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THE EFFECT OF AMINO ACID SUPPLEMENTATION ON WEIGHT, BODY COMPOSITION, MUSCLE SIZE, AND MUSCLE STRENGTH IN AMATEUR WEIGHTLIFTERS

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THE EFFECTS OF AMINO ACID SUPPLEMENTATION ON WEIGHT, BODY COMPOSITION, MUSCLE SIZE, AND MUSCLE STRENGTH IN AMATEUR WEIGHTLIFTERS (83 pp.)

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Fifteen amateur weightlifters, between the ages of 21 and 35 years volunteered to participate in a study to determine the effect of an amino acid supplement on muscle size, muscle strength, body composition, and body weight. A blind protocol was followed in which eight of the participants were administered the amino acid supplement and seven received a placebo. Each subject was tested before and immediately after the ten week experimental period for height, weight, skinfolds (4 sites), hydrostatic weighing, body circumferences (11 sites), static strength (4 measurements), and dynamic strength (2 1RM tests). Because of small sample size, both parametric and nonparametric statistical designs were used to analyze the data. These included the dependent T test, independent T test, and sign test.

According to dependent T test results, no significant changes in weight, percent body fat, and static strength occurred from pre to post supplementation in the amino acid or the placebo group. There was one significant change in dynamic bench press strength in the placebo group. All other changes in dynamic strength measurements were not significant in the placebo and amino acid groups.

From pre to post supplementation, the nonparametric sign test results revealed significant trends for change in dynamic leg strength and static quadricep strength in the amino acid group and dynamic leg strength in the placebo group.

Post supplementation, independent T test indicated that the differences in percent body fat, weight, circumference measurements, static strength, and dynamic strength between the amino acid group and the control group were not significant. Therefore, it was concluded that the amino acid supplement administered in this study had no measured effect on percent body fat, body weight, muscle size, and muscle strength of the participating subjects.

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Chapter I

Introduction

Throughout history men who were interested and involved in athletic performance have searched for a magical potion or special technique that would allow them to perform extraordinarily well and give them the edge over their opponents. In the past 20-30 years there has been an increased interest and research in the attributes of an elite athlete and the factors that effect their performance. The research has concentrated on the physical characteristics, physiological parameters, training methods, and dietary habits of the elite athlete. There has also been a concerted effort to predict the maximum potential in athletic performance.

Ergogenic aids have frequently been used in an effort to improve an athlete's performance. Ergogenic aids are substances or procedures that proport to improve physical performance or hasten the post exercise recovery of the performer. Many substances have been used, suggested, and studied. A few of the more popular potential ergogenic aids studied are: pharmaceuticals (amphetamines, anabolic steroids), carbohydrates, oxygen, blood doping, hypnosis, and mental practice. Some studies have shown certain substances may effect physical performance, but many do not show any effect. Studies on ergogenic aids are controversial and contradictory, and often use empirical and testimonial information. Many studies lack sufficient objectivity, controls,

and number of subjects.

It is well documented that numerous athletes use ergogenic aids. Amateur and professional weightlifters and bodybuilders are known to use many of the more ergogenic substances. In these two activities, as well as other body weight oriented sports, specific diets consisting of high protein foods and protein supplements, anabolic steroids, and growth hormones are used to increase muscle strength and mass. The medical profession has deemed that many of these substances are contraindicated and potentially dangerous to an athlete's health.

Historically, many weight oriented athletes consume large quantities of meat to replace substances they believed were lost from the muscles during intense exercise (Astrand and Rodahl, 1981). Skeletal muscle is composed largely of structural proteins. Many athletes ingest not only large amounts of meat, but take extra dietary protein in the form of powders, drinks, and tablets in an effort to replace muscle tissue they believe is broken down during training. Protein supplementation has become a major ergogenic aid for numerous athletes, particularly weightlifters and others desiring muscle strength and size.

Since it is well known that the building blocks of a protein molecule are amino acids, athletes are now taking amino acids in tablet form. Promoters of amino acid supplements claim the ergogenic aid can significantly increase muscle size and strength, burn fat, and increase energy production. Many popular health and fitness magazines claim that the exogenous amino acids are absorbed and assimilated by the body more readily than protein, and therefore, are more effective than protein supplements.

Although significant research has been performed concerning protein supplementation (Lemon et al., 1984, Laritcheva, et al., 1978, Golding et al., 1974, Pitts et al., 1944, Darling et al., 1944), limited research (Elam, 1988, Elam et al., 1989) has shown how amino acids effect the performance of an athlete, particularly one in good health and following an adequate diet.

Statement of the problem

The purpose of this study was to investigate the effects of an amino acid supplement on the strength and size of skeletal muscle, body composition, and body weight of trained amateur weightlifters.

Need for the study

Many athletes believe that they need greater than normal amounts of amino acids (protein) for optimal athletic performance. Amino acids are widely promoted and distributed as a successful ergogenic aid but there is very limited scientific evidence to support the claims. Objective controlled studies are needed to determine the effect amino acid supplements have on athletic performance.

Limitations and Assumptions

There were several limitations and assumptions to this study:

1. In order to minimize the training effect, only trained weightlifters were recruited as subjects. It was assumed that the subjects, who worked out regularly, were trained.

2. Subjects were asked not to take any additional dietary supplements or drugs during the experimental period. It was assumed that they adhered to this request.

3. It was assumed that the subjects would continue to follow their regular weight training routines and not increase their exercise regimen.

4. All subjects were told they were taking amino acids although the control group took a placebo. It was assumed that the placebo group believed they were taking the amino acid supplement.

5. The subjects were not supervised while taking the amino acids. It was assumed that they took the prescribed dosage at the designated times.

6. The subjects did not train as a group, but worked out independently. It was assumed that they performed the programs they reported.

7. Since the sample size was small (Amino acid group N=8, Placebo group N=7), the inferences made from the results about the general population were limited.

Chapter II

Related Literature

Introduction to Protein and Amino Acids

Food is essential for human survival. It provides the body with materials for growth, development, and repair. It also provides the fuel needed to carry out the body's metabolic processes. To function efficiently the human body requires a diet including carbohydrates, fats, proteins, vitamins, and minerals. Primarily carbohydrates and fats, and to a small degree, proteins supply the body with energy. The most important source of building material for the body, however, are proteins. The body's need for protein is actually a need for amino acids, the building blocks of protein molecules.

Twenty percent of the human body is composed of complex protein molecules (Lemon et al., 1984). Most proteins are large molecules formed by the linkage of many small subunits called amino acids. There are approximately 20 different amino acids. They are composed of hydrogen, carbon, oxygen, and nitrogen, and in some cases, sulfur. Characteristically, each amino acid contains a nitrogen component in the form of a nitrogen radical NH_2, and an acidic carboxyl group COOH, and has the molecular configuration R' -CH-NH_2.

$$R'\text{-}\underset{\displaystyle \text{COOH}}{\underset{|}{\text{CH}}}\text{-}NH_2.$$

Each amino acid differs only by the radical R' which stands for a general representation

of a carbon chain unique to each amino acid (Guyton, 1968, Lehninger, 1982, Vander et al., 1980). During protein formation, amino acids are joined in a linear fashion into peptide linkages. Biochemically the amino radical (NH_2) of one amino acid links with a carboxyl group (COOH) of a second amino acid producing a peptide bond between the two. Many amino acids will combine in this manner to form a polypeptide chain or protein. Proteins differ in the number of amino acids they contain and in the sequence in which the amino acids are joined (Guyton, 1968, Lehninger, 1982, Vander et al., 1980). The twenty amino acids can be divided into two major groups; essential and nonessential. Essential amino acids are those which the liver can not synthesize. These consist of: Threonine, Lysine, Valine, Phenylalanine, Leucine, Tryptophan, Isoleucine, Methionine, and Histidine. Since the liver can not produce these amino acids, they must be supplied through the diet. Essential amino acids are found in complete protein foods such as milk, cheese, eggs, beef, and fish. Structural amino acids are also found in vegetable sources although plant proteins do not contain all nine essential amino acids. Plant proteins are therefore termed incomplete protein bearing foods. Combinations of vegetables must be eaten to obtain all nine essential amino acids. If the essential aminos are not consumed in the diet, adverse health effects, and even death occur depending on the length and degree of the deficiency (Fox and Mathews, 1981, Lemon et al., 1984).

Nonessential amino acids can be synthesized by the human liver with available molecules of hydrogen, nitrogen, carbon, and oxygen even when no protein is consumed. The nonessential amino acids are: Glycine, Serine, Cysteine, Cystine, Aspartic Acid, Glutamic Acid, Tyrosine, and Proline.

Amino acids have numerous functions within the body. They play a role in forming enzymes, structural proteins (such as those in muscles), peptide hormones, neurotransmitters, plasma, hemoglobin, and under certain circumstances produce energy. Proteins and amino acids are continuously undergoing synthesis, degradation, and reutilization within the body. Often amino acids not utilized for protein synthesis undergo oxidation, and the carbon, hydrogen, and oxygen atoms released are used for the synthesis of glucose, fatty acids, or as an energy source. Sometimes the nitrogen released during the oxidative process is used to form urea, ammonia, creatinine, uric acid, or other nitrogenous wastes. The wastes are usually excreted from the body in the urine, sweat, or sloughed skin, nails, and hair (Haymes, 1983, Slavin et al., 1988, Food and Nutrition Board, 1980, Martin et al., 1981).

Recommended Dietary Allowances of Proteins

A balanced diet including all the essential nutrients (carbohydrates, fats, proteins, vitamins, and minerals) is required to provide the energy and building materials for proper human growth and development. With such an important role it is reasonable to assume that dietary habits may also affect an individual's athletic performance. It has been well established that a diet lacking in the proper nutrients will impair physical performance (Fox and Mathews, 1981). To meet increased physical demands, the question exists as to whether athletes require more of the essential nutrients than a nonathlete. In particular, the required amount of proteins and amino acids ingested by an athlete has been under question.

Dietary protein must be sufficient to replace essential amino acids and nitrogen

lost through normal protein turnover or excretion by the body. When the amount of nitrogen ingested in the form of protein/amino acid equal the amount of nitrogen lost from the body, a state of nitrogen balance exists. The Food and Nutrition Board (1980) states that to maintain nitrogen balance the recommended dietary allowance (RDA) for protein is .8 grams per kilogram of body weight per day. The RDA was determined after examination of several studies investigating obligatory nitrogen losses of young adults on protein free diets (Calloway and Margens, 1971, Scrimshaw et al., 1972). The value was derived with a 30 percent margin of safety to meet the demands of most members of the population.

The Food and Nutrition Board (1980) states that an increase in protein intake may not be needed for muscle development except for a small amount that may be required if calories consumed is not adjusted for the increased physical work performed (Torun et al., 1977). The possible small increase is easily met through the 30 percent margin of safety built into the RDA.

An individual's daily caloric and protein intake varies with each person depending on size, sex, and degree of physical activity. An average sedentary adult male weighing 75 kg should ingest approximately 60 grams of protein according to the RDA. An increase in protein intake, however, would be expected when caloric intake increased to meet the physical demands of athletic training. An athlete would maintain his total protein intake at 10-15 percent of his total calories. As his caloric intake increased to meet the physical demands of his sport, so would his protein intake (Haymes, 1983). For example, an athlete who increases his caloric intake from 3000 to 40000 kcal/day

for training would also increase his protein consumption from 90 to 120 g/kg/day if 12 percent of his calories consumed were protein. His protein intake relative to his body weight would increase from 1.3 to 1.7 g/kg/day to meet the increased physical demands.

Recommended Dietary Allowances of Amino Acids

Nine amino acids are considered essential amino acids and must be provided in the diet. Estimated requirements of these nine, based on published data, are given in Table 1. The adult values have been adjusted upward by 30 percent to account for individual variability. Even with the adjustments, the values required for maintenance are small. The amino acid Histidine is essential to an infant's diet, however, in an adult its requirement has not been established. Arginine is no longer an important requirement for infant growth and development (National Food and Nutrition Board, 1980).

Theories Behind Protein Supplementation

Many coaches, trainers, and athletes are not in agreement with the National Food and Nutrition Board (1980) and the established protein and amino acid requirements (Paish, 1987, Hoffman, 1983, Page, 1982). There are several prevailing theories that attempt to explain why athletes may need more protein than the RDA specifies (Wilmore and Freund, 1986, Yoshimura et al., 1980).

A popular theory proposed that protein degradation or protein "breakdown" increases with exercise and therefore, an athlete would require greater amounts of dietary protein to compensate for the loss (Hatfield, 1987, Paish, 1987). Among the many studies conducted to examine the theory (Dohm et al., 1978, Lemon and Mullin, 1980,

Table 1

Estimated Amino Acid
Requirements of Man*

Requirement,
mg/kg body wt/day

	Infant	Child	Adult
Histidine	33	unknown	unknown
Isoleucine	83	28	12
Leucine	135	42	16
Lysine	99	44	12
Total S containing			
Amino Acids	49	22	10
Total aromatic			
Amino acids	141	22	10
Threonine	68	28	
Tryptophan	21	4	3
Valine	92	25	14

*National Research Council Food and Nutrition Board, 1980

Refsum and Stromme, 1974, Laritcheva et al., 1978), several different techniques for measuring protein catabolism have been used.

Several studies measuring serum urea, a byproduct of protein degradation, have demonstrated an increase in protein catabolism during endurance exercise (Dohm et al., 1978, Lemon and Mullin, 1980, Refsum and Stromme, 1974, Haralambie and Berg, 1976, Gontzea et al., 1974). Elevated urea excretion has also been demonstrated during strength training activities such as weightlifting (Laritcheva et al., 1978, Dohm et al., 1982). In a recent study, however, no acute changes in urea excretion were observed in subjects following a standard weight training regimen (Hickson et al., 1986). Although many studies have used urea excretion as an estimator of protein catabolism, the technique has been deemed indirect and unreliable by some investigators (Lemon et al., 1984, Lemon, 1987). Too many factors exist that may influence the way in which urea is produced and excreted from the body during exercise.

Some investigations have used the urinary excretion of the amino acid 3-methyl-histidine as an indicator of protein degradation during exercise (Hickson et al., 1986, Meredith et al., 1989, Dohm et al., 1982, Rennie et al., 1980). Found in the muscle myofibrils actin and myosin, 3-methyl-histidine is a byproduct of myofibrillar protein catabolism (Carter and Smith, 1979). When formed the amino acid is not reutilized or catabolized by the body, but completely eliminated in the urine (Young and Munro, 1978). By measuring this amino acid, some studies have shown an increase in muscle protein breakdown during exercise (Dohm et al., 1982), while several studies have found that protein degradation decreased (Bates et al., 1980, Rennie et al., 1980), or undergoes

no change at all (Decombaz et al., 1979, Hickson et al., 1986, Meredith et al., 1989).

Utilization of 3-methyl-histidine as an estimator of protein degradation may not be accurate since it appears that not only skeletal muscles, but the gastrointestinal tract, may influence the excretion of the amino acid during exercise (Lemon et al., 1984). As well, the intensity and duration of exercise and the time at which urine collection is made post exercise can significantly effect the experimental outcomes (Lemon, 1987).

In recent years a more precise and direct technique to study protein degradation during exercise has been used (Lemon et al., 1982, Millward et al., 1982, Wolfe et al., 1982). The technique employs radio-labelled amino acids to trace how an amino acid(s) is utilized by the body. These studies, completed using endurance exercises, have indicated that: energy derived from amino acid utilization increases with exercise intensity (Lemon et al., 1982), protein degradation may increase with exercise (Millward et al., 1982), and that certain amino acids are used for muscle contraction (Millward et al., 1982). Unfortunately, few studies using radio-labelled amino acids to study strength training and its effect on protein catabolism exist. The common belief that weightlifting breaks down muscle tissue (protein) has not been proven (Lemon et al., 1984). Further research is needed to accurately determine if endurance and strength training exercise increases protein catabolism.

The complement of protein degradation is protein synthesis (anabolism). A second theory to explain the increased protein requirement for athletes suggests that protein supplementation enhances the production of protein within skeletal muscles. The increased production, in turn, increases muscle size, muscle strength, and overall athletic

performance (Wilmore and Freund, 1986). Several investigations have indicated that protein anabolism increases due to endurance exercise (Vanderburg and Kaufman, 1979, Brevet et al., 1976, Hamosh et al., 1967), and weightlifting (Rennie et al., 1980). Others, however, have observed a decrease (Bates et al., 1980) or no change at all (Goldberg et al., 1975) in the synthesis of protein during physical activity.

It has been suggested that exercise duration is a major factor in determining how protein synthesis is affected by exercise (Booth et al., 1982). For exercise that lasts 1-2 hours it appears that protein synthesis may decrease and remain so for several hours after exercise. Protein anabolism then increases as recovery from exercise continues (approximately 2-3 hours) (Booth et al. 1982). For exercise lasting 4-12 hours, protein production actually increases and may remain elevated after exercise is ceased (Booth et al., 1982, Lemon and Mullin, 1984). Goldberg et al. (1975) suggests that a change in protein synthesis along with a decrease in protein degradation allows for an increase in muscle size. Booth et al., (1982) has concluded that change in protein synthesis is more significant for causing changes in protein levels due to exercise than a change in protein catabolism. Further study, however, is needed to fully understand the impact exercise has on protein synthesis in skeletal muscles.

A third theory behind the significance of protein supplementation suggests that a special condition called "sports anemia" exists among athletes in training (Wilmore and Freund, 1986, Haymes, 1983). In a series of experiments Yoshimura et al. (1980) determined that individuals who were sedentary and then undergo strenuous exercise training develop an anemic condition in which red blood cells are destroyed faster than

they can be replaced. "Sports anemia" generally appears in the first 2-3 weeks of training and disappears when exercise is ceased or the training period is continued for a period of time. The condition does not occur in well trained athletes. The anemia can limit athletic performance due to a decrease in the oxygen carrying capacity of the blood as erythrocytes are destroyed (Horstman, 1972). "Sports anemia" has been found to be strongly related to protein metabolism, specifically hypoproteinemia (protein deficiency) (Yoshimura et al., 1980).

To prevent both the anemia and protein deficiency experienced in "sports anemia", Yoshimura et al. (1980) recommends that an individual's protein intake is increased. By taking more than 2 g/kg/day of protein, of which 30 percent is animal in origin, or 1.3 g/kg/day, of which 60 percent is animal in origin, "sports anemia" can be avoided.

Protein Supplementation Studies

Numerous controlled studies have examined the possible effects of protein supplementation on exercise performance. Darling et al. (1944) was one of the first to examine the effects of a low protein diet (53 g/day) on endurance performance compared with diets containing normal (95-113 g/day) and high (151-292 g/day) levels of protein. No significant difference in endurance was found among subjects on the low, normal, and high protein diets. Pitts et al. (1944) also found no significant difference in endurance performance among experimental groups receiving diets of low, normal, and high protein.

Rasch and Pierson (1962) performed a study in which one half of a physical

training platoon of military candidates received 25 grams of protein per day while the other one half received a placebo. Both groups underwent 6 weeks of strength training. The training program significantly increased both groups' exercise performance, however, there was no significant difference in body weight and strength between the two groups that indicated the additional 25 grams of protein per day was beneficial.

A later study by Rasch and associates (1969) also investigated protein supplementation on two groups of marines undergoing 4 weeks of a physical training program. One group received .69 g/kg/day of protein while the other received a placebo. No significant difference in strength and endurance were noted between the groups at the end of the 4 weeks of training.

Furthermore, a study using trained weightlifters and bodybuilders found no significant changes in body weight, muscle size, and muscle strength in subjects receiving a protein supplement as opposed to those taking a placebo (Golding et al., 1974). A study examining two groups of men administered two different high protein diets also demonstrated that additional protein did not improve physical work performance (Consolazio et al., 1975).

A more recent investigation contradicts the results of many of the earlier studies of protein supplementation and exercise. Dragan et al. (1985) examined the effect of a milk protein powder called "Refit" on the exercise performance of a group of elite weightlifters during 9 months of training. Following a double blind protocol, 10 weightlifters received the milk protein supplement, and 10 received a placebo. The dependent variables of fatigue, body composition, and strength were examined. From

data collected, the researchers concluded that lean body mass, strength, and fatigue post exercise improved significantly in the group administered "Refit" as compared to the placebo group. From the results of this and the previous studies, it is clear that the debate over whether protein supplementation is beneficial to athletes still needs to be resolved.

Nitrogen Balance Studies

Over the last 15-20 years evidence has accumulated to show that protein utilization does occur during exercise contradicting the general consensus of earlier researchers that protein metabolism was not affected by physical work (Astrand and Rodahl, 1986, Fox and Mathews, 1981). Much of the research performed has examined the effects of exercise on nitrogen balance in athletes and suggests that increased muscular activity may increase dietary protein requirements in man.

Gontzea et al. (1974) studied nitrogen balance in men receiving 1.0 g/kg or 1.5 g/kg per day of protein. Nitrogen balance became negative during endurance training when protein intake was 1.0 g/kg.day. Laritcheva et al. (1978) observed Russian weightlifters whose diets consisted of 14-18 percent protein. Those diets that maintained an intake of 2 g/kg/day of protein resulted in negative nitrogen balance as training intensity increased close to competition. For less intense weightlifting, nitrogen balance was maintained with 1.3-1.8 g/kg.day. Protein intake below 1.3 g/kg/day produced a negative nitrogen balance.

Another study investigated weightlifters during training (Celojowa and Homa, 1970) and found that although participating athletes were consuming 2 g/kg/day of

protein, five of the ten subjects were in negative nitrogen balance. In a 4-6 week isometric training program subjects consumed either .5 g/kg/day or 1.0 g/kg/day of protein. Nitrogen balance was reported negative in those individuals receiving .5 g/kg/day (Torun et al., 1977).

More recently, a study investigated the protein dietary needs of a group of six young endurance trained men and six middle aged endurance trained men (Meredith et al., 1986). The two groups consumed .6, .9, and 1.2 g/kg/day of protein over three different ten day periods as they maintained their exercise training. Both groups were in negative nitrogen balance at .6 g/kg.day of protein. The researchers estimated that the protein requirement for both groups was .94 g/kg/day and concluded that regular endurance exercise requires a dietary protein intake greater than the RDA of .8 g/kg.day.

A few studies examining nitrogen balance have indicated that the amount of protein needed during strenuous physical activity may be related to total energy intake (calories consumed). In a study by Iyengar and Rao (1979), four subjects were fed at two different protein levels (1.0 g/kg/day and 1.2 g/kg/day and two different energy levels (44.4 kcal/kg and 55.5 kcal/kg). Subjects were in positive nitrogen balance when the energy intake was at 55.5 kcal/kg at both protein levels. However, positive nitrogen balance at the lower energy level was seen only with the high protein diet. Protein intake, therefore, was adequate only if energy intake was equal to energy output. Higher protein levels were needed if the energy requirement was not met. Investigators such as Torun et al. (1977), the National Nutrition Board (1980), Marble et al. (1979), and Dohm et al. (1984) also support the concept that protein requirement varies with total

energy intake. Dietary protein or protein supplementation may not be required if caloric consumption is increased to meet the increased demands of an athlete's activity level. However, further study is necessary to understand the effects of exercise on protein metabolism.

Theories of Amino Acid Supplementation

The practice of amino acid supplementation, like protein supplementation, has evolved in an attempt to enhance physical performance, particularly in weightlifting sports. Because amino acids are the building blocks of protein molecules, essentially the same theories that try to promote protein supplementation can apply to amino acid supplementation as well. However, additional theories exist to explain why amino acid supplements may be more advantageous as ergogenic aids than protein supplements.

A common layman's theory behind amino acid supplementation reasons that because amino acids are the smallest subunits of proteins, they are absorbed and used more readily by the body than protein supplements (Reifkind, 1984, Arthur, 1987, Murray and Bucci, 1987, Zale, 1985). Many amino acid supplements are manufactured and packaged as free form, or peptide bond amino acids. Numerous health and fitness magazines and health stores promote, advertise, and report testimonial evidence to support the advantages of these forms of amino acid products (Reifkind, 1984, Everson, 1985, Comerski,1986, Hoffman, 1983,Murray and Bucci, 1987). However, there is no evidence that indicates amino acids are more readily or easily absorbed and used by the body than proteins (Silk, 1979, Jones, 1983, Gupta, 1958).

Many testimonial articles in popular "trade" magazines propose that amino acid

supplements, because they are believed to be absorbed and assimilated more efficiently than protein supplements, are highly effective in increasing muscle size, muscle strength, and body weight. They also claim the supplements are beneficial in decreasing body fat and recovery time between regular workouts (Reifkind, 1984, Centrella, 1984, Everson, 1985, Comerski, 1986, William, 1987). Only a few scientific studies exist, however, to support or deny these claims (Elam, 1988, Elam et al., 1989). One recent study investigated the effects of weight training and supplementation of the amino acids arginine and ornithine on body mass, body fat, and body girth measurements of eighteen untrained adult males (Elam, 1988). The subjects ranged in age from 27-57 years old, and all participated in a five week progressive weight training program. The experimental group recieved one gram of arginine and one gram of ornithine per day. Elam (1988) found that there were significant decreases in body fat and body mass in the group receiving the amino acids as compared to the group taking the placebo. No significant difference was observed for the circumference sizes between the groups. Elam (1988) concluded that the amino acid supplements did decrease body fat and body weight but had no effect on circumference measurements which were indicative of muscle size.

Another study conducted used a double blind protocol in which twenty two males participated in a five week progressive strength training program (Elam et al., 1989). Eleven of the participants received one gram of L-arginine and one gram L-ornithine per day while the other eleven received a placebo. Tests for lean body mass, strength, and urinary hydroxyproxyline levels were performed following the five week experimental

period. It was found that lean body mass and strength increased significantly in the amino acid group as compared to the placebo group. Urinary hydroxyproxyline levels decreased significantly. Elam et al. (1989) concluded that arginine and ornithine supplements taken in the prescribed dosage, and in conjunction with strength training, increase lean body mass and muscle strength. The supplements also decreased recovery time from training by decreasing tissue breakdown as indicated by lower urinary hydoxyproxyline levels.

A scientifically based theory to support the practice of amino acid supplementation indicates that strenuous aerobic exercise may cause the body to utilize amino acids for energy. Several studies have proposed a glucose-alanine cycle exists within the human body (Felig et al., 1970). This cycle consists of the formation of the amino acid alanine from a glucose byproduct called pyruvate found within the skeletal muscle. The alanine is transported from the muscles to the liver where it is converted to glucose. As the glucose is metabolized (i.e. during exercise) its pyruvate byproduct is freed to enter in the process of alanine formation and the cycle begins again (Felig et al., 1970, Mallette et al., 1969). The branced chained amino acids (leucine, isoleucine, and valine) are essential to the cycle since they are the nitrogen source which aids the body in converting pyruvate to alanine (Felig and Wahren, 1971a, Goldberg and Chang, 1978). Subsequent studies to support the theorized cycle have been performed (Felig, 1973). Exercise appears to enhance the release of alanine (Felig and Wahren, 1971a, Felig et al., 1979) and the oxidation of the branch chained amino acids (Alhborg et al., 1974) suggesting augmentation of the cycle does occur during exercise (Wahren et al., 1984).

The glucose-alanine cycle is possibly an important source of energy during exercise. Well known is the fact that glucose can yield up to 38 molecules of ATP which serves as an energy source for working muscles. Anaerobically, glucose provides only two mol ATP when converted to lactate. However, when a glucose molecule is converted to alanine, eight mol ATP is formed and more energy is available to the working muscles. In addition, when the branch chained amino acids are oxidized and utilized in the cycle, 32-42 mol ATP energy are released to be used by the exercising muscles.

From the research concerning the glucose-alanine cycle it is conceivable to propose that amino acid supplementation would be beneficial to endurance athletes. The more amino acids available to enter the cycle, the more energy available to the working muscles, and the better the athlete performs and recovers. There is, however, no scientific evidence to prove that amino acid supplementation enhances the cycle or the overall metabolic efficiency of the human body for endurance or weight oriented athletes.

A final and popular theory behind the use of amino acid supplementation claims that particular amino acids stimulate the production of human growth hormone (Jacobson, 1990, Willaims, 1987, Paish, 1987, Hoffman, 1987). The hormone is an important anabolic hormone that influences muscle growth. It has been shown to increase muscle hypertrophy in animals but not muscle strength (Slavin et al., 1988). Excessive levels of growth hormone can cause such problems as acromegaly (enlargement of the head, face, hands, and feet) in which muscle size increases but muscle strength does not.

The nonessential amino acids arginine and ornithine are highly promoted in health

and fitness magazines as growth hormone simulators (Centrella, 1984, Hoffman, 1983, Paish, 1987, Zale, 1985, Slavin et al., 1988). Clinical studies conducted have suggested that oral administration of arginine (Merimme et al., 1969) and arginine and lysine (Isidori et al., 1981) may lead to growth hormone release. However, as one study indicated, the amount of arginine available in most supplements is too small to effect growth hormone release (need at least 250 mg/kg to stimulate release) (Besset et al., 1982). Combinations of specific amino acids may be required to initiate growth hormone release (Isidori et al., 1981). A recent study examined the effects of six weeks of weight training and six different programs (one per week) of diet, amino acid supplementation, and placebo intake on growth hormone release (Pricker et al., 1988). It was found that the amino acid supplement did not significantly enhance growth hormone release in the five Australian throwers participating in the study. Further study of the effect of amino acid supplementation and exercise on growth hormone release is necessary, particularly since excess growth hormone can lead to severe physical deformity such as acromegaly.

A few articles have warned against excessive amino acid and protein intake (Aronson, 1986, Coleman, 1988, Layman, 1987, Slavin et al., 1988). It has been indicated that excessive consumption of either could:

1. overburden the kidneys and liver as excess nitrogen is secreted in the urine
2. cause dehydration as urine output increases
3. cause ketosis
4. cause gout
5. increase the loss of calcium in the urine

6. increase body fat.

Amino acid supplements may cause imbalances and toxicities in the body especially if a single amino acid is taken in excess. A concern is that the use of a single amino acid may interfere with the absorption of essential amino acids (Coleman, 1988). Experiments on research animals have found that among the branch chained amino acids, an excess of one will disturb the absorption of the others. Also, this type of antagonistic relationship has been observed between arginine and lysine (Slavin et al., 1988).

Although amino acids are frequently promoted and advertized in popular health and fitness magazines, the athletic community should be fully aware that there have been limited studies conducted on the effect of amino acid supplements, in conjunction with exercise, on human subjects (Elam, 1988, Elam et al., 1989, Pricker et al., 1988). No margin of safety has been determined concerning the supplements. As Slavin et al. (1988) states "Amino acids taken in large doses are drugs with unknown physiological effects".

Summary

Although the RDA for protein (.8 g/kg/day) was established by the National Research Council (1980) to meet the demands of most members of the population, protein/amino acid supplementation is still practiced by athletes. There are several prevailing theories that propose why athletes may need more protein/amino acids.

A primary theory suggests that protein supplementation may replace protein that is believed to be catabolized during exercise (Hatfield, 1987, Paish, 1987). A second theory proposes that protein supplementation increases the process of protein synthesis

(Wilmore and Freund, 1986). A special condition called "Sports anemia" is also believed to be improved through protein supplementation (Yoshimura et al., 1980).

In many studies, protein supplementation has been shown not to enhance athletic performance in endurance and strength sports (Pitts et al., 1944, Darling et al., 1944, Rasch and Pierson, 1962). However, several nitrogen balance studies have indicated that increased protein consumption may be required during physical training (Gontzea et al., 1974, 1975, Laritcheva et al., 1978, Marable et al., 1979). Further research is needed to determine exactly how protein metabolism is effected by exercise and whether protein supplementation is beneficial.

Theories behind the use of protein supplementation can be applied to the use of amino acid supplementation since amino acid molecules are the building blocks of proteins. However, several theories try to explain why amino acid supplements are more advantageous than protein supplements. A popular theory reasons that since amino acids are the smallest subunits of proteins, they are more readily absorbed and assimilated by the body (Reifkind, 1984, Zale, 1985, Arthur, 1987). Easy absorption, in turn, makes the supplements highly effective in increasing muscle size, muscle strength, and body weight and decreasing body fat and post exercise recuperation time (Comerski, 1986, Everson, 1985, Centrella, 1984, Zale, 1985).

Another theory claims that supplementation of amino acids enhances energy production via the glucose-alanine cycle (Lemon et al., 1984). Certain amino acids are also believed to promote the production of growth hormone which has been shown to increase muscle size (Slavin et al., 1988). Few studies involving the effects of amino

acid supplementation on athletic performance have been performed (Elam, 1988, Elam et al., 1989). Whether the supplements are safe and effective is not known.

Chapter III

Methodology

Information about this study was published in a flyer which was placed in local health clubs, the university education complex, and student union. Seventeen apparently healthy males volunteered. The volunteers met the following prerequisites in the study:

1. Age 21-35 years old (x = 27.6 yrs ± 3.69 yrs).
2. Completed at least 6 months of weight training.
3. No use of steroids or amino acid/protein supplements 6 weeks prior to the study.

Experimental design

A blind protocol was used so that the subjects were not aware of whether they were receiving the amino acid supplements or the placebo. The seventeen subjects were divided into two groups; the amino acid group ($n=10$) and the placebo group ($n=7$). All subjects were told that the study was investigating the effects of two different commercial amino acid supplements. Subjects in the placebo group were told they were taking an experimental amino acid supplement not yet on the market.

The experimental period was 10 weeks. The distribution of the supplements was done weekly to reaffirm the subjects were training and taking the supplements as instructed. The weekly contact also helped to keep the subjects motivated. After the study began, two subjects in the amino acid group decided not to continue to participate

decreasing the number in the experimental group to eight.

Subjects were not randomly placed into the two groups. Since a number of subjects (6) had previously taken amino acid supplements and were familiar with the structure, smell, and taste of the tablets, they were placed in the amino acid group. The average length and time of the subjects' workout sessions, dietary protein intake, and daily caloric intake are presented in Table 2.

The amino acid supplement used in this study was a commercially marketed brand*. Each tablet contained 1200 milligrams of the following 19 amino acids:

L-Glutamic Acid 217mg
L-Lysine 140.5mg
L-Proline 107.5mg
L-Leucine 91.1mg
L-Aspartic Acid 79.3mg
L-Valine 72.5mg
L-Arginine 70mg
L-Serine 60mg
L-Isoleucine 55.7mg
L-Phenylalanine 48.8mg
L-Threonine 46mg
L-Ornithine 40mg
L-Tyrosine 35.6mg
L-Alanine 34.1mg
L-Methionine 29.5mg
L-Histidine 28mg
L-Glycine 21.2mg
L-Tryptophan 12.4mg
L-Cystine 10.2mg
Calcium 10 mg
Vitamin B6 4mg

*MEGA-PRO 100% Natural Meg-Amino Formula

The dosage of the amino acids were determined through a formula recommended by the

Table 2
Descriptional Statistics
of Amino Acid and Placebo Group

	Amino Acid Group		Placebo Group	
	Mean	SD	Mean	SD
Height (cms)	177.25	± 5.08	182.07	± 6.71
Weight (kg)	79.27	± 10.5	80.5	± 11.6
Workout time (minutes)	77.86	± 26.54	93.57	± 21.55
Workout (times/week)	4.5	± 1.17	3.7	± 1.18
Protein intake (grams)	105.51	± 15.17	95.95	± 29.95
Protein intake (g/kg body weight)	1.34	± 0.379	1.19	± 0.263
Caloric intake (kcal)	2333.47	±266.33	2197.10	±742.24

manufacturers. This formula used the individual's activity level, body weight, and appropriate dietary intake:

$X1 \times X2 - X3 \div 5 \div 1.2$ = Dosage of amino acid tablets daily

where:

X1 = activity level (see scale below)*

X2 = body weight (in lbs.)

X3 = dietary protein intake (in grams)

5 = concentration of amino acid

1.2 = grams per tablet

*The activity level had three numerical representations:

1.0 = moderately active (1 hour of exercise every other day)

1.2 = strenuous training (1 hour of exercise every day)

1.4 = high intensity training (1 1/2 hours of exercise daily)

In this study, due to the subjects' reported training regimens, the activity level 1.4 was used to calculate the daily amino acid intake.

It has been determined that the average male consumes half of his weight (in pounds) in grams of protein per day (Kirschman, 1979), so protein intake was determined by body weight. For example, a 190 lb. athlete would consume 190/2 or 95 grams of protein per day. The dosage of amino acid tablets for each subject ranged from 22 to 31 tablets per day.

The placebo was a lactose filled gelatin capsule. It was administered in a dosage

of 20 tablets per day.

The subjects were instructed to take the amino acids and the placebo before and between meals 4 to 5 times daily. An intake of 6-8 glasses (8 oz) of water was recommended to both groups.

Data Collection

Prior to testing, subjects were instructed:

1. Not to eat for at least three hours.
2. Not to perform strenuous exercise, particularly weightlifting, prior to testing that day.
3. To wear shorts, t-shirt, and running shoes.

The testing session consisted of:

1. An orientation of the testing procedure.
2. The reading and signing of an informed consent form (Appendix A).
3. The completion of a questionnaire regarding a subject's training experience and previous use of dietary supplements (Appendix A).
4. The collection of anthropometrical data.

Anthropometrical measurements

All results were recorded on a Data Collection form (Appendix A). The exact locations and methods used to measure the anthropometrical data are given in Appendix B. The calibration method for residual volume and vital capacity is given in Appendix B.

Height and Weight

Height was measured to the nearest centimeter with an anthropometer attached to a wall. Without shoes the subject was instructed to stand as tall as possible with heels together looking straight ahead. Weight was measured in kilograms to the nearest gram on a Toledo weighing scale.

Percent body fat

Percent body fat was estimated from the Jackson and Pollack prediction equation using the sum of four skinfold measurements as described by Golding et al. (1989). The 4 skinfold sites were:

1. tricep
2. abdominal
3. iliac
4. thigh

The equation used to calculate percent body fat was:

$\%fat = -0.29288(\Sigma 4) - .00005\ (\Sigma 4) + .15845(age) - 5.76377$

Using Harpenden skinfold calipers, the skinfold measurements were taken on the right side of the body according to the procedure described by Golding et al. (1989). All measurements were determined to the nearest millimeter. In order to use the Jackson and Pollack equation which was developed using Lange calipers, Harpenden measurements were corrected as follows: less than 15 mm, 1 mm was added each measurement. Greater than 15 mm, 2 mm were added to each measurement.

Body circumference

To evaluate changes in muscle size, eleven body circumferences (girths) were measured to the nearest tenth of a centimeter with an anthropometrical tape (McKardle and Katch, 1981, Montague, 1960). To standardize the procedure, all circumference measurements were taken on the right side of the body.

The eleven measurements obtained were:

1. neck
2. relaxed chest
3. expanded chest
4. abdomen
5. relaxed bicep
6. flexed bicep
7. forearm
8. buttocks (hips)
9. upper thigh (groin)
10. mid calf
11. calf

Static strength

Static strength was measured on a strength table (Depew, 1986) (Appendix B). The table was similar in design to the table described by Clarke (1966). The cable tensiometer used by Clarke, however, was replaced by a load cell (Toledo Scale model) that displays either pounds or kilograms on an LED digital read out (Depew, 1986). The

muscle groups tested were:

1. left elbow flexors

2. left elbow extensors

3. right leg flexors

4. right leg extensors

The positions used for the four tests were developed and tested by Depew (1986) and based on the positions described by Clarke and Clarke (1963). For each of the four positions, maximum strength was isometrically tested (Appendix B). Three trials were given for each position and the average used.

Dynamic strength

Dynamic strength was measured using the one repetition maximum (1RM) test. 1RM is the maximum resistance a muscle can move through one repetition (Fox and Mathews, 1981). The 1RM was performed for the bench press (elbow extensors and shoulder flexors) and the leg press (knee and hip extensors). Standard free weight equipment, a flat bench and angled leg press machine, were used. During the test, correct form was required, and the subject had to control the weight. In the bench press, the barbell had to be lowered to the chest and pressed back to the starting position. A subject began the angled leg press test with his legs extended. He then flexed his legs bringing them to a bent knee position. The weight he was supporting was then pressed back to the starting position.

Residual volume and vital capacity for hydrostatic weighing

A closed circuit system as described by Wilmore et al. (1969) was used to determine residual volume. This method used a nitrogen analyzer to assess the nitrogen content of the sample air breathed by a subject. Sample air was obtained by a subject breathing into and out of an anesthesia bag, filled with pure oxygen, seven times. The seven breaths ensured that the oxygen in the bag was equilibrated with the air in the lungs.

All tests for residual volume were performed in a seated, slightly inclined forward position. The systems at the UNLV laboratory allowed residual volume and vital capacity to be measured in one test. Prior to testing, the procedure was explained to the subject (Appendix B). Before any testing began, calibration of the entire system with pure oxygen was performed (Appendix B). The measurement of vital capacity was obtained first, followed immediately by the measurement of residual volume.

Body density (Hydrostatic weighing)

To support the percent body fat values estimated by skinfolds, body density was also determined by a standard method of hydrostatic weighing.

Approximately ten minutes prior to underwater testing the weighted vest and weighted towel, worn by the subject in the water, were placed on the electronic scale in the tank. The subject's land weight was measured using a Toledo weighing scale. Once land weight was obtained, the subject was instructed to shower thoroughly with soap.

Once submerged in the tank of water, the subject was instructed to sit on the electronic scale. The weighted vest was put on, and the weighted towel placed over the

subject's crossed legs to counter buoyancy. For the measurement of vital capacity the subject was instructed to securely apply a nose clip. The subject was then told to maximally inhalate and gently submerge underwater to minimize waves which cause fluctuations in the readings. He was instructed to remain under the water until his weight was recorded on the digital printer. Five underwater weights were recorded for vital capacity.

For residual volume the procedure for vital capacity was followed. However, the subject was instructed to exhale the majority of air in his lungs prior to submerging his head. Once underwater, the subject was told to continue exhaling the remaining air in his lungs and mouth. The subject was directed to remain underwater until his weight was recorded. Five underwater weights were also obtained for residual volume.

For each of the ten weight trials obtained (5 for vital capacity and 5 for residual volume) the weight was recorded six times by a digital printer. The high and low of each trial was thrown out, and the remaining four weights averaged. The first two trials for each method (residual volume and vital capacity) were considered learning trials and eliminated. The last three trial weights were averaged to determine body density. The following formula was used to calculate body density by underwater weighing:

$$D = \frac{Wa}{\frac{Wa - (Ww - Ws)}{Dw} - RV}$$

where: Wa = weight in air

Ww = weight in water

Ws = weight in sinkers

Dw = density of water at 93° F (.99440)

RV = residual volume

D = body density

Body density values obtained were converted to percent fat using the formula of Siri (1956).

$\%fat = 100\ [(4.950 - 4.5) \div D]$

Where D = body density

Statistical methodology

Statistical analysis included parametric and nonparametric tests. The parametric designs used were the independent T test and the dependent T test (Shavelson, 1981). The nonparametric test employed was the sign test (O'Toole, 1964) (Appendix B). Because of the numerous T tests performed, which may have contributed to error in determining significant results, Bonferoni's T procedure (Dunn's multiple comparison procedure) was used (Kirk, 1982). Means and standard deviations were calculated for the dependent variables (Shavelson, 1981).

Chapter IV

Results and Discussion

In order to determine the effect of an amino acid supplement on amateur weightlifters, certain appropriate physiological parameters were measured before and after supplementation. The small sample size and great variability of the data collected dictated the use of both parametric and nonparametric statistics to attempt to show significant effects. The parameters selected were body fat, body weight, body circumferences, static strength, and dynamic strength. Each is discussed separately below.

Body fat

Only a few studies have examined the effect of amino acid supplementation and exercise on body composition. The popular "trade" literature claims that amino acid supplements increase lean body mass (Centrella, 1984, Williams, 1987) and decrease body fat (Centrella, 1984, Comerski, 1986). The scientific literature reports only one study which demonstrated a significant decrease in body fat in subjects taking amino acid supplements, in conjunction with a strength training program, as compared to subjects in control group (Elam, 1988). Similarly, only one study has shown a significant increase in lean body mass in individual's taking amino acid supplements and following a weight training regimen when compared to a group taking a placebo (Elam et al.,

1989).

In this study performed at UNLV, body composition was determined by both skinfolds and hydrostatic weighing. A dependent T test found the mean percent body fat of the amino acid group, determined by skinfolds before and after supplementation (13.2% to 13.8%), did not change significantly (Table 3). The hydrostatic weighing results supported the skinfold data and showed no significant change (12.69% to 12.53%) in percent body fat as a result of the experimental treatment (Table 3). Nonparametric sign test results did not reveal a significant trend for change in percent body fat in the amino acid group.

In the placebo group, mean percent body fat determined by pre and post skinfold measurements (15.15% to 15.43%) did not significantly change (Table 4). The change in percent fat calculated by hydrostatic weighing (17.82% to 16.83%) was not significant also (Table 4). Furthermore, a sign test did not indicate a trend for change in mean percent body fat for the group (Table 4).

Differences in average body fat percentage between the amino acid and placebo group, post supplementation, was examined statistically by an independent T test. Although the amino acid group was slightly leaner (13.8%) than the placebo group (15.4%), this difference was not significant (Table 5).

Weight

There have been a limited number of controlled studies performed on the effect amino acid supplementation and exercise has on body weight. One study supports the popular literature's claims (Centrella, 1984, Williams, 1987, Everson, 1985) that amino

Table 3
Skinfolds, Percent Body Fat, and Weight
Amino Acid Group

	Pre		Post				
	Mean	SD	Mean	SD	Difference	T	Sign
Skinfolds (mm)							
Abdominal	19.19	±10.3	18.19	± 8.4	-1.0	.3752	.6367
Iliac	17.15	± 7.3	21.00	± 7.6	+3.85	.0915	.9961
Tricep	7.31	± 3.4	6.81	± 2.5	-0.50	.3288	.2266
Thigh	12.45	± 4.2	11.63	± 3.6	-0.82	.1324	.3633
Percent Fat (Skinfolds)	13.21	± 4.9	13.80	± 4.4	+0.59	.4089	.9375
Percent Fat (Hydrostatic Weighing)	12.69	± 5.2	12.53	± 2.8	-0.16	.9021	.6562
Weight (kg)	77.27	±10.5	79.42	±11.1	+2.15	.8391	.1445

Significance level: $\alpha = .05$
* = Significant

Table 4
Skinfolds, Percent Body Fat, and Weight
Placebo Group

	Pre		Post				
	Mean	SD	Mean	SD	Difference	T	Sign
Skinfolds (mm)							
Abdominal	22.71	±13.2	22.93	±13.0	+ .24	.8044	.8906
Iliac	18.31	±11.2	20.79	±10.5	+2.48	.0761	.9844
Tricep	9.33	± 3.1	9.29	± 3.6	-0.04	.8771	.5000
Thigh	13.64	± 6.1	13.64	± 6.8	0.00	.9507	.7734
Percent Fat (Skinfolds)	15.15	± 6.2	15.43	± 6.2	+0.28	.5901	.9688
Percent Fat (Hydrostatic Weighing)	17.82	± 5.8	18.83	± 6.4	-0.99	.3563	.2266
Weight (kg)	80.50	±11.6	81.44	±12.1	+0.94	.1897	.2266

Significance level: $\propto$ = .05
* = Significant

Table 5
Skinfolds, Percent Body Fat, and Weight
Mean Difference Between Groups

	Amino Acid Mean Difference	Placebo Mean Difference	Independent T
Skinfolds (mm)			
Abdominal	-1.0000	0.1875	.3875
Iliac	3.8500	2.1625	.4710
Tricep	-0.5000	-0.0375	.4419
Thigh	-0.8250	1.16417	.4429
Percent Fat (Skinfolds)	0.5875	0.2375	.6633
Percent Fat (Hydrostatic Weighing)	-3.2941	-0.8625	.3838
Weight (kg)	0.1481	0.7900	.5341

Significance level: $\alpha = .05$
* = Significant

Bonferoni's T: $\frac{.05}{24} = .002083$

acid supplements and weight training significantly increase body weight by increasing overall muscle mass (Elam et al., 1989). A second study, however, demonstrated a significant decrease in body weight in untrained subjects due to amino acid supplements and five weeks of weight training as compared to subjects receiving a placebo (Elam, 1988).

In this study performed at UNLV, average body weight in the amino acid group did not change significantly from pre to post supplementation (77.22 kg to 79.42 kg) (Table 3).

The apparent increase in body weight in the placebo group from pre to post testing (80.5kg to 81.44kg) was not significant according to a dependent T test. Sign test results also were not significant (Table 4).

Although the placebo group was slightly heavier (81.44 kg) than the amino acid group (79.42kg) at the end of the experimental period, independent T test results found the difference to be nonsignificant (Table 5).

Circumferences

The eleven circumferences or body girth measurements obtained for each subject were divided into three categories: upper extremity, trunk, and lower extremity. In this study, circumference size was used to indicate a change in muscle size; except for abdominal girth which indicated a change in body fat. There has been only one scientific study conducted on the effect of amino acid supplements and strength training on body girth measurements (Elam, 1988). Many health and fitness magazines declare that amino acids increase muscle size (Williams, 1987, Reifkind, 1984, Everson, 1985). These

claims are contrary to the research findings which demonstrated that amino acid supplementation and weight training had no effect on body circumference measurements (Elam, 1988).

In this study performed at UNLV, changes in mean circumference sizes, from pre to post supplementation, of the upper extremities, trunk, and lower extremities in the amino acid group were not statistically significant (Table 6). No significant trend for change was indicated by nonparametric sign test results for any of the body girths (Table 6).

In the placebo group, dependent T test results showed no significant changes in mean circumference measurements of the upper extremities, trunk, and lower extremities from pre to post testing (Table 7). Again, sign test results did not reveal significant trends for change in any body circumferences obtained (Table 7).

Differences observed between the amino acid group and placebo group for upper extremity, trunk, and lower extremity girths at the end of the study were deemed not significant by independent T tests (Table 8). There was, however, a significant difference in upper thigh circumference between the two groups (Table 8). Further statistical analysis using Bonferoni's T test ($\alpha = .002083$) found the significant results to be nonsignificant (Table 8).

Strength measurements

Both static and dynamic strength were measured in this study. "Trade" literature claims that amino acid supplements taken while weight training increase muscle strength (Williams, 1987, Everson, 1985, Comerski, 1986). However, limited objective research

Table 6
Circumference Measurements (cms)
Amino Acid Group

	Pre		Post				
	Mean	SD	Mean	SD	Difference	T	Sign
Neck	38.38	±2.4	38.82	±2.5	+0.34	.1282	.9648
Chest relaxed	100.0	±4.4	99.78	±5.7	-0.22	.7571	.8555
Chest expanded	106.0	±6.6	105.7	±6.9	-0.30	.7078	.8555
Bicep relaxed	32.56	±2.5	32.88	±2.4	+0.32	.5393	.3633
Bicep flexed	37.73	±3.2	37.50	±2.7	-0.23	.5831	.7734
Upper thigh	57.91	±3.3	56.99	±3.8	-0.92	.1447	.9375
Mid thigh	51.55	±3.0	52.36	±3.2	+0.81	.2408	.3633
Buttocks	96.43	±5.5	96.00	±4.8	-0.43	.5665	.8555
Calf	37.48	±2.1	37.03	±2.1	-0.45	.0680	.9648
Abdominal	83.65	±6.6	82.70	±7.3	-0.95	.1545	.1445
Forearm	29.10	±2.5	29.14	±2.3	+0.04	.8232	.3633

Significance level: $\propto$ = .05
* = Significant

Table 7
Circumference Measurements (cms)
Placebo Group

	Pre		Post				
	Mean	SD	Mean	SD	Difference	T	Sign
Neck	38.06	±2.5	38.27	±2.1	+0.21	.2800	.2266
Chest relaxed	96.73	±7.7	98.16	±7.9	+1.43	.0686	.2266
Chest expanded	102.17	±7.5	104.27	±9.1	+2.10	.1169	.0625
Bicep relaxed	30.70	±2.1	30.31	±1.8	-0.39	.5345	.5000
Bicep flexed	34.87	±2.7	35.09	±2.6	+0.22	.4049	.3438
Upper thigh	56.56	±4.0	57.00	±4.0	+0.44	.1568	.6562
Mid thigh	50.20	±2.8	50.54	±3.0	+0.34	.3825	.6562
Buttocks	98.30	±7.0	98.29	±6.6	-0.01	.9322	.7734
Calf	37.46	±2.1	37.41	±2.0	-0.01	.9102	.5000
Abdominal	88.30	±8.7	87.16	±9.7	-1.14	.3629	.2266
Forearm	28.66	±2.4	28.81	±2.3	+0.15	.2551	.1094

Significance level: $\propto$ = .05
* = Significant

Table 8
Circumference Measurements (cms)
Mean Difference Between Groups

	Amino Acid Mean Difference	Placebo Mean Difference	Independent T
Neck	0.3375	0.1875	.5688
Chest relaxed	-0.2250	1.2500	.1335
Chest expanded	-0.312499	1.8375	.1201
Bicep relaxed	0.312499	-0.4625	.2831
Bicep flexed	0.22500	0.1875	.3654
Upper thigh	-0.93499	0.387499	.0494*
Mid thigh	-0.812500	-0.30000	.4882
Buttocks	-0.4299	-0.012500	.6594
Calf	-0.4499	0.012499	.1435
Abdominal	-0.9500	-0.9375	.9395
Forearm	0.037499	0.137499	.6506

Significance level: $\alpha = .05$
* = Significant

Bonferoni's T: $\frac{.05}{24} = .002083$

studying the effects of amino acid supplementation and strength training supports the claim (Elam et al., 1989).

Static strength

The increase in mean static strength measurements of the amino acid group, from pre to post supplementation, were found not to be significant by dependent T tests (Table 9). No significant trend for change in the four static strength measurements was indicated except for leg extension strength (Table 9). A sign test revealed a trend for improvement in static quadricep strength (Table 9).

Placebo group results for mean static strength measurements from pre to post testing were not significant also (Table 10). Sign test results supported the dependent T test outcomes for the group and indicated no significant trends for change in any of the four static strength measurements (Table 10).

Differences in static strength values between the amino acid and placebo groups, post supplementation, were not significant according to independent T test results (Table 11).

Dynamic strength

In the amino acid group changes in average dynamic strength measurements, from pre to post supplementation were not significant (Table 9). The nonparametric sign test uncovered a trend for improvement in leg strength but not upper body strength (Table 9).

In the placebo group upper body strength, demonstrated by the bench press,

Table 9
Static and Dynamic Strength Measurements
Amino Acid Group

	Pre		Post				
	Mean	SD	Mean	SD	Difference	T	Sign
Static Strength (kg)							
Elbow Flexion	47.47	± 7.3	52.18	± 12.4	+ 4.71	.2141	.2266
Elbow Extension	32.88	± 4.5	33.27	± 7.0	+ 0.39	.7008	.7734
Knee Flexion	56.91	± 11.6	64.3	± 12.3	+ 8.39	.0640	.1445
Knee Extension	75.14	± 15.8	86.2	± 18.4	+11.06	.0652	.0352*
Dynamic Strength (lbs)							
Bench Press	260.0	± 39.9	268.1	± 43.9	+ 8.1	.2799	.1445
Leg Press	702.9	±142.39	754.3	±173.7	+51.4	.0516	.0156*

Significance level: α = .05
* = Significant

Table 10
Static and Dynamic Strength Measurements
Placebo Group

	Pre		Post				
	Mean	SD	Mean	SD	Difference	T	Sign
Static Strength (kg)							
Elbow Flexion	35.93	± 16.1	40.81	± 12.4	+ 4.88	.0891	.2266
Elbow Extension	26.79	± 7.6	25.45	± 6.0	- 1.34	.5115	.7734
Knee Flexion	48.28	± 12.2	53.8	± 6.2	+ 6.52	.1173	.0625
Knee Extension	68.14	± 13.9	73.62	± 10.1	+ 5.48	.2228	.2266
Dynamic Strength (lbs)							
Bench Press	176.43	± 65.2	189.29	± 66.6	+12.86	.0248*	.0625
Leg Press	520.71	±130.1	521.67	± 93.8	+ 0.96	.3744	.0312*

Significance level: α = .05
* = Significant

Table 11
Static and Dynamic Strength Measurements
Mean Difference Between Groups

	Amino Acid Mean Difference	Placebo Mean Difference	Independent T
Static Strength (kg)			
Elbow Flexion	-1.8100	4.26875	.5012
Elbow Extension	-3.7725	- 1.17375	.6039
Knee Flexion	7.3925	4.82875	.5710
Knee Extension	11.0600	4.79625	.3333
Dynamic Strength (lbs)			
Bench Press	8.1250	11.2500	.7036
Leg Press Weighing)	45.0000	-64.3750	.2908

Significance level: $\alpha = .05$
* = Significant

Bonferoni's T: $\frac{.05}{24} = .002083$

increased significantly from pre to post supplementation (Table 10). Changes in leg strength, however, were not significant. Only a significant trend for improvement was indicated by the sign test for leg press strength (Table 10).

Although the amino acid group appeared overall stronger than the placebo group throughout the study (Table 9 and Table 10), independent T test results demonstrated that the differences in strength were not statistically significant post supplementation (Table 11).

Summary

The statistical results of this study reveal no significant differences in body composition, body weight, circumference measurements, static strength, and dynamic strength in the group receiving the amino acid supplement as compared to the group receiving the placebo.

No significant changes for body composition, body weight, circumference measurements, static strength, and dynamic strength were observed within either group from pre to post supplementation, except for dynamic bench press strength in the placebo group. Trends for improvement were indicated in static quadricep strength and dynamic leg strength of the amino acid group and dynamic leg strength in the placebo group.

Chapter V

Summary

Throughout history ergogenic aids have been employed by athletes to gain a winning edge over their opponents. Ergogenic aids such as protein supplements, anabolic steroids, and growth hormone are commonly used by amateur and professional weightlifters to increase their muscle size and strength. Recently amino acids, the smallest component of proteins, have become a popular and well advertised ergogenic supplement. Amino acids are promoted as substances that increase muscle size and muscle strength and decrease body fat. Although numerous studies report the effect of protein supplementation on athletic performance, very few scientifically controlled studies have determined the influence of amino acid supplementation on physical performance. The purpose of this study was to determine the effect amino acid supplementation has on muscle size, muscle strength, body composition, and body weight in trained amateur weightlifters.

Fifteen males between the ages of 21 and 35 participated in this study. The subjects were divided into two groups. Eight were administered the amino acid supplements while seven were given a placebo. A blind protocol was used so that the subjects were not aware if they were taking the supplements or a placebo. Each subject was measured before and immediately after the ten week experimental period for weight,

height, skinfolds (4 sites), body circumferences (11 sites), static strength (4 measurements), and dynamic strength (2 1RM tests).

Both parametric and nonparametric statistical designs were used to analyze the data. These included the independent T test, dependent T test, and sign test.

Within the two groups the dependent T test results indicated no significant changes in the dependent variables from pre to post supplementation. There was one significant change in dynamic bench press strength in the placebo group. The sign tests performed showed significant results for dynamic leg press strength within both groups and static quadricep strength within the amino acid group. According to independent T test results, differences in body fat, circumference measurements, static strength, dynamic strength, and weight between the amino acid group and placebo group post supplementation were not significant.

Conclusions:

1. In this study, the amino acid supplements used had no measured effect on body composition, body weight, muscle size, and muscle strength of the participating subjects.

2. Small sample size (N), great variability of the data, and biased selection of the experimental groups do not allow inferences to be made about the total population.

Recommendations:

1. A subsequent study needs to be done using a larger sample size and random selection of the experimental and control groups.

2. The supplements (placebo and amino acid) should be exactly alike in color and structure to be sure subjects can not detect the placebo.

3. The use of a double blind protocol is recommended.

4. Monitoring of subject performance and administration of the supplements was difficult. Ideally, a subsequent study should consist of a class of subjects that meets three times per week for the experimental period. Frequent contact with the subjects is needed to be sure they are following their training routines, taking the supplements, and staying motivated.

APPENDIX A

FORMS

COLLEGE OF HUMAN PERFORMANCE AND DEVELOPMENT
EXERCISE PHYSIOLOGY LABORATORY

Consent to Participate in a Research Project

Title of Study - Amino acid supplements and weight training

Purpose - You are being asked to participate in a research study. We hope to learn from the study how amino acid supplements effect muscle size, body weight, strength, and body composition in amateur weightlifters.

Subjects - Because you are an amateur weightlifter who has been training for at least 6 months, 3-7 days a week, 1-2 hours a day, you have been recruited as a subject.

Procedures - If you decide to volunteer you will be supplied with amino acid supplements for a 10 week period. You will take no other drug or dietary supplements during this period, and you will follow your regular training routine. Before the 10 week period and immediately after the following tests will be administered to you:

Height
Weight
Skinfold measurements
Body circumferences
Bench press and leg press.
Skeletal measurements
Hydrostatic weighing
Static strength measurements

Testing will take approximately one and one half hours.

Risks - The amino acid supplements administered in this study are not prescribed drugs. They are a commercially marketed supplement widely used by many amateur weightlifters. We, therefore, foresee minimal, if any, risks in administering these tablets.

Benefits - Advertised as a supplement that will improve muscle size and strength, a great deal of money is made each year in the marketing and selling of amino acids to amateur weightlifters. There has been very little research done, however, on whether this assumption is true. This study will be beneficial in providing unbiased, concrete

evidence as to whether the supplements do improve a weightlifter's performance and are worth the expense.

Confidentiality - Subject's confidentiality will be maintained by keeping subject data in a locked file only research personnel have access to. Statistical data in computer files will be coded. Names, addresses, and telephone numbers will not be released without the subject's permission.

Right to Refuse - You may refuse to participate in any part of this study, and you may change your mind about being in the study at any time

Questions - Any questions you had about the study, its purpose, design, methodology, procedures, or significance have been answered to you satisfaction. If you have additional questions later, research personnel will be happy to answer them.

Your signature below indicated that you have decided to volunteer as a research subject and that you have read the information provided above and understand the study.

Date:____________ ________________________

Signature of participant

Date:____________ ________________________

Signature of witness

COLLEGE OF HUMAN PERFORMANCE AND DEVELOPMENT
UNIVERSITY OF NEVADA, LAS VEGAS
EXERCISE PHYSIOLOGY LABORATORY

Questionnaire

Name____________________ Phone Number________________
Address____

1. How long have you been weight training?
   under 1 year_____ 3-5 years _____
   1-2 years _____ over 5 years _____

2. Do you lift for
   a. competition _____
   b. to stay in shape _____
   c. to improve performance in a certain sport _____
   d. other _____

3. Do you train 100% with machines (Nautilus, David, Eagle)?
   Yes/No _____
   If yes, what kind?

4. Do you train 100% with free weights? Yes/No _____

5. Do you train with a combination of the above? Yes/No _____
   If yes, what percentage of your workouts do you use machines and what percentage of your workouts do you use free weights (i.e. 40% free weights and 60% nautilus)?

6. Besides weight training what other forms of physical activity do you participate in regularly?
   a. None _____
   b. Running/Jogging _____
      How many times per week, for how long?

c. Swimming _____
How many times per week, for how long?

d. Biking _____
How many times per week, for how long?

e. Other _____
How many times per week, for how long?

7. Where do you train?
   a. UNLV _____
   b. Health Club _____
   Which one?

   c. A gym _____
   Which one?

   d. Home _____
   e. Other _____
   Specify.

8. Have you previously taken amino acid supplements, protein supplements, vitamins, or any other dietary supplements? Yes/No

   If yes, what ones?

   Brand____________________

   Type ____________________

   Dosage____________________

9. What kind of diet are you presently following?
   a. Weight gain _____
   b. Weight loss _____
   c. High protein _____
   How many grams of protein per day?

d. High carbohydrate ______
e. Other ______
Specify.

COLLEGE OF HUMAN PERFORMANCE AND DEVELOPMENT
UNIVERSITY OF NEVADA, LAS VEGAS
EXERCISE PHYSIOLOGY LABORATORY

Data Collection Worksheet

Test No.________

Name______________________ Date____________

Weight____________________ Height__________

SKINFOLDS (mm)

Abdominal ________

Iliac ________

Tricep ________

Thigh ________

% Fat ________

DYNAMIC STRENGTH (lbs)

Bench press 1RM ________

Leg press IRM ________

CIRCUMFERENCES (cm)

Neck ________

Chest relaxed ________

Chest expanded ________

Relaxed bicep ________

Flexed Bicep ________

Forearm ________

Abdomen ________

Upper thigh ________

Mid thigh ________

Buttocks ________

Calf ________

STATIC STRENGTH (cm)

Elbow Flexion			Mean
________	________	________	________

Elbow Extension

________	________	________	________

Leg Flexion

________	________	________	________

Leg Extension

________	________	________	________

APPENDIX B

METHODS AND PROCEDURES

*Skinfold Sites **

ABDOMINAL	A vertical fold approximately one inch to the right of the umbilicus.
ILIUM	A diagonal fold just above the crest of the ilium, (the highest peak along the mid-axillary line).
TRICEP	A vertical fold on the back of the upper arm, midway between the tip of the acromial process of the scapula and the elbow.
FRONT THIGH	A vertical fold on the front of the thigh, midway between the groin line and the top of the patella.

*Golding et al., 1982

Circumferences*

NECK	Measured midpoint between the chin and shoulders.
RELAXED CHEST	Measured at the widest point with the subject in a relaxed state.
EXPANDED CHEST	Measured at the widest part of the chest as the subject maximally inhales and flexes his pectoral muscles.
RELAXED BICEP	Measured midpoint between the elbow and the shoulder while the arm is straight and extended to the side of the body in a supine position.
FLEXED BICEP	Measured at the widest point of the bicep while the elbow is flexed and held outward to the side of the body.
FOREARM	Measured at he widest point with the arm extended outward to the side of the body.
ABDOMEN	Measured one inch above the umbilicus.
UPPER THIGH	Measured just below the buttocks.
MID THIGH	Measured mid point between the knee and the groin.
BUTTOCKS	Measured at the maximum protrusion with the heels together.
CALF	Measured at the widest point midway between the ankle and the knee.

* McKardle and Katch, 1981, Montague, 1960

Static Strength Testing

The following are descriptions of the four static strength measurements tested in this study using a strength table developed by Depew (1986).

KNEE FLEXION

Body Position: Subject was placed in a prone position with legs extended beyond the strength table. The leg not tested was in a relaxed position. The leg not tested had the knee resting on the edge of the table, and was flexed at a 165 degree angle (using a wooden goniometer). The arms were at the subject's side.

Action: The lower leg was lifted upwards (knee flexion)

Belt and Strap placement: 1. One belt was placed across the shoulders. 2. A second was across the gluteals. 3. The third was placed low on the thigh just above the knees. 4. The strap was positioned across the belly of the calf, two inches below the patella.

Cable placement - A three inch cable was attached to the strap, the load cell was attached to the opposite end of the cable. To the other end of the load cell a chain was attached and anchored at an angle to the lower extended center rail of the table.

KNEE EXTENSION

Body Position: The subject was positioned in the testing chair. Both arms were pronated and placed on the arm rests. The leg tested was relaxed. The leg tested was flexed to a 115 degree angle using a wooden goniometer.

Action: The lower leg was extended forward.

Belt and Strap placement: 1. One belt was positioned across the upper chest. 2. A second was positioned over both thighs. 3. The strap was placed six inches below the patella.

Cable placement: A three inch cable was attached to the strap, the load cell was attached to the opposite end of this cable. To the other end of the load cell a chain was attached and anchored to a bottom hook on the chair.

ELBOW EXTENSION

Body Position: The subject was in a supine position with the hip and knee joints flexed and the feet on the table. The free arm was placed to the subject's side. The arm to be tested was flexed at a 90 degree angle using the wooden arm goniometer for proper placement. The hand was closed and pronated. The shoulders were fit tightly into the shoulder guard.

Action: The lower arm was extended, pushing down towards the table.

Belt and Strap placement: 1. The belt was positioned across the hips. 2. The strap was around the wrist.

Cable placement: A three inch cable was attached to the strap, the load cell was attached to the opposite end of the cable. To the other end of the load cell a chain was attached which was then anchored to the outside upright rail of the table.

ELBOW FLEXION

Body position: The subject was placed in a supine position with hip and knee joints flexed and feet placed on top of the table. The shoulders were tight against the shoulder guard. The arm not tested was placed at the subject's side. The arm to be tested was flexed at the elbow at a 115 degree angle. The hand was supinated in a closed fist position.

Action: The elbow was flexed and moved toward the humerus in a curling action.

Belt and Strap placement: 1. The first belt was placed across the clavicle and shoulders. 2. The second belt was positioned across the hips. 3. The strap was placed on the subject's wrist.

Cable placement: A three inch cable was attached to the strap, the load cell was attached to the opposite end of the cable. To the other end of the load cell a chain was attached and anchored at an angle to the outside rail on the same side as the arm that was tested.

Subject Procedure for Measurement of
Vital Capacity and Residual Volume

1. The subject is to sit on a 12 inch bench in a slightly inclined forward position facing the residual volume table.

2. The subject's right hand is to be placed on the table in a ball.

3. The mouthpiece is to be completely in the subject's mouth through the entire test.

4. The nose clip is securely applied to the subject's nose.

5. The subject is to take in a maximal inspiration and signal by raising his right index finger when it is complete.

6. The subject is to exhale maximally when instructed. When all the air is out, the subject is to again signal by raising his right index finger.

7. The subject is to breath back and forth with the anesthesia bag seven times. On the seventh breath the subject is to exhale maximally.

8. The subject may remove his mouth from the mouthpiece and take off the nose clip while a sample of air is being collected.

9. The test is performed three times following this procedure.

Measurement of Vital Capacity and Residual Volume
(see Figure 1)

1. Valve 3 is opened to allow the subject to breath freely on the system.

2. Once comfortable on the system, the subject is instructed to take a maximal inhalation.

3. Valve 3 is closed and the subject is encouraged to attain a maximal inhalation.

4. Once the subject signals all the air is expired, valve 4 is opened connecting the subject to the 5 liter anesthesia bag containing pure oxygen.

5. The subject is to take 7 fairly deep breaths at a rate of one to two seconds.

6. Valve 4 is closed on the seventh breath.

7. Read and record the amount shown on the 13.5 Collins spirometer graph paper for vital capacity.

8. Read and record the percent nitrogen on the nitrogen analyzer.

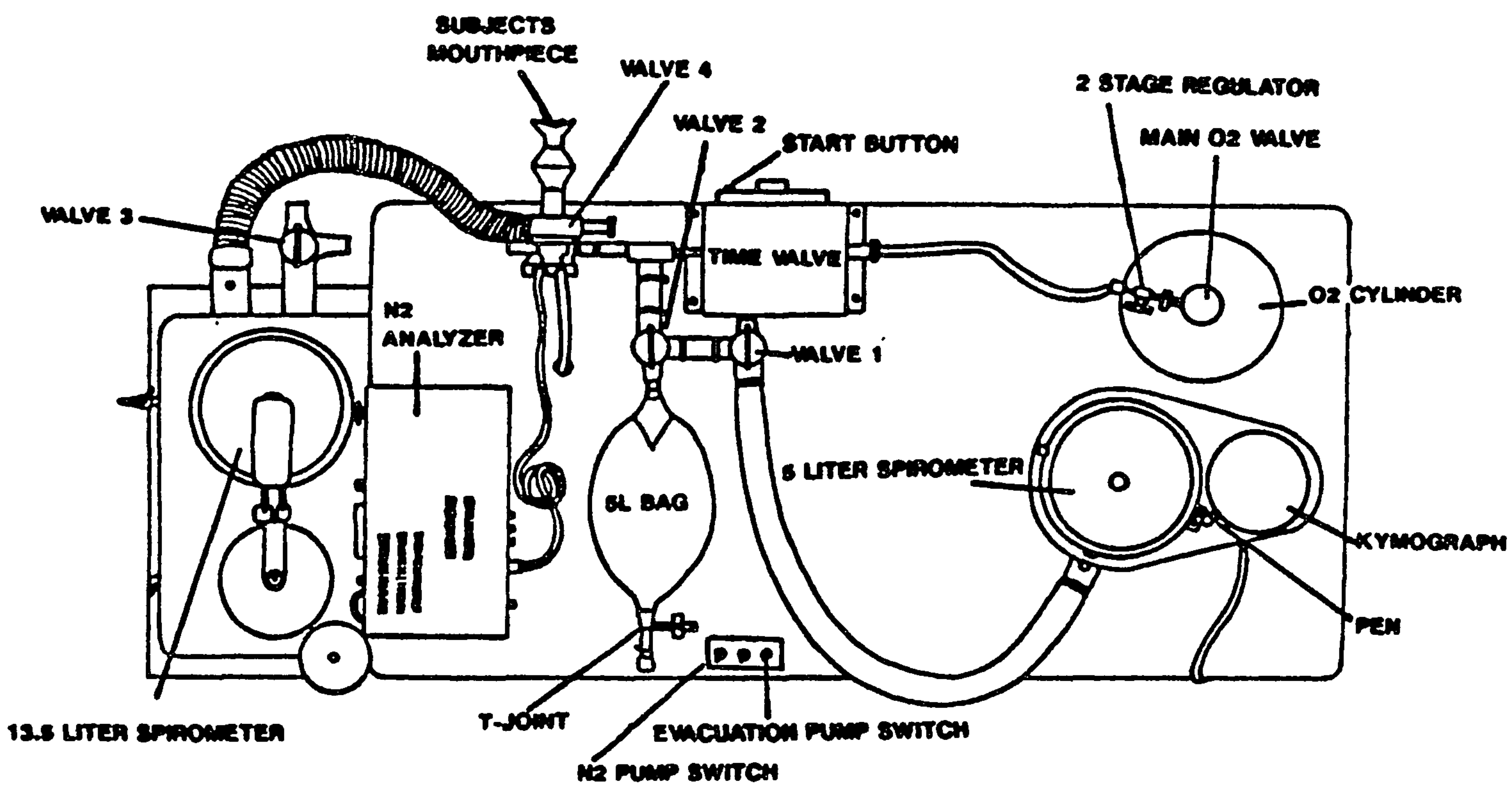

Figure 1

Residual Volume Schematic

Calibration Procedure For Delivering 5 Liters
of Oxygen to Rebreathing Bag
(see Figure 1)

1. Close off valve 2 to the anesthesia bag.

2. Open valve 1 to the Survey 5 liter spirometer.

3. Insert the ink pen to the Survey 5 liter spirometer holder.

4. Open the oxygen tank by turning the valve.

5. Push the start button on the 5 second time valve.

6. Close valve 1 to release the oxygen in the spirometer to the outside.

7. The reading on the spirometer graph paper should read 5 liters, if not, adjust the amount of oxygen released by adjusting the regulator valve.

8. Repeat this procedure 10 times to ensure that exactly 5 liters of pure oxygen is being delivered each time the button on the timed valve is pushed.

9. For testing, close valve 1 to the spirometer and open valve 2 to the rebreathing (anesthesia) bag.

Nonparametric Sign Test*

A nonparametric statistical test does not test a hypothesis according to specific parameters of a population. Instead a nonparametric test analyzes data according to less stringent assumptions such as shapes of distributions and their central tendencies. This type of test generally is used when the assumptions of parametric designs can not be met (unequal sample sizes and variances, homogeneity) thereby decreasing the power of the parametric test. Nonparametric tests, such as the sign test, also tend to be more appropriate in cases of small sample size ($N < 10$).

The nonparametric sign test is generally used when a study employs two related sample groups. A relationship between the samples is established by matching and pairing a unit in one sample to a unit in another. In some studies a before and after experiment is performed in which an experimental group and a control group are used. In this kind of investigation each unit in the before experimental group serves as a perfect match for the after experimental group.

For instance, suppose an investigation is looking at how a specific experimental treatment effects percent body fat in athletes. Two groups, an experimental and control group, are chosen. The subjects in the experimental group serve as matched pairs since they are tested before and after the experimental group is set up below.

Matched pairs	Score before treatment	Score after treatment	Differences	Sign
AIBI	17%	18%	17-18 = -1	-
A2B2	13%	12%	13-12 = 1	+
A3B3	20%	22%	20-22 = -2	-

A4B4	21%	23%	21-23 = -2	-

An = The subject before treatment

Bn = The subject after treatment

In this example a decrease in percent body fat as a result of the experimental treatment is desired. A decrease in percent fat is indicated by a positive sign. Only one of four signs were positive in this study indicating there was only one successful outcome of the experimental treatment. According to a Cumulative Term Binomial Probability Table, the probability of one of four positive signs occurring is .9375. The significance level for this study is α = .05. The probability value .9375, therefore, is not significant and the null hypothesis can not be rejected. A trend for a decrease in percent fat was not indicated according to the probability obtained.

*O'Toole, 1964

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