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The Use of Ergogenic Aids in Athletes

Sheri L. Mounteer
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THE USE OF ERGOGENIC AIDS IN ATHLETES

By

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Bachelor of Science in Physical Therapy
University of North Dakota, 1995

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
May
1996
This Independent Study, submitted by Sheri L. Mounteer 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)
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Title The Use of Ergogenic Aids in Athletes

Department Physical Therapy

Degree Master of Physical Therapy

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Thanks to the faculty, and especially Tom Mohr for all your extra time, hard work, and help with this paper.

Last, but definitely not least, to all my good friends and especially my roommates - thanks for all the great memories that I will cherish forever and keep close to my heart. Without you, PT school would not have been the same. May we always keep in touch, and after graduation when we all go our separate ways, just remember one thing:

Make new friends, but keep the old.

Those are silver, these are gold!
ABSTRACT

Ergogenic aids are substances purported to enhance athletic performance or improve exercise capacity. The use of ergogenic aids in sports is very widespread. It is common for a physical therapist working in a sports clinic to have patients that are either considering using or using ergogenic aids. Use of these aids by patients being treated might affect the patients' response to treatment. Therapists should be able to recognize the signs of ergogenic aid abuse in individuals under their care, and they should be aware of the side effects of these aids. It is also important for therapists to be able to educate and give accurate information to any of their patients who are contemplating ergogenic drug use. Whether ergogenic drugs can actually produce meaningful changes in performance is often debated. Some sources say that ergogenic drugs may potentially affect individual physiological components of performance. Yet other sources state that there is no evidence that nutritional supplements taken in excess of daily requirements will improve physical performance.

The purpose of this paper is to review some of the different ergogenic drugs, their purported effects on performance, and their potential adverse effects.

The procedure being used to perform this study will be a literature review of nutrition for the athlete, and various ergogenic aids. This paper will aid physical
therapists in the awareness of ergogenic aid use, and give some information to pass on to their patients that may be interested in their use.
CHAPTER 1

INTRODUCTION

Sports have become increasingly popular and more competitive in the last few years. The stakes for succeeding in athletics are more serious, including athletic scholarships for college, million dollar salaries in the pro's, and increased demand of today's society to win and "be the best". As a consequence, athletes, coaches, and trainers have searched for ways to improve performance. "In a sporting world in which competitions are won by margins as small as one-hundredth of a second and the best athletes can earn millions of dollars a year, some athletes have turned to various 'ergogenic aids' in an attempt to gain a competitive advantage"(1).

Ergogenic aids are substances purported to enhance athletic performance or improve exercise capacity (1). Some ergogenic aids, such as anabolic steroids and human growth hormone, although shown to increase muscle mass and strength, have been found to be potentially dangerous, not to mention illegal (1,2). Consequently, many athletes are taking more natural ergogenic aids, or nutritional supplements, in hopes of benefiting without threatening their health or eligibility for competition. "An ergogenic nutritional supplement is believed to increase performance either by renewing or increasing energy stores in the body, facilitating
the biochemical reactions that yield energy, modifying the biochemical changes contributing to fatigue, or maintaining optimal body weight" (1).

Attempts to gain competitive advantages over competitors is not a new phenomenon. Herbs and mushrooms were consumed by ancient Greek Olympic athletes in attempts to improve their performance (3). In the 19th century, the French drank a mixture of coca leaves and wine, which reportedly reduced fatigue and hunger sensation during prolonged activity (4). Stimulant use was suspected at the Olympic Games in 1952, anabolic steroid use was widespread in the 1964 Olympics, and at the 1983 Pan-American Games, 19 athletes were disqualified for drug use.

Only recently has the epidemiology of drug misuse among athletes been examined (3). In 1983, researchers at Michigan State University conducted a study looking at the substance abuse habits of collegiate athletes. The study surveyed athletes from five men's and five women's sports, participating at all levels of competition. The results showed that student athletes abused a variety of ergogenic and recreational drugs and in most cases began drug use before entering college (3). Another study showed that 40-67% of the American population report some use of nutritional supplements (7). Belief in direct ergogenic benefits from supplements was also found to be wide-spread among a group of high school athletes, with the majority (>60%) reporting that they believed that vitamin supplements are effective in improving performance, and that there is little or no risk attached to their use (7). "Generally, three types of logic are advanced by athletes
in support of their supplement use: to compensate for less than adequate diets or lifestyles; to meet unusual nutrient demands induced by heavy exercise; and to produce a direct (ergogenic) effect on performance" (7).

Nutritional supplements are promoted through unsubstantiated claims by magazine advertisements, health food stores, coaches, and other sources (1). The FDA (Food and Drug Administration) considers nutritional supplements to be foodstuffs, not drugs, and therefore has not required that they be proved safe and effective (1). Dosage guidelines are inadequate and quality control is poor. The FDA has begun to revise regulations governing labeling and health claims for these products.

The IOC (International Olympic Committee) and the NCAA (National Collegiate Athletic Association) has lists of banned substances. According to the IOC, ergogenic drug use is defined as "the administration of or use by a competing athlete of any substance foreign to the body or of any psychological substance taken in abnormal quantity or taken by an abnormal route of entry into the body with the sole intention of increasing in an artificial manner his/her performance in competition" (3).

For a physical therapist working in a sports clinic, it may be very common to have patients that are using ergogenic aids. Use of ergogenic aids by patients being treated might affect the patients' response to treatment (4). Therapists should be able to recognize the signs of ergogenic aid abuse in individuals under their care, and they should be aware of the side effects of these aids. Side effects of
some ergogenic aids can affect heart rate, blood pressure, or other physiologic measures (4). Adolescents and their parents often look to physical therapists providing sports therapy services for information on ergogenic aids. To effectively counsel these parties, it is important that the information disseminated be concise and factual (5). This purpose of this paper is to summarize current concepts regarding some of the more popular ergogenic aids.
CHAPTER 2
NUTRITION FOR THE ATHLETE

Athletes differ from nonathletes in their nutritional requirements (8). Energy requirements vary depending on body weight, height, age, sex, and metabolic rate, and on the type, intensity, frequency, and duration of the sport (9). Proper determination of nutritional needs in athletes requires knowledge of the athlete's body-fat composition and daily caloric expenditure. A balanced diet for athletes consists of 50-60% of calories from carbohydrates (CHO), 10-15% from protein, and 25-30% from fat (8,1). "Endurance athletes, however, should consume 60-70% of their calories from carbohydrates" (9). Other important considerations include adequate intake of vitamins, minerals, and fluids. Proper nutrition is important for all athletes, and can improve performance even for casual, non-competitive athletes (8).

Body Composition:

Lean body mass is the portion of total mass that is composed of muscle, bone, and organs (8). The desirable lean body weight and percentage of body fat tend to vary with different athletic activities. "The average American has 16-24% body fat; the ideal for men would be approximately 15% and for women approximately 22%" (8).
Caloric Needs:

For both aerobic and anaerobic activities, a diet high in CHO's and low in fat meets the demands of highly active muscles (8). Caloric expenditure is related to the intensity and duration of exercises and is influenced by body-surface area, the person's age and sex, and the external environment. The body meets caloric needs through the conversion of fats to fatty acids, protein to amino acids, and CHO's to simple sugars. Glycogen, the body's immediate fuel source, is produced and stored in the liver and in muscle. Glycogen is a form of CHO used to fuel muscle contraction. As glycogen stores are depleted during exercise, endurance and performance plummet.

Muscular Contraction:

Skeletal muscles derive energy for muscular contraction from adenosine triphosphate (ATP). ATP contains high energy phosphate bonds, which release energy when split into adenosine diphosphate (ADP) plus an inorganic phosphate (12). A constant resupply of ATP is generated through the breakdown of CHO's, fats, and protein (12).

Carbohydrates:

"Carbohydrates are the main energy substrate for prolonged endurance exercises at a relatively high percentage of one's aerobic power (greater than 65-70% VO2 max)" (10). CHO's are also the fuel of choice for short-duration, high intensity exercise (11). The body has a limited ability to store glucose, although muscle glycogen levels can be increased both by training and by the habitual
consumption of a high CHO diet. Depletion of muscle glycogen may be one of the factors contributing to the premature onset of fatigue (10). Athletes who eat a normal, mixed diet generally ingest around 300-350 grams of CHO (1200-1400 cal) per day, and up to 500-600 grams of CHO (2000-2400 cal) per day for high endurance athletes (9).

Proteins:

Strength/power athletes have considered protein their most essential nutrient when attempting to accrue muscle mass (10). It is now apparent that protein catabolism can account for 5-10% of energy production during endurance exercises (6).

There are eight essential amino acids that must be provided in the diet (12). Amino acids from the amino acid pool may be catabolized for energy needs, stored as fat, utilized for protein synthesis, or contributed to nonprotein nitrogen needs of the body (12).

In addition to normal needs, proteins are important in sports nutrition in three areas: endurance, strength training, and muscle fiber repair (12). The protein requirements of athletes are controversial. The recommended daily allowance (RDA) for the average adult has been established at 0.8 grams per kg of body weight per day (1). However, a number of sources indicate that athletes, especially those in endurance sports and weight training, require more dietary protein, ranging from 1.0-2.3 g/kg/day (1,8,9,11). Athletes may require slightly more protein than sedentary people to maintain positive nitrogen balance (1,9).
Fats:

Fats represent the major source for muscular energy at low intensities, and training enhances the ability to metabolize fats for muscular energy during exercise (6). Fat should not be excluded from the diet because it is an essential energy source, particularly when exercise continues beyond twenty minutes (1). Dietary fat should however be limited to 30% or less of total caloric intake; no more than 10% being derived from saturated fatty acids (1). A high fat content has been linked to health problems, as well as reduced endurance. Even persons with very low body fat store huge amounts of energy as triglycerides in intramuscular and adipose tissue deposits that can be used as energy.

Vitamins and Minerals:

"Adequate vitamin and mineral status is a requirement for optimal sports performance, since many of the micronutrients play a key role in exercise metabolism, recovery, and adaptation" (7). There is a general agreement that a deficiency of at least some of the vitamins will impair work performance (7). Athletes who consume low energy intakes and/or restricted food variety may consume suboptimal intakes of micronutrients. A daily multivitamin is thought to be beneficial to this type of athlete. "In general, an athlete's vitamin and mineral requirements are met by a well-balanced diet that meets all the RDA's" (1).
Carbohydrates role in the body:

Researchers have suggested that fatigue during periods of intense training may be related to a gradual depletion of muscle glycogen stores due to lack of availability of CHO in the diet or an inability to fully replenish muscle glycogen stores during intense training (13). Consequently, it has been generally recommended that athletes involved in intense training increase dietary availability of CHO in an attempt to maintain muscle glycogen stores, lessen symptoms of fatigue, and maintain performance capacity (13). The mechanism of increased CHO consumption during exercise has been thought to be the increased availability of glucose in the blood to replace that utilized by muscles during exercise (14).

Carbohydrate loading:

Currently, CHO loading involves increasing the muscle glycogen stores through high-CHO intake during a period of reduced exercise for several days before an event. Six days before competition, the athlete exercises hard (70-75% aerobic capacity) for 90 minutes. On that day and for the next two days, the athlete consumes a normal diet providing 50% CHO. On the second and third days, training is decreased to 40 minutes at 70-75% of aerobic capacity. On the next two
days, the athlete consumes a high-CHO diet providing 70% CHO and reduces training to 20 minutes at 70-75% of aerobic capacity. On the last day, the athlete rests while maintaining the high-CHO diet (6,9) (Table 1).

Table 1. Carbohydrate Loading Program (from Berning & Steen⁹).

<table>
<thead>
<tr>
<th>Day</th>
<th>Exercise Duration</th>
<th>Dietary CHO</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>90 min.</td>
<td>60%</td>
</tr>
<tr>
<td>2</td>
<td>40 min.</td>
<td>60%</td>
</tr>
<tr>
<td>3</td>
<td>40 min.</td>
<td>65%</td>
</tr>
<tr>
<td>4</td>
<td>20 min.</td>
<td>70%</td>
</tr>
<tr>
<td>5</td>
<td>20 min.</td>
<td>70%</td>
</tr>
<tr>
<td>6</td>
<td>Rest</td>
<td>70%</td>
</tr>
<tr>
<td>7</td>
<td>Competition</td>
<td>---</td>
</tr>
</tbody>
</table>

Carbohydrate loading enables the athlete to maintain high-intensity exercise longer, but will not affect pace for the first hour and a half of the event. CHO loading will only help athletes who are engaged in continuous endurance exercise lasting longer than 90 minutes. Greater than usual glycogen stores will not enable the athlete to exercise harder during short-duration exercises. In fact, the stiffness and heaviness associated with the increased glycogen stores can hurt performance during shorter events (9).
Carbohydrate intake before exercise:

In the past, athletes have been discouraged from eating on the morning before competition. The rationale is that if any food remains in the stomach at the start of exercise, the athlete may become nauseated when blood is diverted from the gastrointestinal tract to the exercising muscle (9). Therefore, many athletes who compete in the morning simply forego food before exercise. This overnight fast lowers their liver glycogen stores (the body’s main source of blood glucose) and can impair performance if the athlete attempts to train or compete in a prolonged endurance event (longer than one hour) that relies heavily on blood glucose (9).

The available evidence suggests 1-4 grams of CHO per kilogram body weight be consumed 1-4 hours before exercise (9). Good examples of solid high-CHO foods for pre-exercise meals include fruit, grains, yogurt, and fruit juices.

Carbohydrate intake during exercise:

Carbohydrate feedings during endurance exercise lasting longer than 90 minutes may enhance endurance by providing glucose for the muscles to use when their glycogen stores have dropped to low levels.

One study measured the effects of CHO feedings on the onset of fatigue and decrease in work capacity of cyclists (9). The CHO feedings enabled the cyclists to exercise an average of 33 minutes longer before reaching the point of fatigue. The available evidence suggests that athletes should take in 25 to 30 grams of CHO (100-200 cal) every half hour (9). CHO replenishment during exercise is most easily achieved by consuming commercially available sports drinks (6).
Carbohydrate feedings after exercise:

The restoration of glycogen stores after strenuous training is important to minimize fatigue associated with repeated days of heavy training (9). Glycogen repletion occurs faster immediately after exercise because the blood flow to the muscles immediately after exercise is much greater, and the muscle cell is more likely to take up glucose (9).

Athletes therefore should consume CHO's immediately after exercise. Delaying CHO intake for too long after exercise will reduce muscle glycogen storage and impair recovery. The available evidence suggests taking in 100 grams of CHO (400 cal) within 15 to 30 minutes of exercise and additional 100 gram feedings every two to four hours thereafter (8). Sports drinks are very useful since most athletes aren't hungry immediately after exercise.

Simple vs. complex Carbohydrates:

A big question athletes always ask is does the type of CHO (simple or complex) have an effect on muscle glycogen storage? The research is not clear on this issue (9). One study compared the effects of simple and complex CHO consumption during a 48-hour period after a glycogen depleted exercise (14). During the first 24 hours, no differences were found in muscle glycogen synthesis between the two types of CHO. At 48 hours, however, the complex CHO (starch) diet resulted in significantly greater muscle glycogen synthesis than the simple CHO (glucose) diet. However, in another study with similar comparisons, these findings were not replicated.
An advantage of complex CHO is that they are more nutrient dense. They provide more B vitamins necessary for energy metabolism and more fiber and iron, thereby contributing to a nutritionally balanced diet (9).

Other forms of carbohydrate supplementation:

Some athletes train so heavily that they have difficulty eating enough food to obtain the amount of CHO needed for optimum performance. The stress of hard training can decrease appetite. Also, consuming a large volume of food can cause gastrointestinal distress and interfere with training. Last, the athlete may be spending so much time training that there are few rest hours available for replenishment. Athletes who have difficulty consuming enough CHO may want to use a commercial high-CHO supplement (9). These supplements are usually in the form of powder, which when mixed with milk or fruit juices, makes a high-CHO shake. These products do not replace regular food, but are designed to supply supplemental calories and CHO's when needed.

Adverse effects of too much carbohydrate intake:

Carbohydrates cannot be stored in excess of 600 grams (9). Any amount beyond this is usually not of any concern, except possibly weight gain. Precautions in consuming high-CHO diets, however, should be noted for children, adolescents, or athletes with diabetes or hypertriglyceridemia (12).

Studies supporting carbohydrate supplementation:

One study's purpose was to determine the effects of CHO supplementation during intense training on dietary patterns, psychological status, and markers of
anaerobic and aerobic performance (13). Seven members of the U.S. National Hockey Team were matched to seven team counterparts. One group was blindly administered a CHO drink containing 1 gram per kilogram of CHO four times daily, while the remaining group blindly ingested a flavored placebo during seven days of intense training. Results revealed that the CHO-supplemented group had a greater total energy intake, CHO intake, and change (pre vs post) in time to maximal exhaustion following training while reporting less post-practice psychological fatigue (13). However, CHO supplementation during heavy training did not appear to affect overall psychological status, physiological responses to incremental maximal exercise, or selected tests of anaerobic performance capacity.

Another study of CHO loading compared the exercise time to exhaustion at 75% of VO2 max after three days of three diets varying in CHO content: a low-CHO diet (less than 5% CHO calories), a normal diet (50% CHO calories), and a high-CHO diet (82% or more CHO calories) (9). The low CHO diet provided muscle glycogen stores that sustained only one hour of exercise. The normal diet sustained 115 minutes of exercise. The high CHO diet provided muscle glycogen stores for 170 minutes of high-intensity exercise (9).

In summary, available research has demonstrated ergogenic benefits from ingestion of increased amounts of CHO, whether it be in the form of CHO loading, a CHO rich diet before exercise, CHO supplementation during exercise, or CHO replenishment following exercise (6).
CHAPTER 4

CAFFEINE AS AN ERGOGENIC AID

Caffeine is the most widely used drug known today (15). Approximately 80% of the adult population in the United States consumes coffee or tea daily (4). Caffeine’s prevalence in society also means that it is routinely consumed by sports competitors. Caffeine has been reported to be an important ergogenic supplement to exercise (16). Caffeine has been proposed to increase performances during prolonged continuous endurance exercise and high-intensity intermittent exercise (15,16).

Physiological effects of caffeine:

There are a couple major theories for the ergogenic effect of caffeine during exercise. The first theory involves caffeine blocking adenosine receptors in the central nervous system (CNS). This blockage facilitates the release of neurotransmitters. The resultant CNS stimulation may increase mental alertness and reduce the perception of fatigue (3). After consumption, caffeine is completely absorbed from the gastrointestinal tract and reaches peak blood levels in approximately 30 to 60 minutes (4). Caffeine enters the brain quickly after absorption, thus producing the rapid alertness noted after consumption.
The most popular theory for the endurance enhancing effect of caffeine is that it spares glycogen by increasing fat metabolism, as well as reducing CHO metabolism (12). Caffeine or a caffeine metabolite may mobilize free fatty acids (FFA) from adipose and/or intramuscular stores indirectly by increasing circulating epinephrine or directly by antagonizing adenosine receptors that normally inhibit FFA mobilization (15). The greater FFA availability increases muscle fat oxidation and decreases CHO oxidation, presumably improving performance in exercise situations where CHO availability limits performance (15).

Studies examining ergogenic efficacy:

Studies examining the ergogenic effect of caffeine have produced mixed results (4). Differences in the quantity and timing of caffeine administration, variations in exercise protocols and subject nutritional status, and inconsistency in the subject's normal caffeine consumption (tolerance to caffeine) have likely produced this disparity (4).

Costill et al. (17) found that elevated plasma FFA levels in seven cyclists who ingested 330 mg of caffeine resulted in a 40% decrease in the rate of muscle glycogen depletion (4,15,17).

Flinn et al. (18) studied the effects of a 10 mg/kg body weight caffeine dose given three hours prior to an incremental cycle ergometer test in nine male caffeine naive subjects. Subjects worked longer, performed more work, and exhibited higher FFA levels in the caffeine trial than during control or placebo trials. The authors
concluded that caffeine was ergogenic when taken three to four hours prior to exercise in fasting subjects with diets normally low in caffeine (4,18).

Another study studying caffeine consumption in athletics controlled for pre-experimental diet, training status, caffeine dose, and experimental exercise modality and intensity. The ergogenic effect of a high dose of caffeine (9mg/kg body weight) was demonstrated with elite runners who ran and cycled at about 85% VO2 max (Fig.1) and with recreational cyclists who cycled at about 80% VO2 max (15).

Figure 1. Performance times for subjects running and cycling to exhaustion following either caffeine or placebo ingestion (after Spriet15)

Trice and Haymes (16) studied the effects of caffeine ingestion on exercise-induced changes during high-intensity, intermittent exercises (16). Eight male subjects ingested either caffeine (5mg/kg body weight) or a placebo one hour prior to exercise at 85-90% of maximum workload. Subjects were encouraged to
complete three 30-minute intermittent cycling periods. The time to exhaustion was significantly longer during the caffeine trial than during the placebo trial. Serum FFA levels were significantly greater during the caffeine trial than the placebo trial (16).

In contrast, Tarnopolsky et al (19) concluded that a 6mg/kg caffeine dose administered 60 minutes prior to exercise in six habitual caffeine consumers had no potential ergogenic effect. Caffeine administration increased plasma FFA levels prior to and during exercise, but did not change oxygen consumption, heart rate, respiratory exchange ratio, or rate of perceived exertion (4,19).

Titlow et al. (20) also found no ergogenic benefit from ingesting 200 mg of caffeine prior to a treadmill test in five male subjects. The authors found no difference in performance or substrate utilization. Information on the caffeine habits of subjects in this study was not provided (4,20).

In summary, while the relationship between caffeine use and performance is not clear, there is an indication that caffeine can spare muscle glycogen and increase oxidation of intramuscular fat in some caffeine-naive, trained individuals, leading to improvement in performance or work output during long-term endurance running or cycling (6).

Adverse Effects:

Excessive caffeine usage can produce anxiety, irritability, restlessness, nervousness, diarrhea, insomnia, and, with higher doses, heart arrhythmias, mild hallucinations, hypertension, and cholesterol abnormalities (3,12,15). As a diuretic, caffeine can decrease the body's water level, limiting the athlete's cooling ability.
**NCAA and IOC guidelines:**

Because of caffeine's potential ergogenic effect, the International Olympic Committee and the NCAA have banned the use of high doses. A urinary caffeine concentration of 12mg/ml is considered a positive result under IOC standards. The NCAA cut-off point is 15mg/ml.

Over a two to three hour period, a dose of 100 mg of caffeine will result in a urine concentration of 1.5 mg/ml. Thus 800 mg of caffeine, which could be obtained from five to six cups of strong coffee, could exceed the legal limit (9).

**Dose suggestions:**

Guidelines for caffeine ingestion to enhance endurance performance in trained, non-caffeine drinking individuals are 200-300 mg, equivalent to two to three cups of coffee one hour before and event (6).

Anyone contemplating using caffeine during competition should use moderate caffeine doses and should experiment with caffeine prior to competition.
CHAPTER 5

CHROMIUM PICOLINATE AS AN ERGOGENIC AID

In today's world of athletics, many competitors believe that supplementation of specific vitamins and minerals will enhance performance and provide the competitive edge for success (9). Chromium is an essential trace mineral, believed to increase lean muscle mass while promoting fat loss (1). Many advertisements for chromium supplements promote them as a safe, undetectable alternative to anabolic steroids.

The RDA for chromium is 50-200 mcg/day (1). Good dietary sources of chromium are raw nuts, whole grains, brewer's yeast, cheese, mushrooms, black pepper, prunes, molasses, asparagus, wine, and beer (1). In a survey of one U.S. city, it was found that the average daily chromium intake was 25 and 33 mcg/day for men and women respectively (1,21). Researchers suggested that up to 90% of the general population may have a deficient chromium intake (1).

In a study of nine male runners, Anderson et al. (22) found that strenuous exercise resulted in marked mobilization of chromium from body stores, serum chromium concentration was elevated after the subjects completed the run (1,22). The authors also reported that urinary chromium excretion was significantly increased on exercise days compared with non-exercise days. Most chromium that
is mobilized from tissue stores is eventually excreted in the urine, since the rate of reabsorption of chromium is less than 5% (1). From these studies, the authors conclude that athletes require more chromium than sedentary individuals.

**Physiological effects of Chromium:**

"Chromium functions in carbohydrate and lipid metabolism and in glucose homeostasis by potentiating the effects of insulin" (23). Insulin is responsible for transporting blood-borne sugars and amino acids into cells and regulating protein metabolism and protein synthesis (23). Primarily because of its role in protein synthesis, chromium has been touted as a supplement that will enhance muscle building during strength training (23). Chromium has also been promoted to reduce body fat. Chromium sensitizes insulin-sensitive gluco-receptors in the brain - notably those in the ventromedial hypothalamus (VMH). The VMH glucoreceptors are activated by glucose in the presence of insulin, and exert effects relevant to weight control - controlling appetite and activating the nervous system to stimulated thermogenesis (24). These central effects of efficient insulin activity would tend to promote a more negative caloric balance (24). Moreover, chromium supplementation may be important for athletes since the dietary intake of chromium for the general population is so low, and being an athlete makes a person more at risk since exercise decreases chromium stores in the body.

In an effort to produce an effective transport form of chromium, chromium picolinate has been produced (24). This is the form that supplemental chromium is sold in the stores.
Studies of Chromium efficacy:

Evans, a chemistry professor at Bemidji State University, administered 200 mcg of chromium picolinate daily in two separate studies on collegiate weightlifters (25). The first study found significant increases in lean body mass for the supplemented group, compared to a placebo group (+2.2 vs +0.4 kg), and less body fat percentage (0.0 vs +1.1%) after forty days (6,25). Ten total subjects attending a weight-lifting class twice weekly served as subjects. The second study divided 31 football players in a supervised weightlifting program for six weeks into two groups. The supplemented group received 200 mcg of chromium picolinate daily, and compared to the placebo group, showed larger gains in lean body mass (2.6 vs 1.8 kg) and greater decreases in body fat percentage (3.6 vs 1.2%) (6,25). These studies, however, have been accused of having inadequacies (1). The methods used to measure body composition are not reliable for research purposes, dietary intake and other exercises were not well controlled for, and pre-trial chromium status was not established (1).

A study on males and females enrolled in a weekly aerobic class for 12 weeks was also done by Evans (26). The group was divided into two groups, with one group receiving placebo and the other 200 mcg (females) or 400 mcg (males) of chromium picolinate per day. Lean body mass increased 1.8 kg in females and 2.1 kg in males receiving chromium picolinate compared to .6 kg in females and .7 kg in males receiving placebo (26).
Results from seven other completed studies in subjects ranging from exercising young people to overweight volunteers, demonstrated a modest trend toward increased lean mass, but an even more striking reduction in body fat (24). For example, in overweight volunteers not asked to participate in any specific diet or exercise program, an average of 4.2 pounds of fat were lost during ten weeks of supplemental chromium picolinate - as compared to only .4 pounds lost during the crossover placebo period (24).

Clancy et al. (23) studied the effects of nine weeks of daily chromium picolinate supplementation (200 mcg) in football players during the off-season strength-training program (23). The results of the study showed that 200 mcg of chromium picolinate increased urinary excretion by five times. Despite the increased chromium intake, the results suggested that chromium supplementation was ineffective in bringing about changes in body composition or strength during spring training (23). There were some problems with this study, however. The strength testing procedures were not specific to the training the football players were undergoing. There was no control on whether the players came to the lab in a rested (i.e., not post-exercise) condition (23).

Although most all of these studies have some flaws, they suggest that chromium may have desirable effects for weightlifters (6). However, at this time, whether a true ergogenic effect of chromium or simply repletion of marginally deficient states was observed has not been differentiated (6). One source states, "There is no reliable evidence that supplementation with chromium picolinate is"
beneficial for muscle growth" (9). Another source states, "Because of the need for safe alternatives for anabolic steroid abuse, safety of chromium supplements, benefits seen in preliminary studies, an attractive mechanism of action, potential losses of chromium due to exercise and sweating, and possible widespread dietary deficiencies or imbalances of chromium for the entire U.S. population, further attention should be focused on chromium as a potential ergogenic aid for weightlifters" (6).

**Adverse effects:**

There is essentially no literature on acute toxicity with dietary chromium, other than mild gastrointestinal disturbances (27). In chronic oral toxicity tests with chromium picolinate, no adverse effects have been observed (24).

Aside from potential toxicities, possibly the real threat to athletes from supplemental abuse is the unrealistic expectation associated with their use, leading athletes to ignore the importance of a balanced diet, adequate rest, and proper training (9).

**Recommended supplemental dose**

Currently, no guidelines for chromium supplementation as an ergogenic aid are substantiated (6). To date, clinical studies have used 200 or 400 mcg chromium daily; but no studies have compared the efficacy of various dose levels (24).
CHAPTER 6

CREATINE AS AN ERGOGENIC AID

Creatine is an amino acid (methylguanidine-acetic acid) that occurs naturally in the diet, being present in meat and fish (28). The normal daily intake is less than one gram, but the estimated daily requirement for the average individual is about two grams (28). In addition to being present in the diet, creatine is endogenously synthesized by the liver and pancreas, with the primary site being the kidney (28,29). Ninety-five percent of the body creatine pool is found in skeletal muscle, in the form of phosphocreatine, ordinarily being present at a concentration of about 125 mmol/kg dm (29).

Recent research has suggested that creatine supplements, taken orally, may increase muscle levels of phosphocreatine and enhance performance (10).

The IOC has not yet added creatine to the list of banned substances, although creatine appears to contravene the doping law because it is taken with the intent of enhancing performance (10). It may be that the IOC will limit the amount that can be consumed, as they have with caffeine. But for now, it is legal for athletes to consume creatine to try and gain a competitive edge over their opponent.
Metabolic role of creatine:

Phosphocreatine (PCr) itself is present in resting muscle in a concentration approximately three to four times that of adenosine triphosphate (ATP), the immediate energy source for muscle contraction (28). When the cellular ATP concentration falls too far, fatigue ensues. Because muscle fatigue is associated with decreased intracellular ATP concentrations, regeneration of ATP at a rate close to that of ATP hydrolysis is essential if fatigue is to be delayed. Transfer of the phosphate group from PCr to adenosine diphosphate (ADP) is catalyzed by the enzyme creatine kinase, resulting in the restoration of ATP and the release of free creatine (C). This is represented as follows:

\[
\text{PCr} + \text{ADP} \rightarrow \text{ATP} + \text{C}
\]

The resting ATP content of muscle is about 24 mmol/kg, but this cannot fall by more than about 30%, so the need for rephosphorylation of the ADP formed during contraction is obvious (28). The PCr store is finite, however, and increasing the PCr content of muscle ought to allow a greater amount of work to be done using this energy source (28). "Creatine/PCr availability is essential to muscle function during short-duration maximal exercise" (29).

Studies of creatine efficacy:

Greenhaff et al. (29) measured the ability of two groups of subjects to complete five bouts of thirty maximal voluntary contractions on an isokinetic dynamometer: half the group then received a placebo and the others received 24g of creatine per day for five days (29). Peak torque did not differ after the placebo
treatment compared with the initial measurements, but the creatine-supplemented group demonstrated significantly improved peak torque production (29).

Harris et al. (32) used a creatine dose of 30g per day for six days and again compared parallel treatment and placebo groups (11,32). The subjects in their study were trained runners and two different exercise tests were conducted on separate days. One test consisted of four 300-m runs with a four minute rest between runs, and the other test consisted of four 1,000-m runs with a three minute rest between runs. The results showed a significant benefit of creatine supplementation: at the 300-m distance the improvement was only statistically significant for the last run of the set; at the 1,000-m distance the total time for all four runs improved by a mean of 13.0 seconds (28).

In the study of Birch et al. (31) two groups of seven healthy male subjects performed three bouts of maximal isokinetic cycling at 80 revolutions/minute before and after creatine or placebo ingestion (4 x 5g of creatine daily for 5 days) (29,31). Each exercise bout lasted for thirty seconds and was followed by four minutes of rest. The total amounts of work performed during bouts 1-3 were similar when values were compared before and after placebo ingestion. After creatine ingestion, work output for each of the seven subjects was increased during exercise bouts one and two, but no difference was observed during exercise bout three (29). The lack of an effect of creatine on performance during the third bout of exercise was unexpected (31). However, it is possible that fatigue at this stage of exercise is unrelated to energy substrate availability (31). The present results demonstrate that
"Creatine loading" is achievable in normal healthy individuals, however, they also suggest that increases may be most dramatic in those individuals with the lowest pre-feeding creatine level (30). It was postulated in this study that the observed ergogenic effect may have been the result of creatine ingestion maintaining the required rate of ATP resynthesis for longer during exercise (31).

In contrast, no beneficial effect of creatine supplementation was reported by Odland et al. (28,33). They used a crossover design involving control, placebo, and creatine supplementation trials; creatine was administered for three days (20g/day). The exercise test consisted of a single three-second Wingate test. Muscle free creatine content and the muscle total creatine/ATP ratio were enhanced by the treatment, but neither total creatine nor PCr content were significantly altered. The clear difference between the study by Odland et al. (33) and the others, is that the experimental model consisted of a single exercise test rather than multiple exercise bouts (28). It is also the case that the total creatine dose was smaller (60g) in their study than in any of the others mentioned, wherein the dose used was generally 100 to 180g (28).

In summary, it has been demonstrated that creatine ingestion can significantly increase the amount of work that can be performed during repeated bouts of maximal exercise (30). The ergogenic effect of creatine ingestion may be attributable to an increased muscle creatine content, accelerating PCr resynthesis between exercise bouts (30).
**Adverse effects:**

Although there is no evidence of any risks to health associated with long-term use of high doses of creatine, the studies that have been performed have been of relatively short duration (5 to 14 days) (28). Studies are currently under way to investigate some of the effects of long-term creatine supplementation.

**Dose Suggestions:**

"It is now clear that the ingestion of 20g/day of creatine for five days can produce, on average, more than a 20% increase in muscle creatine, of which approximately 20% is in the form of PCR" (29). The majority of tissue creatine uptake seems to occur during the initial days of supplementation; the creatine not retained by the tissue is excreted by the kidneys (29). It is important to point out that human muscle appears to have an upper limit of creatine storage of 150-160 mmol/kg dm, which once achieved, with or without supplementation, cannot be exceeded (29). Thus feeding creatine to someone with an already high muscle creatine content or ingesting high doses of creatine for a prolonged period will be of little additional benefit, and is without question, a waste of money (29). Individuals with the lowest levels of creatine in their muscles appear to achieve the most pronounced increases following creatine ingestion.
CHAPTER 7

L-CARNITINE AS AN ERGOGENIC AID

Carnitine has been referred to as a vitaminlike molecule because it performs a useful biologic function in the body. Nevertheless, it is not classified as an essential vitamin for adult humans, and a specific dietary need or RDA has not been determined (9). This is probably because carnitine can be synthesized in the body from the amino acids lysine and methionine (9,34). Dietary intake from foods is a minor source and can be found in meat and dairy products and in small quantities in grains, fruits, and vegetables (9). The typical non-vegetarian diet provides approximately 100-300 mg/day (34).

Mechanism of action:

The primary function of carnitine is to carry activated long-chain fatty acids from the cytosol of the cell across the inner mitochondrial membrane (1). Therefore, carnitine is essential to the oxidation of long-chain fatty acids. Proponents of L-carnitine supplementation assert that it enhances aerobic and anaerobic capacity and promotes fat loss (1). It is claimed that supplemental L-carnitine exerts these ergogenic effects by (1) increasing fatty acid oxidation in exercising muscle, leading to a glycogen-sparing effect and allowing the athlete to work out for a longer period; (2) rapidly replenishing the carnitine lost during heavy exercise and thus contributing
to the homeostasis of free and esterified L-carnitine in plasma and muscle; and (3) enhancing the buffering capacity of pyruvate and thus decreasing the accumulation of lactic acid in muscle (1).

Exercise of sufficient intensity and duration produces large decreases in plasma and muscle free carnitine levels (6). Low intensity, submaximal exercise (30-40% VO2 max) for durations between 3 to 60 minutes did not change levels of carnitine metabolites in muscle biopsies (6). However, during and after exercise of higher intensities (60-90% VO2 max) decreased free carnitine was seen in muscle biopsies (6). "Thus, carnitine metabolism (homeostasis) is affected primarily by strenuous exercise and less by mild exercise. In other words, normal levels of carnitine in muscle are sufficient to provide enough fatty acids for mitochondrial energy production pathways during exercise of low intensity. However, strenuous exercise places a metabolic demand upon carnitine function. In these cases, it is hypothesized that exogenous carnitine may facilitate greater entry of fatty acids into mitochondria and/or longer production of muscular energy" (6).

Studies on efficacy:

Marconi et al. (35) administered 4g/day L-carnitine for two weeks to six trained long-distance walkers in a randomized crossover blind study. Total, free, and esterified carnitine levels in serum increased significantly after supplementation, suggesting uptake into tissue occurred. Maximal aerobic power (VO2 max) was increased slightly (6%), but significantly after carnitine supplementation (6,35).
A study of 30 males and 20 females at the Sports Polyclinic in Burcharest, Romania, given 3g/day carnitine for 21 days found significant increases in VO2 max (11%) and less blood lactate levels after exercise (6,36).

A series of six double-blind, placebo-controlled, randomized crossover trials at the Sports Polyclinic was conducted with 110 elite athletes to study effects on physiological parameters of carnitine supplementation (6,37). Both acute, single doses of one gram of carnitine and daily doses of one to three grams of carnitine for three weeks were administered. Significant changes after both acute and chronic carnitine administration, compared to placebo periods, were seen for post-exercise plasma lactate, triglycerides, free fatty acids, and evoked muscular potential (6,37).

Arenas et al. (38) studied the effects of L-carnitine activity in muscle of endurance athletes. Sixteen well trained long-distance runners were divided into two groups: the first group was treated with two grams orally of L-carnitine for 28 days; the other group received placebo during the same period of time. The athletes participated in a four week endurance training program. The weekly program consisted of running at 40-50% VO2 max for 90 minutes/day for five days, and at 70-80% VO2 max for two days, corresponding to 130-140 km per week. A muscle biopsy was performed before and after the training program. Total carnitine and free carnitine levels were significantly higher after treatment, than before, in long distance runners supplemented with L-carnitine. These athletes, upon L-carnitine loading, were able to increase their values of VO2 max (38).
In contrast, a double-blind crossover trial of carnitine supplementation (5g/day for 5 days) to 7 trained male subjects exercising on a cycle ergometer for 120 minutes at 50% VO2 max measured physiological parameters related to carnitine functions (6,39). Carnitine supplementation doubled plasma carnitine levels and resulted in lower heart rates during exercise. However, oxygen uptake, plasma free fatty acid levels, and uptake and turnover during exercise were unchanged by carnitine supplementation. The authors concluded that short-term carnitine supplementation did not influence muscle substrate utilization at rest or during low-intensity, submaximal exercise (6,39).

In one of the first controlled studies, experienced distance walkers were given four grams of L-carnitine daily for two weeks and then were monitored in a laboratory during a treadmill walk at 65% of their VO2 max (9). Relative to fuel utilization, carnitine did not affect blood lactate levels, suggesting no change in CHO utilization, nor did it modify the use of fatty acids during this prolonged exercise task (9).

Brass et al. (40) studied the effects of short-term administration of carnitine vs. placebo on exercise in 14 normal healthy male subjects. Protocol 1 included 185 umol/kg carnitine and high-intensity exercise (30 minutes at a workload midway between the lactate threshold and VO2 max). Protocol 2 included 92.5 umol/kg carnitine and the same exercise as #1. Protocol 3 included 185 umol/kg carnitine and low-intensity exercise (60 minutes at 50% of workload corresponding to lactate threshold). The maximal VO2 during exercise was unaffected by carnitine in all
three protocols used. Neither muscle content nor plasma concentration of lactate was different at peak exercise when comparing placebo with carnitine treatments with either high or low-intensity exercise. The authors concluded that "short-term intravenous administration of carnitine has no effect on skeletal muscle carnitine homeostasis during exercise and does not modify any of several important parameters of fuel metabolism during exercise in healthy subjects" (40).

Barnett et al. (41) studied the effects of L-carnitine supplementation on muscle and blood carnitine content and lactate accumulation during high-intensity sprint cycling. Eight healthy males were used as subjects. The subjects were tested before and after 14 days of 4g/day supplementation of L-carnitine. The results of the study demonstrated that "the supplementation of L-carnitine did not increase the content of L-carnitine within the muscle and therefore in this instance could not alter skeletal muscle lactate accumulation during high-intensity sprint cycling exercise (41).

In summary, carnitine supplementation as an ergogenic aid has shown mixed results. For submaximal (low intensity) exercise, carnitine appears to have little or no value as a performance enhancer (6). However, it is also possible that L-carnitine supplementation will have little effect if not continued for a sufficient period of time to alter the mechanism involved in the active transport of carnitine across the muscle membrane (41). However, chronic administration of L-carnitine in doses exceeding 1g/day have been associated with some benefits in exercise metabolism and performance, when exercise has been sufficiently intense (6). Decreased heart
rate for a given workload, improved VO2 max, improved use of lipids as a fuel, and stabilization of carnitine metabolite fluctuations during exercise have been observed in some, but not all, studies measuring these parameters (6). Thus, it is apparent that simply taking several grams per day of L-carnitine will not automatically improve exercise performance to a measurable extent. The fact that some studies have shown ergogenic effects means that carnitine may be effective under certain conditions, but not every condition (6).

**Dose suggestions:**

The most commonly cited dosages or oral L-carnitine are 2-6 g/day consumed in two to three doses with meals (1).

**Adverse effects:**

There have been no reports of adverse effects when L-carnitine is taken in the 2-6 g/day dosage range (1). However, large doses may cause diarrhea (34). Athletes desiring to experiment with L-carnitine supplements should be aware that although L-carnitine is commercially available as a nutritional supplement, such supplements currently are not regulated by the FDA and may vary considerably in purity (34). The major drawback to carnitine supplementation is the cost, which at doses of 1-3 g/day may range from $1-3/day (6). D-carnitine and D,L-carnitine are other forms of carnitine that are less expensive than L-carnitine, however, they may be toxic (9).
CHAPTER 8

PROTEIN AND AMINO ACIDS AS ERGOGENIC AIDS

The question of how much protein an athlete should consume has been researched and debated for years. The current recommended daily allowance (RDA) for protein is based primarily on data derived from subjects whose lifestyles were essentially sedentary (42). However, a number of sources indicate that athletes, especially those in endurance sports and weight training, require more dietary protein than sedentary individuals (1). A dosage of 1.4-1.8 g/kg/day for strength athletes and 1.2-1.4 g/kg/day for endurance athletes has been recommended (42). For endurance exercise, the additional protein is probably needed to repair damaged muscle fibers and as an auxiliary fuel source; for strength athletes it may be related to maintaining an optimal environment (positive nitrogen balance) (9). Positive nitrogen balance indicates growth can because more protein is consumed than the body utilizes (9).

Protein Supplementation in strength athletes:

Studies have found alterations in protein metabolism for high protein intakes that may offer benefits for muscular hypertrophy. Dragan et al. (6) noted increases in strength (5%) and lean body mass (6%) in weightlifters after protein intake was increased from 2.2 to 3.5 g/kg/day.
A nutritionally complete liquid supplement containing protein and supplying 500 kcal/day was given to a group of fifteen competitive weightlifters (6). Fifteen, unsupplemented competitive weightlifters served as a control group. After 15 weeks, the supplemented group gained significantly greater body weight (7.1 vs 3.5 lb) and lost significant more body fat (-.91 vs -.30%) than the control group.

As stated before, protein supplementation above the current RDA, to maintain a slightly positive nitrogen balance and facilitate muscular hypertrophy, may be of benefit to strength athletes (44). However, increasing protein intake above that would simply lead to a greater nitrogen excretion and possible storage as carbohydrate or fat (44).

**Protein supplementation in endurance athletes:**

Protein catabolism can account for 5 to 10% of energy production during endurance exercise (6). Thus, proteins are a minor source of energy for exercising muscles. "There is no convincing evidence that increased dietary protein intake provides a significant ergogenic effect for long-term endurance exercise" (6). However, various studies on protein metabolism of long-distance endurance runners suggest that protein needs are elevated 50 to 100% over the U.S. RDA of 0.8g/kg/day (6). Therefore, 1.2 - 1.4g/kg/day is sufficient to provide a positive nitrogen metabolism.

**Amino acid supplementation in strength athletes:**

Recently, amino acids have become a popular nutritional supplement marketed to athletes. Strength athletes consume amino acids in the belief that they
enhance protein synthesis and stimulate growth hormone (GH) release from the anterior pituitary gland (43). An increased serum GH is supposed to increase muscle strength and size and enhance fat cell lipolysis (43). However, this hypothesis has been questioned in that increases in growth hormone may not promote increases in muscle mass in non-deficient muscle or potentiate the effects of resistance training (44).

The hypothesis that amino acid supplementation may increase GH release was primarily based on initial reports indicating that ingestion of 20 to 60 grams of protein stimulated the release of GH (44). In support of these results, Isidori and colleagues (46) reported substantial increases in the release of GH following ingestion of 1.2g of arginine and 1.2g of lysine. Bucci and associates (47) reported large increases in GH release after ingestion of 170 mg/kg of ornithine. However, attempts to reproduce stimulation of GH release after oral protein and amino acid supplementation have been inconclusive (47).

Lambert et al (43) studied the acute effect that amino acid supplementation has on serum GH concentration. Seven, male body builders ingested either a placebo, an amino acid supplementation (2.4g arginine/lysine or 1.8g ornithine/tyrosine), or a protein drink. Blood was taken before treatment and again every 30 minutes for 3 hours for the measurement of serum GH concentration. The main finding was that serum GH concentration was not altered consistently in healthy young males following the ingestion of amino acid supplements in the quantities recommended by the manufacturers (43).
Fogelholm et al (45) studied the effects of a four day combined L-arginine, L-ornithine, and L-lysine supplement (2g/day) on 24 hour level of serum GH concentration in competitive weightlifters. They also found that supplementation did not affect serum GH concentration (45).

**Individual amino acids:**

Although several dozen individual, purified amino acids have been commercially available for many years and have been used extensively by clinicians, few have been applied to enhance athletic performance, and fewer still have been tested objectively for effects on physiological parameters important to exercise metabolism (6).

**Arginine**- Arginine is known to influence several metabolic parameters important to exercise. First, infusion of arginine releases significant amounts of GH (6). Doses used to elicit a release of GH ranged from 15 to 20 grams (6). Second, arginine is a precursor for creatine synthesis and whether this increase in creatine would be sufficient to influence performance is unknown. Third, arginine is an intermediate in the urea cycle, which converts ammonia (toxic to the body) into urea, a relatively harmless waste product (6). Ammonia is produced during exercise and may be one major factor in determination of fatigue. Eighteen untrained adult males initiated a five week resistance training program with and without amino acid supplementation (6). Ten subjects received 1g each of arginine and ornithine, while eight subjects received placebo. After five weeks, results suggested that oral arginine/ornithine
supplementation reduced body fat and mass to a greater degree when combined with a resistance training program for untrained, sedentary adult males (6).

Thus, several mechanisms with supportive evidence in humans suggest that loading of arginine may benefit performance of athletes, particularly weightlifters (6).

At this time, guidelines for use of arginine supplements as an ergogenic aid for weightlifters are only speculative. Chronic, high-dose supplementation (2-10g/day) is suggested as possibly effective for enhanced reduction of body fat during resistance training (6).

Glycine- Glycine administration to athletes or exercising subjects has produced ambiguous results. Acute ingestion of large oral (p.o.) doses of glycine appears to stimulate release of GH and increase creatine synthesis rates (6). Oral administration of 6.75g of glycine to nineteen subjects increased GH significantly for 3 hours (6). A study by Chaikelis (6) showed an increase in muscle strength after glycine, probably due to increased levels of GH affecting a whole-body resistance training program. Another report found no increases in strength of forearm muscles of two subjects consuming 15g of glycine for 30 days (6). In that report, six or twelve grams of glycine daily for ten weeks did not improve grip strength of eight men.

Although acute ingestion of large p.o. doses (>6g/day) of glycine appears to stimulate release of GH and increase creatine synthesis rates more research is needed (6).
Ornithine- Like arginine, ornithine infusion can release GH in humans (6). However, clinical observations did not find increases in serum GH 2 or 4 hours after p.o. doses of 10g of ornithine to normal subjects. Ornithine has been shown to reduce ammonia toxicity or blood levels in experimental situations (6). Thus, ornithine may have practical ability to reduce exercise-induced ammonia levels and possibly delay fatigue. Whether a practical benefit from ornithine supplementation can be sustained in athletes remains to be determined (6).

Amino acid supplementation in endurance athletes:

Protein and amino acid supplementation has historically been thought to be of greater benefit for strength athletes attempting to promote tissue accretion than for endurance trained athletes. However, energy balance studies with athletes engaged in moderate to high intensity endurance exercise training have indicated that endurance training may also increase the relative protein needs above the RDA (44). The most probable causes for the increased protein need would be to cover an increased loss of amino acids oxidized during exercise and to provide additional raw materials to replace any exercise-induced muscle damage.

During endurance exercise, the branch-chained amino acids (BCAA) leucine, isoleucine, and valine are taken up by the muscle (from the plasma BCAA pool) to contribute to oxidative metabolism (44). Plasma BCAA levels may decline during prolonged endurance exercise. BCAA supplementation has been hypothesized to prevent fatigue in the latter stages of prolonged endurance events by preventing the formation of neurotransmitters that may induce fatigue (10). The decline in plasma
BCAA levels increases the ratio of free tryptophan to BCAA, which has been postulated as one cause of fatigue (10). Theoretically, BCAA supplementation will decrease the free tryptophan:BCAA ratio.

Blomstrand et al (48) determined the effects of BCAA on mental performance in six female soccer players after a match. Players were given a CHO drink with or without BCAA. Mental performance was significantly improved after the soccer match in which players ingested the BCAA, whereas mental performance was unchanged in the placebo group.

In a similar study, Blomstrand and associates (49) studied the effects of BCAA supplementation on endurance performance and psychological responses to a 30km and a 42.2km run. No significant differences were observed in final performance times of all study participants between the placebo and BCAA trials. However, when the participants were divided into subgroups of runners who completed the 30km run in less than 3.05 hours or between 3.05 and 3.30 hours, performance time ratios were significantly lower in the slower runners who received BCAA, indicating that run performance was improved in this group. However, the faster runners did not improve performance capacity.

While there is preliminary support for the hypothesis that BCAA supplementation may affect the physiologic and/or psychological responses to endurance exercise, many questions remain regarding the hypothesized mechanisms of action, physiological, and/or psychological effects on endurance exercise performance and training (44). Therefore, results should only be viewed
as preliminary in nature, providing insight into the validity of presented hypothesis and direction for future research in this area (44).

**Adverse Effects:**

One report stated the consumption of too much protein can have deleterious effects (1). Excess dietary protein is not stored in the body but rather is metabolized and excreted. The metabolism of excess protein results in the production of urea, which is eliminated in the urine through an energy-requiring process that results in the loss of water. Excessive supplementation with proteins or amino acids can lead to dehydration, gout, liver and kidney damage, calcium loss, and impaired absorption of essential amino acids (1).

Another report stated, "the health concern regarding high protein intakes has been overstated, at least in individuals with normal kidney function" (42). There is no published evidence that the high protein intakes routinely consumed by strength/power athletes lead to kidney disease (6,9,42). Excess dietary protein is not recommended for patients with liver or kidney failure (6). It is also recommended that athletes consuming high levels of protein should increase fluid intake in their diets to minimize dehydration effects (9).
CHAPTER 9

CONCLUSION

At various levels of sport's competition, genetic endowment and training levels may be so well matched that the outcome of an event may be determined by milliseconds or centimeters. Thus, when athletes believe that they have maximized the effects obtainable through training, they may try to go beyond training, to use ergogenic aids as a means to enhance performance and obtain a competitive edge over their opponent (10).

Whether drugs can produce meaningful changes in performance is often debated. Because performance in sport may also be the result of factors such as skill level, opponent's skill level, playing conditions, and the athlete's psychological factors, to conclude that drugs produce a definite cause-and-effect relationship to overall performance is difficult (3).

Some sources say that ergogenic drugs may potentially effect individual physiological components of performance, yet other sources state that although nutritional deficiencies can impair athletic performance, there is no evidence that nutritional supplements taken in excess of daily requirements will improve physical performance (3,11). Therefore, "supplementation with vitamins, minerals, or protein is usually only necessary for athletes who, for various reasons, cannot consume a
well-balanced diet (12). Table 2 summarizes whether substances have proven to have an ergogenic effect.

Table 2. Summary of ergogenic effect of various aids.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Proven Ergogenic Effect</th>
<th>Unproven Ergogenic Effect</th>
<th>Questionable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrates</td>
<td>Yes, for endurance events &gt; 90 min.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caffeine</td>
<td></td>
<td>For caffeine naive subjects for prolonged endurance &amp; high-intensity, intermittent exs.</td>
<td></td>
</tr>
<tr>
<td>Chromium Picolinate</td>
<td></td>
<td>May work if athlete is deficient in this mineral.</td>
<td></td>
</tr>
<tr>
<td>Creatine</td>
<td>Yes, for repeated bouts of max. exs.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L-carnitine</td>
<td></td>
<td>Chronic administration may work for high-intensity exs.</td>
<td></td>
</tr>
<tr>
<td>Proteins</td>
<td></td>
<td>May work if athlete has protein deficient diet.</td>
<td></td>
</tr>
<tr>
<td>Amino Acids</td>
<td></td>
<td>None proven to work, except creatine.</td>
<td></td>
</tr>
</tbody>
</table>

Despite the lack of scientific evidence on dietary supplementation, glossy advertisements heralding the purported effects of many nutritional supplements fill the pages of fitness magazines. Along with these advertisements, athletes consider health food store personnel, coaches, gym owners and instructors, and fellow
athletes as their main source of information on nutritional supplements (1). It is on such hearsay and anecdotes that athletes often base their consumption of these products. That is why it is so important for physical therapists, especially those working in sports settings, to be able to give accurate information to inquiring athletes. Effective education will not only ensure that dietary supplements are used correctly, but that the real plaudits go to optimal sports nutrition rather than a 'magic' product (7).
REFERENCES


