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Ergogenic Aids for Athletes

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University of North Dakota

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ERGOGENIC AIDS FOR ATHLETES

By

Eric Kamimura
Bachelor of Science in Physical Therapy
University of North Dakota, 1994

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of the requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
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1995
This Independent Study, submitted by Eric S. Kamimura in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title         Ergogenic Aids for Athletes
Department    Physical Therapy
Degree        Master of Physical Therapy

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ABSTRACT

The use of ergogenic aids is widespread, with users ranging from recreational to professional athletes. Perhaps the Olympics has received more publicity regarding the use of ergogenic aids than any other athletic event.

It is widely understood that anabolic steroids and other drugs can be very dangerous. As a result, more and more athletes are seeking safer alternative methods in order to enhance athletic performance. With this attitude, a number of athletes are purchasing protein, multi vitamin/mineral, and carbohydrate supplements as well as other ergogenic aids in the belief that these supplements will improve their athletic performance. However, some of these supplements are questionable in safety and effectiveness.

It is not right to assume that the RDA for nutrients is adequate for optimal performance. It should be realized that the RDA is meant for a population and not an individual.

The use of proteins, carbohydrates, and vitamin/mineral supplements should be based on individual requirements. One must look at which nutrients they are deficient in and correct these deficiencies. Any increase in performance is probably attributed to a correction in deficiency rather than an ergogenic effect.
Intake of these nutrients was found to be higher than the RDA for athletes. Vitamin/mineral supplements will always list their nutrient sources and have an expiration date and full address on their bottles. Studies have also shown that chromium picolinate, vanadyl sulfate, and creatine monohydrate may well be the only proven and effective ergogenic aids.

The user must thoroughly review the literature as well as his/her dietary needs before considering the use of any ergogenic aids. Athletes are on a constant search for ergogenic aids which can improve performance. It is easy to be deceived by manufacturers claiming that their products can enhance their performance. Finally, there is no ergogenic aid that will be of value without hard work, proper diet, and rest.
CHAPTER I
INTRODUCTION

Ergogenic aids can be defined as the use of nutritional supplements and/or drugs in an attempt to enhance athletic performance. The use of ergogenic aids by athletes, health enthusiasts, and the general population goes back a long way. Even the ancient Chinese used herbs to enhance vitality, quality, and longevity of life. Athletes ingesting substances in an attempt to improve performance have been reported since the Greeks started the Olympics. Also, the use of anabolic steroids to enhance performance has been practiced for over three decades.

We are presently living in an era in which fitness and a healthy lifestyle are greatly emphasized. This is evident in magazines, newspapers, and television ads. Whether it is from pressure in developing a body that is currently acceptable and admired by society or through sheer competitiveness, athletes, health enthusiasts, and the general population are easily deceived or persuaded into buying supplements ranging from amino acids to exotic herbs, which claim to increase health, vitality, strength, and even muscle mass. Even corporations are adding fitness facilities and hiring corporate fitness instructors to encourage their employees to exercise.
The list of ergogenic aids is steadily becoming longer and is ever changing because of individuals who are interested financially and in turn are promising incredible strength gains and fat loss, or researchers discovering other nutrients, herbs, or drugs with a possible potential to be an ergogenic aid.

Although there are some ergogenic aids available that are proven safe and effective when taken properly, there are a great number of them out there that are not backed by scientific research. The latter can cause serious side effects which can be life threatening when taken. Aids such as steroids are very effective, but also illegal and banned by most athletic organizations.

There are also ergogenic aids which are sworn to work by opinion only and are taken without any regard to possible side effects. Supplement companies often advertise their product as an ergogenic aid and then back it up by stating opinions which were given by supposed users of this particular supplement. They state that they have become stronger and leaner as a result of this supplement. There is often no research to back their claims, just opinions.

It is easy to be lured into taking various ergogenic aids ranging from simple supplements, such as amino acids and vitamins, to those that are both dangerous and illegal.

In this literature review, I will discuss the complex and controversial world of ergogenic aids. As I discuss the more popular ergogens which are presently being used today, I will try to elucidate which ones work, which ones do not,
and which aids show promise according to scientific research. I will also examine any possible side effects or precautions that may exist with the use of these ergogenic aids.
Due to genetic variations, individual bodies are biochemically different from each other. In the same manner that your external features differ from one another, there are differences in your organs, glands, nerves, and brains. Everyone who strives for optimal performance needs to understand that his nutritional requirements are very different from the next individual. When choosing various ergogenic aids, keep in mind that your total nutritional program (including nutritional supplements) must fit your individual needs. It is not reasonable to think that just because a supplement works for another individual or an advertisement tells you that their supplement is all you need, it should work for you.\textsuperscript{10}

Sports magazine advertisements and health food stores continue to promote various one-size-fits-all supplements implying that is all your individual body needs. Biochemical individuality has been well established in medical science. Scientific research has consistently shown that individuals differ in needs for nutrients. One recent study has demonstrated that use of vitamin C by individuals can vary up to tenfold.\textsuperscript{10} Some subjects took as much as 5000
mg of vitamin C showing only minimal excretion through their urine. Other subjects showed a large excretion of vitamin C after taking only 1000 mg. This just shows that the use and needs of various nutrients can vary considerably from individual to individual. This may especially be true for athletes.  

Reliability of the RDA

Though the concept of biochemical individuality has been well established, medical professional and the food industry have misused the RDAs in regard to a standard for individual nutrition. In actuality, the RDAs were not meant for individuals. The RDA handbook states that the RDA are recommendations for the average daily amounts of nutrients that population groups should consume over a period of time. RDA should not be confused with requirements for a specific individual.

Former Chairman of the RDA Committee, Dr. A. E. Harper, stated that the RDAs are not recommendations for the ideal diet and that the term "recommended allowance" was adopted to avoid any implication of optimal requirements. As you can see, using the RDAs to plan your nutritional program should be considered if one intends on optimizing performance or athletic potential.
CHAPTER III
PROTEIN

Protein Supplements

Protein supplements are perhaps the most widely used ergogenic aid by athletes and weight lifters wishing to gain strength and muscle mass. These powders range from simple proteins obtained from soy, milk, or egg protein to exotic concoctions consisting of protein and amino acids, carbohydrates, vitamins/minerals, herbs, and enzymes. These exotic mixtures often claim to be metabolic or anabolic activators, promising an increase in metabolism and muscle mass. However, these claims have not been proven, so this paper will focus on the basic protein powders consisting of the basic forms of protein.

What are Proteins?

Protein, which is found mainly in the muscle, makes up about 15% of our body weight. They are made up of units called amino acids, also known as the building blocks of protein. These amino acids may be divided into both essential and non-essential. Those that cannot be produced by the body are called essential amino acids. In order for protein to be utilized by the body, protein food must contain all the essential amino acids.
Protein may be utilized for energy needs, stored as fat, used for protein synthesis, or for the production of hormones.

Protein supplements are available in three different forms. The first form is intact proteins or polypeptides (many amino acids joined together). These are the same as protein foods of which most protein powders (casein, whey, egg, or soy protein) are made. As your body digests proteins, they are broken down into single amino acids, dipeptides, and tripeptides. Second, is hydrosylates made up of dipeptides and tripeptides (two or three amino acids joined together). Third and lastly, is free-form amino acids which are just single amino acids not joined together.²,¹⁰,¹¹

Nitrogen Balance

To assess changes in protein metabolism (changes in the rates of protein synthesis and breakdown), nitrogen balance is measured.³ To do this, all nitrogen (a component of protein) consumed food and all nitrogen that is excreted through urine, feces, and sweat is measured.³ A positive nitrogen balance exists when intake exceeds excretion.³ When protein intake is insufficient, a negative nitrogen balance exists.³ A positive nitrogen balance is required for muscle growth.³ During periods of negative nitrogen balance, muscle tissue breaks down (catabolism) to produce amino acids for other uses.³ Because essential amino acids can only be supplied through one’s diet, sufficient amounts of protein intake is important for those attempting to increase muscle mass and strength.³
Protein Requirements

Presently, the National Research Council of the National Academy of Sciences RDA for protein is .8g/kg of bodyweight/day.\(^1\) The NAS/NRC believes there is little evidence that muscular activity increases the need for protein.\(^1\) However, there has recently been great controversy over the recommended amount of protein required for optimal athletic performance.\(^1\) Research literature has been accumulating that questions the adequate of these recommendations for meeting the needs of the competitive athlete.\(^1\) The protein RDA is only an approximation and is based on data from relatively sedentary people.\(^3\)

Research Studies

Recent studies on endurance athletes have indicated the importance of protein utilization for energy substrate during times when glycogen stores in the body are low.\(^1\)

Both endurance exercises and intense, intermittent exercises, such as weight training, have been found to require protein intakes of up to 2 g/kg per day for both novice and experienced athletes. This protein is used to maintain a positive nitrogen balance, minimize loss of blood proteins, and provide amino acids for exercise fuel or muscle repair.\(^1,3\) Increases in lean body mass and strength have resulted with protein levels well above the current RDA.\(^1\) Three theories which explain the beneficial effects of protein have been suggested.\(^1\) First, protein provides raw material for protein synthesis and decreases muscle catabolism (muscle tissue breakdown).\(^1\) Strength training combined with a high
protein intake increases nitrogen retention thereby decreasing the chances of falling into a negative nitrogen balance in which muscle tissue is broken down.1 Second, protein can be used as an alternative energy source thereby sparing muscle protein.1 Third, growth hormone may be stimulated with increased intakes of protein.1

Is the RDA Sufficient?

Athletes consuming 100% of the current RDA for protein may experience both a decrease in muscle mass and strength.3 This may be caused by an insufficient intake of food calories due to the increased energy expenditure of training or if food intake is restricted to help reach a certain body weight for sports, such as wrestling or gymnastics.3

Mechanism of Protein Use in Exercise

How might endurance exercise and strength training alter protein needs? Endurance exercise causes an increased utilization of branched chain amino acids (leucine, isoleucine, and valine) as exercise fuel.3 High intensity exercises, long duration exercises, and endurance training could alter rates of protein synthesis or breakdown, and lead to an increased daily protein requirement.3

Studies on elite weight lifters consuming 250% of the RDA for protein were found to be in negative nitrogen balance due to muscle catabolism.3 Also, world class weight lifters demonstrated increased strength gains (5%) and muscle size (6%) with protein intakes of up to 438% of the RDA.
Timing of Protein Intake

Research also suggests that the timing of protein ingestion should be during the immediate post exercise time period.¹ This is particularly important to accelerate muscle recovery, since this is a period of optimal protein uptake by the body.¹

Are Athletes the Same as Sedentary People?

Both endurance and strength athletes have an increase protein requirement as compared to the sedentary population.¹ Protein requirements of 1.2 to 2.0 g/kg per day or 15% to 20% of daily calories have been suggested.¹

Toxicity

The fact that high protein diets cause liver and/or kidney disorders is not documented in healthy athletes and is of no concern at modest protein intakes.³,⁴ However, protein does produce a diuresis effect and may increase the potential for heat related injuries.⁴ There also appears to be a relation between high protein intakes and elevated calcium loss.⁴ Therefore, increased fluid intakes and possibly calcium supplementation should accompany a high protein diet.⁴ Also, it must be remembered that protein intakes substantially in excess of the RDA in an effort to increase strength and muscle mass have not been shown effective. Any long-term health risks associated with these intakes are unknown.
Individual Requirements

It is important to individualize protein requirements based on training demands, calorie intake, and special requirements.\textsuperscript{1} Protein supplements taken in excess of one's calorie requirement will only cause gain in fat not muscle.\textsuperscript{5} Increased protein intake through one's diet or the use of a protein supplement may be most beneficial for strength athletes who include endurance exercise in their training or athletes who consume insufficient total energy (calories) to support their training regimen.\textsuperscript{3} One must keep in mind that the use of protein supplements in one's diet can help keep the fat and calorie intake down, since animal products, such as red meat and pork, can increase the fat content of one's diet.\textsuperscript{4} In fact, attempting to increase protein intake through the consumption of high cholesterol and fat sources, such as red meat, are typically arthrogenic (promoting hardening of the arteries).\textsuperscript{6}

In conclusion, evidence on the effects of increased protein intakes through one's diet or a protein supplement are not yet conclusive. More studies are needed to confirm these observations. Only then can the quantity of dietary protein necessary to maximize training induced gains in muscle strength and size be established.
CHAPTER IV
CARBOHYDRATES AND PERFORMANCE

Carbohydrates and Their Role

Carbohydrates are compounds composed of carbon, oxygen, and hydrogen. These include sugars (glucose), glycogen, starches, dextrins, and celluloses.

Carbohydrates' main function is to provide a continuous energy supply to the cells within the body. Adequate carbohydrate intake serves as a protein sparing effect in which the use of protein for energy use is limited. This allows protein to do its job in maintenance, repair, and tissue synthesis.

Carbohydrates which are ingested ultimately turn into glucose and circulate in the blood. They may then be used as energy, stored in the liver and muscles as glycogen, or stored as fat if in excess of required caloric intake. Glycogen stored within the muscle is used initially upon the beginning of exercise. However, after 20 to 30 minutes, muscle glycogen stores are depleted and blood glucose together with liver glycogen take over. After approximately one and one-half to two hours of continuous exercise, unless carbohydrates are replenished, the body will deplete the carbohydrate resources.
Athletes and Carbohydrates

Athletes have been loading up on “carbos” in an attempt to enhance performance for some time now. Athletes are very aware of the importance of carbohydrates during prolonged exercise. Adequate muscle glycogen stores are critical to optimal performance. However, surveys of different groups of endurance athletes reveal an inadequate carbohydrate intake in their dietary regimen.

Resistance and Endurance Training

A great number of carbohydrate supplements, also known as energy drinks or sports beverages, are advertised for energy, endurance, and/or recuperation. Studies on the effects of carbohydrate supplements on resistance trained individuals are few in number. However, research on endurance trained individuals is very well documented. These supplements seem to be of great value during continuous endurance exercise in which glycogen stores are depleted.

Due to the fact that weight training is intermittent in nature and involves different muscle groups, it is less likely to exhaust glycogen stores. Research shows that between 13% and 45% of muscle glycogen stores are used during resistance training. Also, this form of training increases resting muscle glycogen levels and blood glucose levels are not reduced during weight training in trained individuals. However, a decrease in strength may occur if carbohydrate intake is chronically low and glycogen levels decrease. Strength
may also be altered if individuals engage in other types of activities that affect glycogen utilization.\textsuperscript{2} In addition, body-builders also follow a variation of carbohydrate-loading during the few days before competition in an effort to improve muscle size and definition. In these cases, a carbohydrate supplement may be useful in increasing carbohydrate intake without the excess of calories and fat that some carbohydrate foods may contain.

The Right Carbohydrate Drink

Recent research indicates that for prolonged exercise which exceeds one hour, a solution of 4\% to 10\% carbohydrate of any type consumed at 20-minute intervals can elevate blood glucose levels, maintain muscle glycogen, and enhance endurance.\textsuperscript{9} Concentrations greater than 10\% slow the rate of gastric emptying and may impair fluid replacement.\textsuperscript{9}

Practical Use and Timing of Carbohydrate Supplements

Competition and/or training creates a condition of muscle glycogen depletion, and glycogen that is depleted must be replaced through one's carbohydrate intake.\textsuperscript{5} Sometimes it is not always convenient or possible to consume a carbohydrate meal after exercise and/or a workout.\textsuperscript{5} Also, a meal may not always be feasible due to a suppression of appetite immediately after training. Therefore, a carbohydrate supplement consumed immediately after training can be used to replenish muscle glycogen stores.\textsuperscript{5} In addition, for athletes with very high energy needs, a carbohydrate supplement may prove to
be helpful in meeting one’s caloric requirement and boosting carbohydrate intake without having to force-feed themselves.

A modified carbohydrate loading technique proves to be more conducive to training than the classical carbohydrate-loading method. With the modified carbohydrate-loading regimen, the athlete consumes a mixed-diet three to six days prior to competition and tapers training; this is then followed by a high carbohydrate diet the few days remaining before competition. This is a less drastic procedure which results in comparable glycogen stores to the classical method. Carbohydrate supplements can be very useful in this situation. In addition to one’s diet, they provide a convenient means to increase one’s carbohydrate intake.

Carbohydrate supplements can be found in any nutritional store or supermarket. They provide an alternative to traditional food and beverages to athletes during training to performance. They may also be a source of carbohydrate for the repletion of muscle glycogen after exercise.
CHAPTER V

VITAMIN AND MINERAL SUPPLEMENTS

Vitamin and Mineral Use

Vitamin and mineral supplementation has been popular among athletes and the population for quite some time. Seventy-two percent of 609 world-class athletes report consistent use of these nutritional supplements. Many believe that the stress and trauma caused by intense physical exercise may increase one's need for vitamins and minerals. Claims of increased performance made by supplement manufacturers have convinced a great number of athletes to buy into their products.

Roles and Functions

Multi-vitamin and mineral supplements are not only found individually but are also found as added ingredients in other supplements. Vitamins and minerals are required in very small amounts and are responsible for performing specific metabolic functions. Some of these functions include: metabolism of protein, carbohydrates, and fats for energy and maintenance, maintaining bone strength, anabolism (building of muscle tissue), and regulation of hormones.
Vitamin/Mineral Supplements and Performance

Most research studies reveal that vitamin and mineral supplementation does not enhance athletic performance in well-nourished people.\(^1,^2\) However, an athlete with a poor dietary intake may be deficient in a number of nutrients. In this case, vitamin and mineral supplementation is warranted. This is, however, discouraged due to the susceptibility to toxicity and the interference in metabolism of other nutrients.\(^1,^2\) Of greatest concern is the possible toxicity of vitamins A and D caused by excessive nutrient intake.

Recent studies have suggested that exercise may increase the need for vitamin C and riboflavin (B12) and also seems to affect the metabolism of vitamin B6.\(^5\) Consequently, supplementation of vitamin C can enhance performance in those individuals who are deficient in this particular vitamin.\(^5\)

Iron supplementation has been shown to increase performance in athletes with depleted iron stores. The depleted iron stores are often found in male and female runners. The iron losses may occur through sweat and gastro-intestinal blood loss (ulcers) in addition to an inadequate intake of iron in the diet.\(^5\)

Minerals that are also lost through the sweat include sodium chloride (greatest loss), potassium, magnesium, calcium, copper, and zinc. Under normal circumstances, these electrolytes are easily replaced through one's diet.\(^5\) However, in the unacclimatized and ultra endurance athlete who exercises in the heat and sweats copiously, these vital electrolytes may not be easily
replaced. In this situation, an electrolyte replacement drink, which is found in most carbohydrate supplement drinks, is suggested to prevent the impairment of one's performance.\(^5\) It is absolutely not necessary to take salt tablets in order to replace sodium. One may suffer side effects such as nausea, vomiting, and intracellular dehydration.\(^5\)

**Individual Vitamins and Minerals**

The following is an overview of various individual vitamins and minerals that are perceived by most athletes to be ergogenic aids.

Vitamin B6 (Pyridoxine)

This water-soluble vitamin is involved in all levels of protein and amino acid metabolism. The requirements for vitamin B6 increase when one consumes a high protein diet and when energy expenditure increases. Some studies suggest an intake of 4.0 mg per day as compared to the RDA's 2.0 mg. Studies have also shown enhanced aerobic capacity and decrease in lactic acid build-up. However, excessive intakes over 100 mg for months can cause severe nerve damage and liver disease. Mega doses of B6 can cause the body to deplete its glycogen stores more rapidly and can, therefore, be anti-ergogenic.\(^1,10\)

Therefore, eliminate the idea of excessive B6 supplementation and try to obtain an adequate intake of B6 from foods such as chicken, fish, or eggs.

Vitamin B12 (Cyanocobalamin)
This particular B-complex vitamin has been very popular among athletes. They can be purchased in all types of forms, such as tablets, sublingual drops, and nasal drops. Numerous athletes receive mega dose shots of B12 in belief that it will increase performance.

Studies show absolutely no ergogenic benefits of excessive B12 supplementation. Athletes often show a placebo effect in which they feel they can do better. This, however, is all psychological and any increase in performance is highly unlikely.1,10

The current RDA for B12 is 6 mg. Studies have shown that athletes may require more than the sedentary individual, but values for optimal performance are still questionable. However, very few athletes show a B12 deficiency and doses up to 10,000 times the RDA appear to be non-toxic.10

Vitamin B12 can be found in all animal meats. Unless you are a vegetarian, it is highly unlikely that you are deficient in B12. Therefore, supplementation of B12 is probably not needed by most athletes.1,10

Vitamin C.

Perhaps the most important function of vitamin C in athletes is its role as an antioxidant. Although it has no ergogenic ability, its effect as an immunity enhancer can profoundly aid in combating illnesses and injury that can be a result of intense exercise.1,10

The RDA for vitamin C is 60 mg; however, studies suggest 2 to 12 g per day for athletes. It is a water soluble vitamin and is, therefore, excreted rather
rapidly from the body. Because of this, toxicity for vitamin C is rather low. Reports of kidney stones and gout formation with excessive intakes of vitamin C are unsubstantiated. Experts have concluded that there is absolutely no evidence that excessive intakes of vitamin C cause gout or kidney stones.\textsuperscript{10}

Coenzyme Q10

This naturally occurring substance controls the flow of oxygen within cells and is a vital catalyst in the energy cycle of the mitochondria. Although supplementation of Q10 has not been proven effective, recent studies suggest that supplementation of Q10 can enhance performance by up to 12%. However, the effects of Q10 in athletic performance are still in question and need to be further investigated.\textsuperscript{10,11}

It is highly unlikely that sedentary people would be deficient in Q10 since it is found in vegetable oil and the body can obtain this through the amino acid methionine. However, it is possible that an athlete's need for Q10 may be higher due to his/her high energy turnover.\textsuperscript{10,11}

Iron

The main function of iron is to form hemoglobin which, in turn, carries oxygen in the blood stream. It is available in whole grains, vegetables, and eggs. With all of this iron, deficiency is still quite common in athletes.\textsuperscript{1,10}

Part of the reason for this is the fact that heme iron from meats and vegetables are only 1\% to 10\% bioavailable. This means that about 90\% to 99\% is not capable of being absorbed by the body. Also, calcium and fiber
inhibits the absorption of iron; whereas vitamin C increases its absorption. Iron is also lost through heavy intense training and can increase the probability of iron deficiency.\textsuperscript{10}

A male athlete should, therefore, take in a minimum of 36 mg of iron per day and a female 41 mg. According to studies on athletes’ diets, a male athlete would have to eat 6,000 calories a day to fulfill this requirement. Since this is not a favorable alternative, a supplementation of 20 to 25 mg per day would make more sense.\textsuperscript{10}

Iron is not ergogenic, but a deficiency in iron can hinder performance. Therefore, an athlete should make sure he/she is taking in sufficient iron. Mega doses of iron, above 100 mg per day, can cause an increase in one’s risk of infection and have multiple side effects, such as damage to the heart, liver, and pancreas.\textsuperscript{1,2,10}

Boron

Due to boron’s function to provide biochemicals for the manufacturing of some steroid hormones, it has been marketed as an anabolic enhancer and is claimed to increase testosterone levels.\textsuperscript{10,11}

No studies have yet been performed on athletes, but boron is necessary for normal testosterone production. According to research, most athletes do not get enough boron through their diets. It seems as though 2 mg. would be sufficient, but intakes above 50 mg per day can cause adverse effects.\textsuperscript{10}
Boron supplements containing 10 mg of boron per pill are being sold to athletes as an ergogen. It does not cause the body to produce more testosterone. If you are sufficient in boron, then increasing your dosage does absolutely nothing. In fact, athletes who have used this supplement reported no significant increase in strength or muscle mass.\textsuperscript{10,11}

\textbf{Are You Getting Your Money's Worth?}

Not all vitamin supplements are created equal. Also, not all supplements you find at a nutrition store or pharmacy are genuine, potent, true to their label, or made of the best forms.

To demonstrate this, let's look at L-carnitine, a supplement touted to increase the utilization of fat. In a research concerning the quality of L-carnitine, one particular brand of L-carnitine containing 500 mg was found to be a complete fraud. The reason for this was that you cannot fit 500 mg of L-carnitine into one tablet or capsule while at the same time keeping it small enough to swallow.\textsuperscript{10}

Another example of this is multi vitamins. A recent study showed that out of 257 brands of multi-vitamins that were evaluated, only 49 were considered adequate. The others were considered incomplete or had too little or too much of one nutrient. Remember that vitamins work in synergism; too little or too much of one nutrient can interfere with the absorption and utilization of another.\textsuperscript{10,12}
Bioavailability

Besides being true to the label and potency, one should also understand how different forms of nutrients are used by the body.

Pyridoxal-t-Phosphate (P-5-P), the expensive form of vitamin B6, is often touted by supplement manufacturers as being the superior form of B6. They claim that this is the form best used by the body. However, this is not true. Manufacturers do not tell you that P-5-P is broken down by the body to pyridoxine (vitamin B6). After it passes through the intestinal wall, the body turns it back to P-5-P. Therefore, inexpensive pyridoxine hydrochloride is as effective as P-5-P.¹⁰

In contrast, the body absorbs various forms of calcium differently. Calcium in the form of calcium gluconate is only 9% elemental calcium. A supplement which claims to contain 1000 mg of calcium gluconate actually has only 90 mg of calcium. By just looking at the label, one would think 1000 mg of calcium gluconate is sufficient, but you would actually have to take 26 of these pills just to obtain the RDA.¹⁰

The best and most potent form of calcium is calcium carbonate, which is 40% elemental calcium.

Which Vitamin/Mineral Supplements Are the Best?

Decent vitamin/mineral or supplement manufacturers always state their nutrient source and their actual elemental quantities. They give full disclosure
of all ingredients and always have an expiration date and full address on their bottle (not post office box).\textsuperscript{10}

**Natural or Synthetic**

Some manufacturers would lead you to believe that natural vitamins are better than synthetic vitamins. First of all, your body does not recognize a vitamin as being natural or synthetic. Your body will use both in the same manner.\textsuperscript{7,10,12} Second, all vitamins today are predominantly synthetic. This means they are pure chemicals created out of a food base. Those supplements that claim to be “all natural” are mostly synthetic with a minute addition of natural vitamins.\textsuperscript{10}

**Toxicity**

Nutrient toxicity has generated controversy. Some nutritionists feel that the addition of a vitamin/mineral supplement in one’s diet can predispose a person to possible toxicity.\textsuperscript{7,10,12} Research shows that a majority of reported toxicity cases were a result of coincidental infections, foods eaten, and other events not related to nutrient intake. Of the few that were actual nutrient toxicity, none was serious and symptoms disappeared upon cessation of supplement use.\textsuperscript{10}

In 1985-1990, 2,251 deaths occurred as a result of the use of prescription drugs. Within the same time period, one death occurred and this was a result of an overdose of niacin. Deaths concerning all other vitamins and minerals were nonexistent.\textsuperscript{10} This is not an excuse to go and overdose yourself
with supplements, because too much of anything can be harmful. Supplements should always be used in sensible amounts and never abused.

Individualize Your Intake

Before you ingest any vitamin/mineral supplement, know your nutrient status and what nutrients in which you may be deficient. Increasing your intake of a nutrient in which you are already adequate does nothing. Also, nutrients work in synergy. Increasing one nutrient without increasing the other is a waste of time and money. Too much of one nutrient can interfere with the absorption of another.\textsuperscript{7,10,12}

Anabolics

Many supplement manufacturers claim that this particular nutrient has drug-like effects, such as anabolic, testosterone booster, or ergogenic, when in fact it is just a simple correction in deficit. This sets up an optimum environment for which your body can achieve its full potential.\textsuperscript{10}

As you can see, research over the past 40 years remain controversial over the effects of vitamin and mineral supplementation. It seems as though vitamin and mineral supplements are not needed for those athletes consuming an adequate diet and, therefore, not lacking in any vitamins or minerals. However, the question still remains. Just what exactly is adequate?

On the other hand, for those who routinely consume an inadequate diet (ex: controlling one's body weight), a multi vitamin and mineral supplement may be of use.\textsuperscript{5}
CHAPTER VI
AMINO ACID

Amino acids are among the post popular nutritional supplements among athletes. They are often touted as anabolic enhancers that can increase strength and power, stimulate growth hormone release, replenish muscle protein, and reduce body fat.

Amino acid supplements can be found in tablet, capsule, or powder form. They are often described as being ‘free form’ or ‘peptide bonded.’ Manufacturers claim that these amino acids are absorbed and utilized quicker and more efficiently than intact proteins. 2,5,11

What Are Amino Acids?

Amino acids are the “building blocks” or basic units of protein. They are small organic compounds that can be viewed as the end products of digestion. 7,13

There are 20 different amino acids that are necessary for metabolism and growth. Of these, 12 are nonessential which means they can be manufactured by the body. The other eight cannot be synthesized by the body and are, therefore, termed essential. These essential amino acids must be obtained through one’s diet in order to maintain normal cellular function. 7,13
Free Form Amino Acids

With this form of amino acids, protein is broken down into single amino acids. This is probably one of the biggest money makers in the supplement industry. Manufacturers and marketers claim that these supplements can increase strength and muscle mass while reducing body fat through increased protein and fat metabolism.\textsuperscript{2,11}

Scientific research has shown that free form amino acids do not increase muscle mass or increase the rate of lipolysis. Though free form amino acids do not have to undergo digestion and can be absorbed in the small intestine, their ability to retain nitrogen is poor.

This point was demonstrated in a study that showed improved nitrogen absorption was with free form amino acid. However, a diet supplement with free form amino acids produced poor nitrogen retention. This is because free form amino acids lose nitrogen faster than peptide-bonded amino acids. Keep in mind that dietary proteins are preferably absorbed and retained in the body in the peptide-bonded form.\textsuperscript{2,11}

Another problem with free form amino acids is the fact that they are not properly absorbed by the body for several reasons. First, amino acids have different molecular weights and the aminos with the larger molecular weight will be absorbed first while the aminos with the smaller molecular weight will be absorbed last or sometimes not at all. This can result in an unequal balance or negative nitrogen balance (catabolic state). Second, the body does not have a
separate system for free form amino acids like it does for peptide bonded aminos.\textsuperscript{10,11} Although protein supplementation can be beneficial to athletes in certain situations, as stated in Chapter I, protein as free form amino acids is not the best choice.

Side effects associated with free form amino acids include stomach discomfort and/or intestinal disturbances. Studies also reveal that free form amino acids are so poorly utilized that toxic levels of urea can accumulate in the kidneys.\textsuperscript{2,11}

Free form amino acids are the most expensive type of protein supplements. They, however, are no more effective than cheaper forms of protein, such as those that are peptide-bonded or pre-digested.

Peptide-Bonded Amino Acids

Peptide bonded amino acids are natural proteins that have been predigested or hydrolyzed in a laboratory. They are also called hydrosylates and consist of dipeptides and tripeptides (2 or 3 amino acids joined together).

The human body is very efficient at digesting whole intact proteins. They are broken down into hydrosylates and absorbed. For this reason, the human gut has a special transport system for peptide bonded amino acids. Studies have shown that peptide-bonded amino acids have a 16 times greater nitrogen retention and twice as fast absorption rate than free form aminos. Research also shows that animal subjects supplemented with peptide-bonded aminos grew 50% faster than those who supplemented with free form aminos. They
also grew 30% faster than subjects who were taking intact or whole proteins.\textsuperscript{10,11}

Peptide-bonded amino acids signal certain physiological responses that free form amino acids cannot. Recent studies have shown that dipeptides and tripeptides signal the liver to produce somatomedin C which is an anabolic growth factors that stimulates muscle growth.\textsuperscript{10,11}

In conclusion, supplementation with amino acids can be justified in the same situations that are stated in Chapter I (proteins). They are no more effective than protein supplements. Which type of amino acids is better? Studies show that peptide-bonded amino acids derive from whey (lactalbumin) protein or egg whites are higher in quality and effectiveness than casein (milk) or soy protein. They are, however, a little more expensive due to the sophisticated process in which they are made.\textsuperscript{10,11}

**Branched Chain Amino Acids**

Branched chain amino acids (BCAA) consist of leucine, isoleucine, and valine in their free form (not bonded together). They make up one-third of muscle protein and are the primary amino acids metabolized during exercise. These amino acids are oxidized and used for energy. When muscle glycogen is depleted, BCAA can contribute 5% to 15% of the body's energy requirements. Factors that increase the oxidation rate of BCAA are high intensity exercises, long duration exercises, and decreased carbohydrate availability.\textsuperscript{2,3,5,11}
Recent studies have shown that moderate exercise lasting two hours resulted in leucine oxidation equal to 90% of the total daily requirement for leucine given by the RDA. It is also believed that similar losses occur with both isoleucine and valine. Exercise was found to increase the activity of branched chain keto-acid dehydrogenase, an enzyme responsible for the degradation of BCAA. For optimal performance, it is likely that an athlete will need more than that.\textsuperscript{5,10,14} Studies at MIT show that even sedentary people are in negative leucine balance and require much more leucine than the RDA states.\textsuperscript{10}

A deficiency in BCAA can result in muscle atrophy and a loss of strength and endurance. Protein synthesis is altered due to the fact that all other amino acids required for tissue maintenance and growth are compromised due to the principle of synergy. Remember that all necessary amino acids must be present (complete protein) in order for protein synthesis to occur. Studies have demonstrated that supplementing with BCAA will increase blood levels.\textsuperscript{10}

Based on recent studies, an athlete who is participating in high intensity exercise would require an intake of at least 60 mg/kg/day for leucine, 50 mg/kg/day for isoleucine, and 20 mg/kg/day for valine.\textsuperscript{10}

Supplementation of BCAA can be extremely beneficial to those athletes who are on restricted diets. Many athletes who supplement with BCAA acids believe that this is an effective way of replenishing these amino acids that are oxidized during exercise. This can, in turn, increase protein synthesis and
recovery time and, as a result, increase strength and energy. More long-term studies are needed to substantiate this.\textsuperscript{4}

Before supplementation with BCAA, take into account those that are present in your normal dietary protein. If you do plan on supplementing with BCAA, be sure they are in free form and L-amino acids. Light will oxidize BCAA, so be sure they are in a dark glass bottle with expiry dates. They should be taken with meals as well as one to two hours before training and sleep and 90 minutes after training. New evidence has shown that BCAA taken before exercise and sleep can spare muscle BCAA and increase testosterone and growth hormone levels. BCAA have also been found to increase insulin production which, in turn, promotes amino acid (protein) uptake.\textsuperscript{10,11} One negative effect of BCAA is the fact that leucine increases ammonia in the body which can be detrimental to performance. Ammonia reduces glycogen synthesis, energy, and brain function. This problem can be solved by taking leucine in the form of ketoisocaproate. Ketoisocaproate produces no ammonia and actually acts as an ammonia scavenger. This action in itself can benefit athletic performance.\textsuperscript{10}

Arginine/Orthinine

The amino acids arginine and orthinine have also been especially popular among athletes wishing to increase muscle mass and strength while decreasing body fat. Manufacturers claim that arginine and orthinine can stimulate the secretion of growth hormone by the pituitary gland.\textsuperscript{2,5,15} The fact
that these amino acids can increase growth hormone levels and increase muscle mass and strength are still controversial.

Studies have shown that the injection of arginine stimulates growth hormone release, but the fact that arginine taken orally can increase growth hormone level more than exercise itself still remains in question.⁵

Some studies have shown that arginine administered orally in doses as high as 2.4 grams had no effect on growth hormone secretion. There are researchers who feel that it is doubtful that arginine/orthinine can stimulate muscle growth even if they do potentiate growth hormone secretion. A recent study has shown that subjects given arginine/orthinine showed no increase in muscle protein synthesis or strength. Most studies on arginine/orthinine use doses way above that of the manufacturer's recommendation. To see if doses administered at the manufacturer's recommendation had any effect on growth hormone levels, a study was done using these amino acids at the manufacturer's prescribed dosage. The results showed that the ingestion of arginine or orthinine does not consistently increase growth hormone concentrations.²⁴¹⁵

There are other studies that do show positive effects on growth hormone concentration with the ingestion and injection of arginine/orthinine. There are presently over 50 research studies that demonstrate arginine's/orthinine/s potential in releasing human growth hormone. Arginine is even used to test the function of the pituitary in undersized children. Most of these studies are based
on arginine or orthinine administered intravenously. The question is whether or not these amino acids can be equally as effective when given orally.\textsuperscript{2,10,11}

One recent study showed that a 250 mg/kg oral dose of arginine aspartate increased growth hormone level during sleep. Another study demonstrated that 1200 mg of arginine taken orally in combination with lysine increased growth hormone secretion.\textsuperscript{2,10}

Orthinine also shows the potential to increase growth hormone levels. One recent study demonstrated a significant rise in growth hormone levels 90 minutes after ingesting 170 mg/kg of orthinine.\textsuperscript{2,10}

The studies that demonstrated increased growth hormone release with such small doses are few in number and contrast with the majority of studies. Some researchers believe that even if arginine/orthinine given orally increases growth hormone levels, the doses would have to be very large (40-60 grams). This amount would probably cause stomach problems.\textsuperscript{2,10,11}

As you can see, studies are not yet conclusive on the effects of arginine/orthinine on growth hormone release. However, recent studies on athletes suggest that 200 mg of arginine and/or 100 mg of orthinine alpha-ketoglutarate can be effective in enhancing the release of growth hormone. They should be taken on an empty stomach and three hours distant from any meal.\textsuperscript{10,11}

Some side effects associated with arginine/orthinine are upset stomach, diarrhea, headaches, and promotion of herpes outbreak in athletes with oral or
genital herpes. To alleviate this problem, one gram of lysine three times a day would be taken. Since lysine can diminish the effect of arginine and orthinine, it should not be taken at the same time with arginine or orthinine. It should also be remembered that the long-term safety on these amino acids are still unknown.\textsuperscript{10}
CHAPTER VII

CHROMIUM

Recently, reports of increased muscle mass, strength, and loss of body fat has led athletes, sports nutritionists, and coaches in believing they have finally found a safe and effective ergogenic aid. This supposed anabolic supplement has also been marketed to the general population with claims that chromium will reduce body fat in sedentary people.

Whatever the story may be, this may well be the first nutritional supplement with convincing and substantial research to back up its proposed anabolic qualities.

Role of Chromium

Chromium is an essential trace mineral which should be adequately contained in one's daily diet. There is no recommended daily allowance (RDA) for this particular nutrient. However, the National Research Council has established a range of 50 to 200 ug for adults as an adequate intake. Chromium picolinate is an essential component responsible for insulin sensitivity and is a major component of the glucose tolerance factor (GTF). The glucose tolerance factor is the active ingredient which is responsible for maintaining normal glucose tolerance in the body.
Chromium also stimulates the activity of enzymes responsible for the metabolism of glucose for energy and metabolism of fatty acids and cholesterol. It increases the effectiveness of insulin and its ability to handle glucose. Chromium also seems to be involved in the synthesis of protein.\textsuperscript{11,17,18}

How Does Chromium Work?

Muscle synthesis or hypertrophy requires four basic nutrients: glucose, fat, amino acids, and a hormone to activate the systems that produce muscle proteins. Recent research has suggested that insulin plays a major role in determining whether or not these nutrients reach muscle cells when they are needed.\textsuperscript{19,21}

Insulin combines with specific chemical groups on the outside of cells. A message is then sent inside summoning special proteins to mobilize to the cell wall. These proteins are called glucose transporters and takes glucose inside of the cell. If this special chemical system does not send a strong enough signal to inside of the cell, little or no glucose is transported into the cell. If the call from insulin/chemical group to the cell is weak or misinterpreted, the cell is said to be insensitive to insulin. This condition is known as insulin resistance.\textsuperscript{16,18}

Insulin resistance slows down muscle synthesis and promotes fat deposition because not enough glucose and fat gets to the muscle cell. Before fats can be used for energy, they have to be detached by enzymes that are turned on only when blood glucose drops. Since glucose levels do not drop
with insulin resistance, these enzymes are not activated and the muscle is unable to obtain its source of energy.\textsuperscript{16}

When muscle is unable to use fat, it turns to glucose for fuel. However, glucose cannot be transported inside the insulin resistant cell to be used for energy. Therefore, when muscle is unable to use fat and glucose for energy, it turns to muscle (catabolism) for fuel. This is a condition that all athletes want to avoid. Amino acids should be used for building muscle proteins as much as possible.\textsuperscript{16,20}

The primary cause of insulin resistance is the lack of chromium in one's diet.\textsuperscript{16} Surveys show that 90\% of Americans do not have enough chromium in their diet to support maximum insulin action. The chromium content in foods have varying absorption rate by the body. Only 1\% of inorganic chromium can be absorbed by the body, and chromium in eggs is in a form that cannot be utilized by the body. The most biologically active form of chromium is found in brewers yeast, liver, beef, wheat bread, and mushrooms. The same goes for chromium supplements. Not all chromium supplements are useful because only certain forms can be absorbed.\textsuperscript{12,16}

Glucose is another cause of insulin resistance and Americans have a high carbohydrate diet in the form of simple sugar. Studies have shown that a high carbohydrate diet can cause chromium excretion through one's urine. Therefore, too much glucose and too little chromium can only exacerbate the problem.\textsuperscript{16}
While some individuals may have good glucose tolerance, older individuals may be more susceptible to insulin resistance due to the fact that glucose tolerance does decrease as one gets older.\textsuperscript{20}

**Which Form of Chromium?**

Chromium is not easily moved through the plasma membrane (cell barrier). However, when chromium is attached to picolinate, it is readily absorbed and utilized by the body. Studies have demonstrated that chromium in the form of chromium picolinate prevents insulin resistance and thus accelerates muscle development and can increase the utilization of fats.\textsuperscript{2,16}

The absence of insulin resistance enables muscles to utilize glucose and fat for energy and amino acids to make proteins (muscle). This proper use of essential nutrients helps to accelerate muscle growth and possibly decrease body fat along with lowering blood lipid levels and increasing HDL levels.\textsuperscript{16,20,21}

**Testosterone**

Recent studies show that chromium picolinate may increase the production of dehydroepiandrosterone (DHEA). DHEA is a steroid hormone which is produced by a gland located in the protective fat on each kidney. Although it is not as potent as testosterone (most potent androgen), it can readily be converted into this androgen and, as a result, increase the development of muscle.\textsuperscript{16,20}

When insulin is not functioning properly, such as in insulin resistance, DHEA production is dramatically decreased. During insulin resistance, glucose
is unable to gain entry into body cells and is, therefore, kept in the bloodstream. In response to this, the pancreas continues to produce and secrete more insulin to deal with rising tide of glucose. Because insulin turns off the enzyme that produces DHEA, little or no DHEA is produced.\textsuperscript{16,20}

Research shows that the increased rate in muscle development observed in human and animal subjects given chromium picolinate may be due to the increased production of DHEA. Though exercise by itself can increase DHEA levels by about 20% and improve insulin efficiency, chromium supplementation in conjunction with a weight-lifting program can increase DHEA levels by about 50% and decrease insulin by about 20%.\textsuperscript{2,16,18}

Conclusion

Due to conflicting reports on the efficacy of chromium and the question of its long-term safety, more well controlled research studies are needed to prove the efficacy of chromium supplementation. It is doubtful that chromium supplementation will have an effect on those individuals with good glucose tolerance.\textsuperscript{18}

Also, large, short-term muscle mass increases with chromium supplementation should not be expected since the anabolic nature of enhanced insulin function would likely be long-term. A few studies have shown that increases in muscle mass as a result of chromium supplementation were likely to be moderate to marginal.\textsuperscript{17}
Given that chromium intake for the general population seems to be suboptimal, and that chromium is lost through urine as a result of exercise, chromium supplementation may be justified. This is considering the fact that insulin resistance increases with age. However, encouraging a high chromium diet consisting of unprocessed food and establishing a good eating habit should be the primary goal.¹⁷
CHAPTER VIII

VANADYL SULFATE

Not long after the emergence of chromium picolinate, a new supplement called vanadyl sulfate made its "debut" on the ergogenic scene. Research studies demonstrating improved glucose tolerance and decreased muscle loss in diabetic humans and animals led supplement manufacturers and some experts to believe that this compound may also apply to healthy individuals and possibly possess some ergogenic effects. Combined with reports of increased strength, muscle mass, and loss of body fat by athletes using this supplement, it became an instant success in the nutritional supplement industry. Some research experts believe that vanadyl sulfate works much in the same manner that chromium picolinate does to decrease body fat while increasing strength and muscle mass.\textsuperscript{10}

Roles and Functions

Vanadyl sulfate is a form of vanadium which is presently being researched in regard to its ergogenic effects. Vanadium is present in most body tissues and is necessary for the proper development of bones, cartilage, and teeth. It is also believed to be important for iron metabolism and red cell growth.\textsuperscript{12}
Although studies have been done on humans, effects of vanadium on rats have been well documented. Research has shown that vanadium can improve glucose tolerance and reduce muscle loss in diabetic rats. Also, studies using vanadyl sulfate have been shown to maintain normal metabolic state in diabetic animals several months after the cessation of vanadyl supplementation. Two theories have been proposed in explaining these effects. First, it is believed that vanadium improves the efficiency of insulin much in the same way that chromium does. On the other hand, vanadium may function not only by enhancing insulin efficiency, but by also mimicking the actions of insulin independently.\textsuperscript{10,22,23}

Whatever the mechanism, the result is increased shuttling of glucose and amino acids into muscle cells which may account for the marked improvement in the diabetic rats. This has led some to believe that vanadium supplementation may also work with humans. As a matter of fact, some physicians prescribe the use of vanadium to treat mild forms of diabetes.\textsuperscript{10,22}

This year, the first study on the effects of vanadium supplementation in diabetic humans was performed. Subjects (Type I/Type II) took 125 mg of sodium metavandate (form of vanadium) daily for two weeks. Results demonstrated increases in insulin sensitivity and glycogen synthesis in both type I and type II diabetic subjects. A similar study was done by Dr. Luciano Rosetti from the Diabetes Research Center at The Albert Einstein College of
Medicine using 100 mg of vanadyl sulfate instead of sodium metavandate.\textsuperscript{23,24} The data indicated an increase in insulin sensitivity after two weeks of vanadyl supplementation. Also, insulin sensitivity continued to increase even after vanadyl supplementation was discontinued. This may indicate a sustained effect of vanadyl sulfate and also a build-up or storage of this mineral within the body. This sustained effect of vanadyl was also demonstrated in several research studies done on animals. These animals demonstrated a sustained effect of up to 13 to 16 weeks after vanadyl supplementation was discontinued.\textsuperscript{23,24}

Another interesting effect found in Dr. Rossetti's study was an increase in the affinity of skeletal muscle glycogen synthetase, the glycogen synthesizing enzyme. There was a 50\% increase in the affinity for this enzyme which suggests that glycogen synthesis would operate more efficiently when glucose enters the muscle cell.\textsuperscript{24}

In contrast, a recent study which used vanadyl sulfate on diabetic rats found that the improvement in these rats was not solely a result of glucose shuttling into muscle cells. Rather, lowered blood glucose concentrations were shown to be a major result of a mere suppression in appetites of diabetic rats. This may also result in a loss of body fat which is often seen in vanadyl research.\textsuperscript{22,23}

However, there is some question regarding this particular study. This food-intake study was done on insulin resistant rats and found that the vanadyl
treated rats experienced greater improvements than the placebo group. Although food intake was less, how could the rats possibly get better without an improvement in glucose disposal and glucose tolerance? In other words, how could diabetic or insulin resistant rats get better without enhancing insulin efficiency and decreasing insulin resistance? Remember that diabetes is a result of reduced insulin and insulin efficiency. This study did not even look at the effects of glucose disposal and glucose tolerance. Perhaps, when looked at, conclusions about vanadyl's effects may differ.\textsuperscript{23}

**Toxic Effects**

Vanadium supplementation has recently been criticized for its potential side effects. These experts often refer to several studies which have used vanadium supplementation on diabetic animals and claim that these animals died as a result of vanadium toxicity. They neglect to realize that the doses used in these studies were extremely high. In comparison, these doses are 20 times the recommended dose for an adult human which is equal to about a one-gram dose.\textsuperscript{10,23,24}

Studies on vanadium supplementation in humans has been studied for over 30 years. These studies have showed that controlled vanadyl supplementation to be virtually toxicity free. Two recent studies done on vanadyl supplementation confirm these findings. However, stomach cramps and diarrhea have been reported when high dosages were given.\textsuperscript{23,24}
Studies which have conducted vanadyl supplementation for a period of one year have demonstrated an almost 4.5 times decrease in death rate for vanadyl treated diabetic rats. Also, several animal studies have shown that vanadium complexes, such as vanadyl sulfate, may have anti-cancer effects.\textsuperscript{24} Although recommended doses (25-30 mg/day) of vanadyl appear to be safe and well tolerated, further studies are needed to prove its safety and effectiveness.\textsuperscript{10,24}

Conclusion

According to studies, vanadyl sulfate appears to be effective and safe in diabetic humans. As to whether or not vanadyl sulfate will produce the same degree of effectiveness in non-diabetic humans remains to be seen. Also, no studies have been conducted in regard to increased strength, muscle mass, and loss of body fat.

According to the available human research, vanadyl sulfate appears to be the best form of vanadium since it is more tolerable than other forms and equally as effective. As far as dosages, 25 to 30 mg/day seems to be effective and safe. Many supplement companies are marketing vanadyl sulfate in liquid form. This, however, can be highly toxic because it is in an unstable unpolymerized form. It would have to be kept in a highly acidic solution to prevent the formation of oligomers (small chains); this can be harsh on the mouth as well as the stomach. This form of vanadyl sulfate is not recommended.\textsuperscript{23,24}
A new form of vanadium called bis (maltolato) oxovanadium (BMOV) is currently being researched. This is vanadyl sulfate complexes combined with maltol, a natural food additive. Studies are showing BMOV to be twice as effective as vanadyl sulfate with a broader safety margin. Results of these research remain to be seen. It is also not licensed for use at this time. Beware of companies trying to market BMOV; this is presently not at all possible.²⁴

The area of vanadyl supplementation is in its beginning stages. More studies on non-diabetic and weight-trained individuals are needed. Perhaps only then can we determine if vanadyl truly possesses an ergogenic effect.
CHAPTER IX

CREATINE MONOHYDRATE

Although relatively new to the nutritional supplement market, creatine monohydrate has become quite popular among both strength and endurance athletes. In fact, it was used by many of the British athletes at the Barcelona Olympics. There are also reports that the Russian and Bulgarian athletes have used creatine in past Olympics.\textsuperscript{25,28}

Its advertised claims consist of increasing creatine phosphate levels, thereby increasing energy and stimulating muscle growth.\textsuperscript{25,26}

What is Creatine?

Creatine is a naturally occurring amino acid and a natural constituent of many tissues in the body. It is manufactured by the kidney, liver, and pancreas and can be made from two amino acids, glycyglycine and arginine. Both skeletal and cardiac muscles contain fairly high concentrations of creatine. In fact, 98% of the creatine pool is found in the skeletal muscles. Also, it can only be replaced at a rate of 20 mg/kg/day.\textsuperscript{25,27,29}

After being synthesized, it is transported to other tissues, such as the skeletal or cardiac muscles. In the muscle, creatine is converted to creatine phosphate (CP) which is a high energy compound stored in muscles. CP
serves as an instant energy reserve donating its phosphate to ADP and, in turn, producing ATP, an energy-rich substrate used for muscle contraction.\textsuperscript{25-27}

CP also serves to absorb hydrogen ions released by lactic acid. This reduces the acidity of lactic acid which builds up during intense physical activity.\textsuperscript{25,27}

It is interesting to know that there is a constant conversion of creatine to creatinine which is of no use to the muscle and is excreted out through the urine. Both raw meat and vegetables contain fair amounts of creatine, but cooking tends to destroy a majority of it.\textsuperscript{25}

**Proposed Mechanism**

Researchers believe that creatine supplementation can increase the creatine content of the muscle and, in turn, increase creatine phosphate (CP) levels. If this idea is true, then there would be more available energy to the muscle. This is especially beneficial for activities consisting of high intensity short bursts.\textsuperscript{25}

More CP in the muscle cell would also mean an increased buffering capacity of lactic acid. This results in a greater resistance to fatigue. This is very beneficial to endurance athletes. Basically, the higher your muscle creatine levels are, the better off you are in competition.\textsuperscript{25,27}
A study done on trained athletes showed that creatine supplementation reduces fatigue significantly. Subjects in this study were also able to perform at their near maximum for longer periods of time.\textsuperscript{25} One recent study showed that oral supplementation of creatine monohydrate increased the creatine content in the muscle. Also, increases in muscle strength, lean body mass, and improved performance were also noted. Dosages that were used in this study consisted of 20 to 25 g per day for six days. Researchers for this study believe that the improvement in performance could be due to an increased synthesis of contractile protein or greater water retention.\textsuperscript{26}

Another recent study done on middle distance runners demonstrated that oral supplementation of creatine monohydrate in doses of 5 mg six times per day for six days significantly improved performance. Compared to the placebo group, improvements were two to three times greater in the creatine group.\textsuperscript{28}

To further prove the link between creatine monohydrate supplementation and increased performance, a study was done at Karolinska Institute. In this study, scientists supplemented 17 individuals with 20 to 30 g of creatine monohydrate for two or more days. Doses were again given in 5 g doses four to six times per day. Results showed a large rise in plasma creatine within an hour of supplementation. This means that the creatine was not broken down in
their digestive systems, but rather absorbed into the blood stream. Creatine levels in the muscle were also boosted by as much as 50 to 60%.28

Individuals in this study underwent an exercise program to see if exercise promoted creatine uptake by muscle. Results demonstrated that exercise can increase creatine uptake by 11%. This could be due to the increased blood flow to the muscles during exercise or the changing rate at which muscle obtains creatine from the blood.28

Uses

Most researchers feel creatine supplementation is useful mainly in short, high intensity activities, such activities as weight-lifting, sprinting, and ice hockey. Although most physiologists agree that CP is useful mostly in short events, there is evidence that high concentrations of CP may help endurance athletes. The reason for this is that CP carries energy out of the mitochondria into the muscle cells.25,28

Mitochondria are units inside muscle cells which provide energy from carbohydrates and fats. However, this energy is useless inside the mitochondria. This energy needs to be transported out of the mitochondria to contractile proteins. CP assumes the role as the transporter and brings the energy out of the mitochondria. Since this energy transport occurs at a high rate during endurance activities, high CP levels can be very beneficial.28
Toxic Effects

Although current studies reveal no side effects with creatine supplementation, some experts feel that doses of 20 to 30 mg per day is a huge dose. There may also be some long-term side effects that are not yet known. Also, a note of caution to those who believe in the theory of the more the better. Taking mega doses in the area of 40 to 60 mg could be very dangerous.28

Creatine is removed by the kidneys through diffusion and requires no energy for this process to take place. Creatine supplementation in the recommended doses contain minimal risk to a healthy individual.

Supplementing with Creatine

The big question is what the appropriate doses are of creatine supplementation in order to obtain an ergogenic effect.

First, it is vital to remember two important points. First, human muscle has a creatine content upper limit of 15 to 160 mmol/kg of dry muscle with the norm being 125. Therefore, those individuals with a creatine content at this level cannot exceed this limit no matter they supplement with creatine monohydrate. Individuals with high CP levels cannot expect to receive much benefit from creatine supplementation.29

On the other hand, individuals with low creatine contents, in the area of less than 120 mol/kg dm, can expect to have a 40 to 50% increase in creatine levels with oral supplementation of creatine.29
Secondly, muscle creatine stores remain elevated for several weeks following creatine supplementation. Therefore, ingesting creatine for prolonged periods if time is useless, not to mention a waste of money since a week’s supply of creatine monohydrate costs anywhere from $30 to $40. Also, creatine absorption by tissues are highest at the initial days of supplementation.\textsuperscript{29}

According to the available information, there is no doubt that creatine supplementation can increase performance. However, further studies on creatine are needed to determine any long-term effects and confirm its proposed effectiveness. Creatine monohydrate is also very expensive, costing anywhere from $40 to $80 for a two-week supply.\textsuperscript{25,28,29}
CHAPTER X
CONCLUSION

As you can see, there is a lot to be considered regarding the use and effectiveness of ergogenic aids. There are many more ergogenic aids out there; in fact, too many to include within this paper. What I have gone over within this literature review are those aids which are presently being marketed and popular among athletes.

Many supplements marketed as ergogens offer no scientific evidence to support their claims. Despite this, the use of these ergogens remains widespread. Also, a lot of the ergogenic aids out there may pose long-term health related risks which are not yet known to researchers.

The use of ergogenic supplements should be tailored to the athlete's nutritional need and sport. Haphazard use of these and other ergogenic aids can be dangerous and detrimental to your performance.

Let us not forget the fact that there exists ergogens which, in fact, offer an ergogenic effect. However, studies on ergogenic aids are very young, and it is only now that we are beginning to understand the functions and roles of ergogens as well as other possible compounds. More well controlled studies are needed to determine the effectiveness and safety of ergogenic
supplements. Also, effective and precise nutritional information should be made available to athletes and the general population. Proper education on ergogenic aids and nutrition can be useful and money-saving for the athlete. Lastly, never forget the fact that without hard work and proper rest, no ergogenic aid will let you reach your full potential.
REFERENCES


