonstrated a significant increase in the number of repetitions performed at 87.5% of subjects’ 1RM in the ARG group compared to the placebo group after 8 weeks of supplementation at (p<.05). Furthermore, the ARG group also showed a significant increase in total volume lifted at 1202.53lb ± 36.8 lb compared to the placebo group at 1020.43lb ± 44.3 lb at 8 weeks of supplementation at (p<.05) (Figure 4).
Figure 2. One repetition max (1RM) from baseline to 8 weeks of supplementation. Values are expressed as means ± SD.

Figure 3. Repetitions at 87.5% of max from baseline to 8 weeks of supplementation. Values are expressed as means ± SD.
Figure 4. Total Mean Volume (TMV) lifted at 8 weeks of L-arginine supplementation. Values are expressed at ± SD.
CHAPTER 5: DISCUSSION

The data from the present study demonstrated that 8 weeks of chronic oral supplementation with L-arginine has an ergogenic effect on upper body muscular strength in college-age, male resistance-trained individuals. The results are similar to those from Campbell et al. (2006), which showed a significant improvement of upper body muscular strength in the bench press with L-arginine supplementation. Campbell et al. (2006) supplemented 35 adult men with arginine α-Ketoglutarate for 8 weeks at 12 grams/day and found a significant increase in the 1RM bench press. While the current study did not demonstrate statistical significance in 1RM following ARG supplementation (p>.05) it was found that the L-arginine group had a 26-lb increase in subjects’ mean 1RM at (254.5 ± 33.9lb) compared to the placebo group who had an increase of 6 lb in subjects’ mean 1RM at (238 ± 37.3 lb) compared to baseline. Thus, the L-arginine group had a 7% higher increase in 1RM than placebo compared to baseline after 8 weeks of L-arginine supplementation. This may have practical significance to individuals who are interested in achieving strength gains. A plausible reason for the greater improvement in 1RM is related to the role that L-arginine plays in increasing creatine stores in skeletal muscle, which may have an ergogenic effect during high bouts of muscular effort thus increasing muscular strength. Another reason for an increase in muscular strength could have been from increased levels of anabolic hormones such as: Methionyl-human growth hormone (met-hGH), endogenous growth hormone (GH) and insulin-like growth factor I (IGF-I); L-arginine has been shown to increase these hormones during resistance training (Chromiak & Antonio, 2002).
The present study showed a statistically significant increase in volume (weight lifted x maximum number of repetitions at 87.5%) following 8 weeks of ARG supplementation (p<.05) at 1202.53lb ± 36.8 lb compared to placebo group at 1020.43lb ± 44.3 lb. The L-arginine group had a 15% increase in mean volume lifted compared to the placebo group at 8 weeks of supplementation. This significant increase in volume with only 8 weeks of supplementation suggests merit for future studies examining L-arginine supplementation for an even longer period of time.

L-arginine not only has an ergogenic effect in resistance training, but also has an ergogenic effect in aerobic training as well. Camic et al. (2010) showed an increase in gas exchange threshold (GET) in 20 college-age male endurance-trained individuals. Following a 4-week supplementation protocol of L-arginine at 3g/day, subjects showed an improvement in gas exchange threshold (GET) but showed no improvements in VO2max. They attributed the significant increase of GET to an increased clearance of metabolic biproducts such as lactate and ammonia and the improvement of blood flow associated with increased NO levels in the blood. They stated that higher doses of L-arginine should have been evaluated with a stricter protocol and increased study duration to establish a dose-dependent relationship with L-arginine supplementation in endurance trained individuals. Even though subjects from the previous study were aerobically trained individuals, biproducts such as lactate and ammonia are greatly produced during resistance training and L-arginine could have used the same clearance effects as the aerobically trained individuals.

L-arginine may benefit special populations with decreased NO levels and decreased insulin response but may not be valid when investigating healthy, resistance-trained males as they do not have deficiencies. Individuals with
cardiovascular disease, diabetes, and hypertension have improved cardiovascular and metabolic responses following L-arginine supplementation. Dumont et al. (2001) demonstrated that when L-arginine was supplemented in rats with hypertension, an increase in tissue weight and capillary density resulted, which created vascular hypertrophy. The increased capillary density may have helped increased glucose metabolism during exercise in addition to increasing the amount of O2 and nutrient exchange in the cell. The increased NO production that supplementing AAKG creates, will lower blood pressure in those with hypertension but may not have the same physiological properties in a healthy, resistance trained population.

L-arginine supplementation has been shown to increase insulin response in individuals with cardiovascular disease. Lucotti et al. (2009) showed that 32 nondiabetic patients with cardiovascular disease who received L-arginine (6.4 g/d) increased their insulin sensitivity index and decreased their arteriole inflammation. It was concluded that L-arginine supplementation helped decrease factors that are associated with heart disease, such as arteriole inflammation, decreased insulin utilization, and cholesterol. L-arginine supplementation may increase insulin response, decrease cholesterol and prevent unwanted inflammation in those with cardiovascular disease receiving only a small dosage of L-arginine (6.4g/day). Since L-arginine appears to help with increasing insulin utilization, arteriole inflammation and increase NO levels in the body, it may have the same effect on muscle inflammation and damage that may be induced during resistance training. An increase in NO levels, decreased inflammation, and increased insulin response in resistance training with L-arginine supplementation may decrease muscle soreness and help increase nutrient delivery and glucose metabolism during resistance training in healthy, resistance-trained individuals. Future studies may
show whether or not L-arginine elicits a greater response in an untrained population compared to a trained population having low levels of NO, creatine phosphate stores, lower insulin response, and decreased levels of anabolic hormones in the body. Future studies should also supplement L-arginine in trained and untrained populations and see if those who are untrained elicit a higher dose-dependent response than those who are trained.

Although it can be concluded that 8 weeks of L-arginine supplementation may elicit a physiological response in the body related to the increase of muscular strength, future studies should examine the effect of L-arginine over longer periods of time to see if L-arginine would show even greater increases in strength than was seen in an 8-week period. Considering the limited research that has been done on supplemental L-arginine, further research should also look at more healthy and unhealthy populations to examine the physiological effects at the cellular level that L-arginine may possess in the body to explain the reason for strength gains with L-arginine supplementation. Conclusive evidence of this physiological effect on muscular strength could have a major impact in the world of sport supplementation and performance.
REFERENCES


The purpose of this study will be to examine the effects of L-arginine supplementation on upper body muscular strength on bench press in healthy, male recreational trained body builders. Upper body muscular strength will be assessed by you doing the maximum number of repetitions that you can complete at 87.5% of your 1 repetition max (1RM) in the bench press (BP).

If you decide to participate in this study, I will require your attendance at the Human Performance Laboratory (HPL), located in the South Gym room 139 on 6 separate occasions. The first day in the lab will involve an introduction to the experimental procedures and a baseline one repetition max on the bench press exercise.

The supplement possibilities are as follows:

1. Placebo treatment: Placebo (cornstarch) thirty minutes prior to testing, and taken throughout the eight weeks of testing.

2. L-arginine treatment: An L-arginine dose (3 grams) thirty minutes prior to testing and throughout the eight weeks of testing.

On the second visit, thirty minutes prior to your test, you will report to the HPL and will ingest either a placebo (cornstarch) or L-arginine (3 grams). Three days later, you will report to lab again and will ingest a powder containing the same content as you did previously. Possible side effects of L-arginine include...
constipation or upset stomach. Each of the 2 supplement possibilities will be
separated by three days to allow full recovery from the exercise bouts.

Prior to each testing session you will be required to withdraw from all
alcohol containing products (beer, wine etc.) for 48 hours. Furthermore, I ask that
you not actively participate in strenuous exercise 48 hours prior to testing. During
each visit to the HPL you will be questioned on your adherence to the dietary
regime explained in the introductory session. You are expected to follow all pre-
testing procedures. Should any circumstances occur which prevents you from
following the specified procedures to perform 87.5% of your one repetition max or
to perform a one repetition max, please notify the investigator as soon as possible.

For the lab testing sessions, you will report to the HPL, and after a
standardized warm-up you will be required to perform either a one repetition max
or perform a predicted 1RM. While performing a standardized test, your strength
gains will be assessed from the predicted max test. Once your 1RM is established,
the number of repetitions that you can perform at 87.5% of your one repetition
max is how your strength gains will be properly assessed. During each trial you
will be asked to perform with a maximal effort.

For the testing sessions in the Human Performance Lab, you will be
required to perform 3 warm up sets on bench press. After warm up you will
perform either a one repetition max or 87.5% of one repetition max as maximally
as possible. Once again, prior to performing your bench press max, you will
undergo a standardized warm-up. During each bout you will be asked to perform
with a maximal effort.

Any information that is obtained by this investigation is strictly confidential
and will only be disclosed with your permission or as required by law. You may
request a copy of the results of the study at any time. If you give us permission by
signing this document, results from this study will be made available to the general public through submission to scientific journals and presentation at professional conferences; however, you will remain anonymous. It is the intent that publication/presentation of the results will add to the body of knowledge in the related fields of exercise physiology.

Your decision whether or not to participate in this study will not affect your future relations with CSU, Fresno. If you decide to participate you are free to withdraw your consent and to discontinue participation at any time without penalty. The committee on the Protection of Human Subjects at CSU, Fresno has reviewed and approved the procedures for the present study.

If you have any questions/comments regarding your participation in this investigation, please feel free to contact Dr. Felicia Greer (559) 278-2005 or the Chair of the University Institutional Review Board, Dr. Constance Jones (559) 278-4468.

You are making a decision whether or not to participate in this study, your signature indicates that you have decided to participate in this study having read the information above.

__________________________________________  __________________________
Participant’s Signature                      Date

__________________________________________  __________________________
Investigator’s Signature                     Date
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Andrew Quesada
Type full name as it appears on submission

November 2, 2010
Date