

**NUTRITIONAL AND NON-NUTRITIONAL SUPPLEMENTS  
(ERGOGENIC AIDS) AND SPORTS PERFORMANCE**

**BY**

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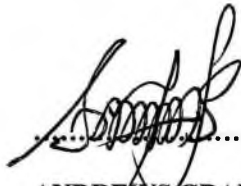
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## DECLARATION

This report is a product of my own work in the libraries of the College of Health Sciences, School of Allied Sciences, Department of Nutrition & Food Science, Department of History, Noguchi Memorial Institute for Medical Research, the Ghana Science Association Secretariat, the Balme Library & Reference Internet Café, the Legon ICT Central Internet café, all of the University of Ghana, Legon under the supervision of Mrs. Adeline Owusu.



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## **DEDICATION**

To Dàdà, my sweet grandma

## ACKNOWLEDGEMENT

My sincere and foremost gratitude goes to the almighty God in whom I live and have my being each day.

And to men, I am most grateful to Mrs. Adeline Owusu, my supervisor for her invaluable inputs in this work.

I also appreciate the numerous helps offered me by the personnel at my reference sources: the Balme library & reference internet café; libraries of the College of Health Sciences, Department of Nutrition & Food Science, Department of History, Noguchi Memorial Institute for Medical Research, the School of Allied Health Sciences, all the University of Ghana, Legon; the secretariats of the Ghana Science Association, Ghana Olympic Committee; and the Ghana Football Association.



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## ABSTRACT

This project report, submitted to the University of Ghana, was on the efficacy of commonly purported ergogenic aids used by athletes. Literature review was conducted on 77 substances to ascertain their ergogenic effects. Possible adverse effects on health and legality were also looked at. Only five (6%) of the supplements had clear scientific support for their ergogenic effects. These include alkaline salts (sodium bicarbonate, sodium citrate), caffeine (including sources of caffeine e.g guarana), carbohydrates, creatine, and water. Those with mixed support formed 9% and include alcohol, choline, antioxidants, dihydroxyacetone pyruvate, glycerol, phosphates, vitamins E, B1, B6, and B12. These need more research to ascertain their status. The rest, about 85%, had no substantial scientific backing. On adverse effects, 32% of the supplements were found to be potentially dangerous, 34% with mild side effects, 14 % had none reported, and 20% were not researched. In terms of legality, 75% were legal while 25% were illegal. For recommendation, there is no doubt physical activity, athletic performance, and recovery from exercise is enhanced by optimal nutrition. Yet there is no one “miracle food” or supplement that can supply all nutritional needs. The key to optimal nutrition is not in commercialized isolates but a balanced diet and good hydration. A well nourished person might not need any supplement. Nutrition advice, by a qualified nutrition expert, should only be provided after carefully reviewing the athlete’s health, diet, supplement and drug use, and energy requirements. Ergogenic Aids should be used with caution, and only after careful evaluation of the product for safety, efficacy, potency, and legality. In conclusion, except for 6% of the ergogenic aids studied, supplementation will not, in general, enhance exercise performance in well-nourished, physically-active individuals.

## Chapter One

### INTRODUCTION

#### 1.1 Background of study

Sports is big business today. Unlike its early beginnings when it was mainly for entertainment, the economic aspect has become the most important focus. Individuals, corporate organizations and governments invest large sums of money into the game. Athletes are virtually bought by competing clubs and their performance is their worth. Competition is very keen and a win, or maybe the winner is the most important. Victory translates into wealth and fame, and failure, vice versa.

But there are other indirect dimensions to the game too. These include national pride, internal and external political leverage, tourism and other implications within the economic cascade. The nationalistic and political impact of Olympic competitions is best expressed in the Latin Olympic motto - Citius, Altius, Fortius, which means "Swifter, Higher, Stronger" (USOC 1993).

At the name of some countries today, a particular sports resonates in people's mind. For example, Brazil is associated with football, USA with basketball and Kenya with the marathon. That is fame and national pride, and gives them a bargaining power among nations on particular issues. The athletic performance of a nation also has political undertones. Sports lovers would not vote for those parties that are perceived to be indifferent to their interest. Sports development also has a link with the travel and hospitality industry. Hosting or just participating in one athletic event brings many economic and other benefits to a nation. Since winning the bid to host a tournament, to some extent, is influenced by the country's athletic reputation, it's no surprise why such an emphasis on the win.

In other words, many livelihoods, both individual and national are dependent on this win. Athletes, team doctors and coaches therefore have little, and sometimes no room for mistakes. Of course, mistakes these days are expensive, ending peoples long built careers. News of coaches being fired at the end of unsuccessful games is commonplace and those of once indispensable players sitting on the bench throughout a season is no wonder. Hence the craze, the search, and mistakes after those competitive edges – the winning connections.

There are two key factors important to athletic success: genetic endowment and state of training. Yet, at certain levels of competition, the contestants generally have similar genetic

abilities and have been exposed to similar training methods, and are therefore fairly evenly matched. Given the emphasis placed on winning, many athletes training for competition are always searching for the ultimate method or ingredient to provide that extra winning edge. Indeed it is reported that, two of the key factors accounting for better athletic records in recent times are improved diet and ergogenic aids (Williams, 2001).

**The word ergogenic is derived from the Greek words ergo (meaning work) and gen (meaning production of), and is usually defined as to increase potential for work output (Williams, 2001).** Today, ergogenic aids are defined as substances or devices that enhance energy production, use or recovery and provide athletes with a competitive advantage. There are different classifications of ergogenic aids depending on their nature of application to sports. Thus ergogenics could be:

Mechanical aids: designed to increase energy efficiency, to provide a mechanical edge. For example: Lightweight racing shoes save energy in running.

Psychological aids: designed to psyche up the athlete and increase mental strength. For example: Visualization, hypnosis and meditation.

Physiological aids: designed to augment natural physiological processes to increase physical power. Eg. Blood doping increases total erythrocyte number and therefore hemoglobin concentration and may increase oxygen transport capacity and thus increase aerobic endurance.

Pharmacological aids: drugs designed to influence physiological or psychological processes to increase physical power or mental strength. Eg. Anabolic steroids may increase muscle size and strength.

Nutritional aids: nutrients or metabolites of specific biochemical pathways designed to influence physiological or psychological processes to increase physical or mental power. Eg protein supplements may increase muscle mass. Carbohydrate loading may augment energy reserves.

But perhaps, the most commonly recognized form of ergogenic aids are the dietary supplements- the nutritional ergogenic aids. According to Burke & Read, 1993, Nutritional Ergogenics contain nutrients or other food components in amounts greater than nutrient RDI levels, or the amounts typically provided by food; propose a direct ergogenic (work-enhancing) effect on sports performance, often through a pharmacological rather than a physiological effect; often rely on theoretical or anecdotal support rather than on documented support from

scientific trials; and are generally not supported by sports nutrition experts, except where scientific trials have documented a significant ergogenic effect.

The number of supplements currently on the market is overwhelming, with creatine, vanadyl sulfate, choline, DHEA (dehydroepiandrosterone), HMB (hydroxymethylbutyrate), branched-chain amino acids, conjugated linoleic acid, antioxidants, ephedrine, Echinacea, caffeine, glutamine, ginseng, glycerol, sodium bicarbonates, cow colostrum, carnitine, co-enzyme Q-10, cytochrome C, chromium picolinate, arginine, ornithine, and inosine, to name just a few, all vying for the limited sports-nutrition money. But the question is: do they really help? Do these supplements really perform those functions for which they are ingested? What about adverse effects on health?

The most commonly used laboratory test to measure exercise performance is the “maximal oxygen uptake ( $VO_2$  max)” which represents the highest amount of oxygen that an individual can consume under exercise situations. In essence, the technique consists of monitoring the oxygen uptake of the individual while the exercise intensity is increased in stages. When oxygen intake does not increase with workload, the maximal oxygen uptake has been reached. Exercise intensity is usually expressed as a percentage of the individual’s  $VO_2$  max stated in milliliters per kg body weight per min (ml/kg/min). A smaller individual has a higher  $VO_2$  max when expressed relative to body weight and therefore has a higher degree of aerobic fitness than the bigger man.

In this review we will attempt to evaluate various purported nutritional ergogenic aids based on sound scientific literature.

## 1.2 Significance of study

The emphasis on supplements is increasing to the disadvantage of good meal plans. Many athletes now put their faith in the magic potions and capsules than the traditional balanced diet. Some follow bizarre menus and recipes whose backgrounds are best described as nutritional quackery. Parallel to this trend is the risk of malnutrition and its attendant health problems. The results are debilitating conditions, nutrient toxicities and many silent deaths in the sporting world. Reports of psychological disorders like depression, chronic diseases like diabetes, and organ failures like cardiac arrests are on the ascendancy. For every one champion there are many unknown brave hearts whose disadvantage, among others, is food faddism and nutritional quackery. A man is still basically what he eats and not which drugs or supplements

he takes. This is a cause of worry to the Dietician and Nutritionist as well as those in the sports profession.

The result of this review will be a summary of the scientific trials done on the efficacy of common ergogenic aids and their possible adverse effects on health, which undisputedly could be a valuable reference piece for those it may concern.

### **1.3 Objectives**

- To review current scientific literature on the efficacy of commonly purported nutritional ergogenic aids. Legality and possible adverse effects on health will be looked at.

**LITERATURE REVIEW****2.1 A historical perspective on the supplements**

The premise of ergogenic aid use is rooted in antiquity and was based upon superstition and ritualistic behavior of athletes who perceived that past performances were predicated upon unique dietary constituents or dietary manipulation. Dietary fads are known from ca. 500-400 B.C., when athletes and warriors used products such as deer liver and lion heart to impart certain benefits, hoping that consumption would produce bravery, speed or strength associated with such animals (Mayer and Bullen 1960, Reed 1977, Van Itallie et al. 1956, Williams 1989b).

Greek and Roman writers described diet and training of Olympic athletes. Diogenes Laertius (died A.D. 222) wrote that Greek athletes trained on dried figs, moist cheese and wheat; then the pattern changed and focused on meat. Epictetus (2nd century A.D.) wrote that Olympic victors avoided desserts and cold water and took wine sparingly. Philostratos deprecated athletic diet in his era, a pattern based on white bread sprinkled with poppy seeds, fish and pork. Americans at the XIth Olympiad in Berlin (1936) consumed beefsteak with average daily intake of 125 grams of butter or cotton oil, three eggs, custard for dessert and 1.5 L of milk. The American pattern at Berlin was characterized by intake of white bread, dinner rolls, fresh vegetables and salads. At Atlanta, more than 5 million meals were served during the Olympic festival. The highly varied menu included fresh vegetables and dips; fruits, cheeses and breads; salads; pasta, rice and fruit salads; soups; meat and seafood entrees; hot vegetables; desserts; and beverages.

Most evidence for relationships between diet and supplements and improved performance, however, stem from the early 20th century, with the advent of research on understanding muscular work, fuel use during exercise, and the specific roles of protein, fat and carbohydrate (Horstman 1972, Van Itallie et al. 1956). Science, specifically exercise science, took the leadership in this research. Before the development of exercise science, fuel use was misunderstood. Indeed, early German pioneers wrote that muscular protein stores were used during exercise (von Liebig 1842). It was not until the turn of the century, with the discovery and isolation of vitamins and with the understanding of their basic role in metabolism, that the search for the competitive edge and the quest for ergogenic substances were placed on a scientific footing.

## 2.2 Protein as ergogenic aid

Protein is perhaps the most common nutritional ergogenic aid or dietary supplement used today. It was known by the turn of the 20th century, however, that protein was not a significant source of energy. Nitrogen balance studies demonstrated that with increased energy expenditure due to exercise, nitrogen excretion was not increased (Atwater and Benedict 1899 and 1902). By the 1940s experiments had demonstrated that supplemental protein did not enhance endurance performance, but athletes continued to use protein as a primary focus of their diet (Darling et al. 1944, Pitts et al. 1944). But experiments also conducted in the 1940s demonstrated that supplemental protein could enhance muscle mass if taken by power or strength athletes (Kraut et al. 1953). Indeed, protein use beyond nutritional-physiological requirements defined in the 1940s increased nitrogen retention (Yamaji 1951, cited in Horstman 1972).

Since the 1940s and 1950s, protein supplements have blossomed into a very wide array of products used by different athletes. When athletes representing a wide variety of different sports have been surveyed, a significant percentage mentioned protein as a very important nutrient in their diet, but depending upon the specific sport, the emphasis on protein is different: football players and weightlifters differ from gymnasts and athletes in track and field (Parr et al. 1984).

In the 1950s and 1960s, athletes increased their protein intakes and focused on high quality sources such as milk and beef. This changed in the 1970s and 1980s to preparations of isolated protein powders and amino acids (Aronson 1986, Short and Marquart 1993). Athletes in the 1980s and 1990s have gone beyond basic protein supplements and have sought information regarding amino acids, protein synthesis, and hormone production that influences protein synthesis and metabolism. In recent years the focus has remained on arginine and ornithine and their theoretical basis for increasing circulating levels of human growth hormone (Grunewald and Bailey 1993, Williams 1993).

In the late 1980s, experiments suggested that branched-chain amino acids served as energy sources during endurance exercise. Athletes learning of this research findings interpreted them to indicate that supplements of isoleucine, leucine and valine would translate into improved performance and maintenance of muscle mass (Applegate 1991, Williams 1994). One focus of the 1990s has been taurine, an amino acid not common in food; it has been packaged as an active ingredient in weight-gain supplements for use by athletes. During the past several years there has been an extraordinary rise in the production and marketing of protein and amino acid beverages (Williams 1993).

### 2.3 Carbohydrate as an ergogenic aid

Carbohydrate as an ergogenic aid has its beginnings strongly rooted in science. Early in the 20th century it was apparent that during very heavy, intense exercise, the primary fuel source was carbohydrate (Horstman 1972). There was little applied effort, however, to manipulate carbohydrate intake in the diet of athletes until the 1920s, when comparative studies of high carbohydrate and high fat diets revealed that high carbohydrate intakes resulted in increased efficiency of muscular work (Krogh and Lindhard 1920). This original research, however, was not without criticism, so researchers from Harvard Medical School planned and conducted experiments at the Boston Marathon in 1924 to test the carbohydrate thesis. There, blood was sampled from the first 20 runners that crossed the finish line, and findings related low blood glucose concentrations to symptoms of fatigue, stupor and inability to concentrate (Levine et al. 1924). The following year, many of these same athletes were supplemented with a large amount of carbohydrate the day before the race. Also, sugar candy was provided to the athletes, along with instructions to eat the candy before and during the event. The researchers sampled blood sugar concentrations following completion of the marathon and found that by normalizing blood glucose concentrations before and during running, symptoms of fatigue, stupor and inability to concentrate were prevented (Gordon et al. 1925). Study of the role of carbohydrates in exercise and especially in endurance performance was begun by Scandinavian researchers in the 1930s (Christensen and Hansen 1939).

It was not until the 1960s, however, that research conducted on carbohydrate by the Swedish team at St. Erik's Sjukhus in Stockholm became the foundation for the dietary regimen for many athletes, when it was demonstrated that high carbohydrate diets improved endurance performance and carbohydrate feedings during exercise delayed fatigue (Ahlborg et al. 1967, Bergström and Hultman 1972, Bergström et al. 1967). Understanding of the use of muscle glycogen during exercise, coupled with manipulation of dietary carbohydrate levels from a carbohydrate-free diet, mixed diet and high carbohydrate diet, demonstrated that muscle glycogen levels could be influenced and, in turn, the result was increased endurance (Bergström et al. 1967). This research by the Scandinavian team in the late 1960s established the foundation that allowed everyday athletes to take advantage of the nutrition findings that pre-event nutrition could boost stores of glycogen prior to exercise. The early 1970s saw a craze in carbohydrate loading when additional research conducted in Scandinavia demonstrated the effect of dietary carbohydrate manipulation on muscle glycogen and endurance; increased glycogen levels

corresponded to improved work time and improved endurance (Åstrand 1968, Bergström et al. 1967).

From this body of literature on carbohydrate, evolved commercial marketing of carbohydrate products during the 1960s and 1970s, and various manipulations of the activity known collectively today as "carbohydrate loading."

Diets based on potatoes, rice and grains are high in bulk, and many athletes complain of an inability to eat enough to maintain energy balance. Additionally, athletes have sought out high carbohydrate foods that could be consumed prior to competition without causing gastric distress (Bensley 1951, Applegate 1988). As a result, new categories of products emerged that have been marketed for dietary carbohydrate supplementation and pre-event nutrition. Researchers had documented that consuming carbohydrate 2-4 h before exercise increased performance; this led to products such as Gator Pro® to be consumed conveniently before events, with little dietary residue. Recent developments in pre-event nutrition have seen the emergence of carbohydrate gels such as Gu® and Reload®. These semisolid products typically are sucrose or glucose polymers that athletes can utilize before or during exercise (Hotell and Faria 1996).

Complementing carbohydrate gels are various energy bars used by athletes, primarily as a source of carbohydrate. Their composition is variable, and the varieties are extensive in this highly competitive market

#### **2.4 Vitamins and antioxidants as ergogenic aids**

In addition to protein and carbohydrate, athletes have been interested in vitamin supplementation since the 1930s after the discovery and isolation of these compounds. By 1939, Tour de France cyclists reportedly performed better after taking vitamin supplements (Mayer and Bullen 1960, Horstman 1972). Research completed in the early 1940s did not support the role of vitamin supplementation in enhancing athletic performance. Nevertheless, athletes have pursued heavy vitamin use in subsequent decades until today. Surveys completed on athletes competing at the 1972 Olympic Games in Munich reported heavy multivitamin supplementation (Darden 1973). Moving beyond multivitamin supplementation, athletes have now sought use of specific vitamins for desired outcomes (Nieman et al. 1989, Williams 1989b and 1994).

Recent studies have provided the scientific basis for use by athletes of some micronutrients, such as antioxidants (Barrarre et al. 1993, Clarkson 1995, Nieman et al. 1989). This has led to the development of commercial products designed to enhance antioxidant intake to prevent oxidative damage during high intensity exercise

## 2.5 Miscellaneous products

As early as the 3rd century B.C., Greek athletes drank wine or brandy or ingested mushrooms before competition because they believed that these products enhanced their performance (Voy 1988). Roman gladiators used alkaloids to improve their chances for survival in the arena (Voy 1991). A wide range of ergogenic substances has been documented since 1865, including alcohol, amphetamines, anabolic steroids, caffeine, cocaine, ethyl ether, erythropoietin, growth hormone, heroine and nitroglycerin (Voy 1988, Williams 1989).

Although it generally has been known throughout the athletic community that certain athletes who died during endurance events used amphetamines, it took the death of a cyclist from an overdose of amphetamines at the 1960 Olympics in Rome for the IOC to take action. The IOC finally defined doping in 1964. Consequently, the IOC began drug testing at the Olympic Games in Mexico City in 1968. Unfortunately, the process was not very effective, and athletes were able to avoid detection (Williams 1989). Although the original IOC statements concerning doping have been modified twice since 1964, the definition and intent remain the same (Voy 1991, Williams 1989).

In addition to amphetamine use, it was known in the late 1950s and middle 1960s that some athletes used anabolic steroids as ergogenic aids before Olympic and non-Olympic competitions. However, the IOC did not ban it until 1975 (Voy 1991). Related stories may be detailed about use of blood doping, erythropoietin or growth hormone.

Other items used by athletes may be called ergogenic aids, among them gelatin, ginseng, sodium bicarbonate (baking soda) and wheat germ oil. Research on these products dates to the 1930s (Barron and Vanscoy 1993, Burke and Read 1993, Cureton 1954, Cureton and Pohndorf 1955, Grunwald and Bailey 1993, Williams 1989 and 1994). More recently, attention has been directed towards creatine monohydrate and chromium picolinate. It has been suggested that these substances enhance power output and delay fatigue during brief, intense exercise (Maughan 1995, Williams 1993), as well as increase muscle mass and strength (Grunewald and Bailey 1993).

Although the effectiveness of caffeine as a means of masking fatigue has been explored since the early 1900s, the use of this ergogenic aid became popular following widely publicized research indicating improved endurance performance (Costill et al. 1978). Caffeine is an example of a readily obtainable ergogenic aid that acts as a stimulant and is banned by the International Olympic Committee (Williams 1994).

The number of ergogenic aids used by athletes is staggering. Whether or not these aids work, athletes will try almost anything in their search for the competitive edge. In this review, we will evaluate commonly purported nutritional ergogenic aids based on clinical action. Possible side effects and legality will be looked at.

## Chapter three

### METHOD

This work was done in two parts. First there was data collection from sports magazines, news archives, newspapers, journals, and the internet to establish a list of supposed ergogenic aids and their actions. Secondly, literature review was conducted on the ergogenic effects of these supplements for efficacy. Possible adverse effects on health and legality were also looked at.



## RESULTS

### 4.1 The supplements, their claimed actions and literature

#### 4.1.1 Protein

*Claimed action:* Protein and its constituent, amino acids, are the building blocks of muscle. Protein supplements are used by some athletes to enhance muscle repair and growth. Inadequate protein intake does cause a negative nitrogen balance, which slows muscle growth and causes fatigue.

*Research:* Athletes in training have increased protein needs. A study (Tarnopolsky et al, 1992) examining the protein requirements of experienced resistance-training athletes found that those consuming the recommended daily allowance for protein (0.8 g per kg daily) had a negative nitrogen balance. The protein intake required for a zero balance was 1.4 g per kg daily, with a recommended intake of 1.8 g per kg daily. Another study (Lemon et al, 1992) using novice resistance-training athlete found their requirements to be 1.6 to 1.7 g per kg daily. Both studies found that protein intakes in excess of these recommendations did not provide additional gains in strength or mass.

From the proceedings of the conference on Nutritional Ergogenic Aids in 1995, Nutritionists claim that normal dietary intake is sufficient. Some dietitians claim 1 gm/kg of body weight per day is all that is needed, whereas a German scientist (Stegeman) has reported that double that amount is required. A general rule-of-thumb is that an appropriate diet would include 15% protein. Most athletes probably have adequate intake of protein if they are not vegetarian. There is likely to be little benefit derived from excess ingestion of protein and/or amino acids (Sherman and Lamb, 1995).

*Adverse Effects:* In an athlete with normal renal function, there are no notable adverse effects to increased protein consumption. It may be healthier, however, to avoid acquiring protein from foods that also contain increased amounts of fat and cholesterol.

*Legality:* Protein supplements are legal.

#### 4.1.2 Branch Chain Amino Acids (BCAA)

*Claimed action:* As blood concentrations of the branched-chain amino acids decline during exercise, levels of tryptophan increases (Bermon et al, 1998). Since tryptophan competes with BCAAs to squeeze through capillaries in the brain and gain access to neural tissue, this may well mean that athletes' brains become relatively full of tryptophan and relatively devoid of BCAAs during extended exercise. Tryptophan is a precursor of serotonin, sometimes called the brain's 'sandman', since it can induce feelings of extreme fatigue and sleepiness. As a result, some scientists have suggested that supplementation with branched-chain amino acids might limit perceptions of fatigue during prolonged physical efforts, and thus enhance performance

*Research for:* In one US study athletes who took in about 14g per day of branched-chain amino acids were able to run considerably faster during the run portion of a triathlon than non-supplemented controls (Ladas et al, 1991). In a study carried out in Copenhagen by the noted Scandinavian exercise physiologists Eva Blomstrand and Bengt Saltin, athletes ingested branched-chain amino acids or a placebo during one hour of cycle-ergometer exercise and a two-hour post-workout recovery period (Blomstrand and Saltin, 2001). The supplements had little effect on protein metabolism *during* the training session, but seemed to produce a smaller release of amino acids from the leg muscles during the post-workout recovery. Blomstrand and Saltin concluded that ingested branched-chain amino acids may have a protein-sparing effect during recovery from exercise. Considerable more work needs to be carried out in this area, but research seems to indicate that leucine may be the key branched-chain amino acid associated with amplified protein synthesis following training

*Research against:* From the proceedings of the conference on Nutritional Ergogenic Aids in 1995, it was concluded that there was little evidence supporting this claim and that more research was required (Sherman and Lamb, 1995).

Micheal Gleeson in a recent paper submitted to American Society for Nutritional Sciences found out that, majority of later studies, using various exercise and treatment designs and several forms of administration of BCAAs (infusion, oral, and with and without carbohydrates), have failed to find a performance-enhancing effect. That no valid scientific evidence supports the commercial claims that orally ingested BCAAs have an anticatabolic effect during and after exercise in humans or that BCAA supplements may accelerate the repair of muscle damage after exercise.

*Adverse effects:* The recommended protein intakes for athletes ( $1.2$  to  $1.8 \text{ g} \cdot \text{kg body mass}^{-1} \cdot \text{d}^{-1}$ ) do not seem to be harmful. Acute intakes of BCAA supplements of about  $10\text{--}30 \text{ g/d}$  seem to be without ill effect.

*Legality:* BCAAs are legal

#### **4.1.3 Tryptophan (TRYP)**

*Claimed action:* In one hypothesis, TRYP serves as a precursor for serotonin, a brain neurotransmitter theorized to suppress pain. Free tryptophan enters the brain cells to form serotonin. Thus, TRYP supplementation has been used to increase free tryptophan and serotonin production in attempts to increase tolerance to pain during intense exercise, thus delaying fatigue.

*Research:* Limited data involving TRYP supplementation are available, but one study reported significant improvements in time to exhaustion at 80 percent  $\text{VO}_2\text{max}$ , accompanied by significant reductions in the psychological rating of perceived exertion. However, research with a more appropriate experimental design did not replicate these findings when subjects ran to exhaustion at 100 percent  $\text{VO}_2\text{max}$ . Moreover, other investigators reported no effect of TRYP supplementation on aerobic endurance performance at 70-75 percent  $\text{VO}_2\text{max}$  (Williams, 1998B). In a review, Wagenmakers (1997) concluded that TRYP supplementation had no effect on endurance performance.

*Adverse effects:* none reported

*Legality.* It is legal

#### **4.1.4 Arginine, ornithine and lysine**

*Claimed action:* These individual amino acids are promoted as 'growth hormone releasers' and arginine especially for nitric oxide production. Supplement manufacturers suggest that these amino acids will increase muscle growth while stimulating breakdown of body fat. Arginine, ornithine and lysine are known to increase levels of human growth hormone when injected into the bloodstream at high doses. Whether there's any effect when these substances are given by mouth is far more controversial

*Research:* Many researchers have found no effect. A couple of studies which found that ornithine supplements increased growth hormone levels used levels so high that nausea and diarrhoea were unwelcome accompaniments to the hormone boost.

Paddon-Jones and his colleagues also investigated the potential ergogenic effects of arginine and this is their account: In some clinical circumstances (e.g., burn injury, sepsis) in which the demand for arginine cannot be fully met by de novo synthesis and normal dietary intake, exogenous arginine has been shown to facilitate the maintenance of lean body mass and functional capacity. However, the evidence that supplemental arginine may also confer an ergogenic effect in normal healthy individuals is less compelling. In contrast to arginine, numerous studies have reported that supplementation with the arginine metabolite creatine facilitates an increase in anaerobic work capacity and muscle mass when accompanied by resistance training programs in both normal and patient populations. Whereas improvement in the rate of phosphocreatine resynthesis is largely responsible for improvements in acute work capacity, the direct effect of creatine supplementation on skeletal muscle protein synthesis is less clear (Paddon-Jones et al, 2004).

*Adverse effects:* If single amino acids are consumed in large quantities, absorption of others may be affected. Nutrient toxicity is not ruled out.

*Legality:* amino acid supplements are legal



#### **4.1.5 Alanine**

*Claimed action:* During exercise the muscles release alanine into the bloodstream in direct proportion to the intensity of the exertion (Wells, 1971 ). The alanine is then picked up by the liver, where it is converted into glucose and released into the blood plasma. Thus, alanine seems to help keep blood sugar levels stable during exercise; and since low levels of blood sugar have been linked with fatigue during exertion, some experts believe alanine supplements might enable athletes to exercise for longer periods of time.

*Research:* A study suggested that alanine ingested during exercise had carbohydrate-conserving effects, as well as enhancing protein synthesis and creating better nitrogen balance in athletes engaged in heavy training (Stone, 2002). In this investigation, six healthy male athletes took in 74g of alanine during prolonged exercise (lasting 180 minutes) at an intensity of 53% of

VO<sub>2</sub>max. During the three hours of exercise, 51g (69%) of the alanine was actually oxidized (broken down to provide energy), providing a whopping 10% of the total energy needed to sustain the workout. By comparison, other amino acids chipped in just 5% of the energy for the session, with carbohydrates adding 48% and fat 37% of the total. An additional impressive finding was that very little of the nitrogen from the supplemented alanine was lost in either urine or sweat, a situation which led to a positive nitrogen balance (+ 8.5g) during the workout. It is reasonable to suppose that this positive nitrogen balance might be associated with better muscular recovery following prolonged exertion.

*Adverse effects:* If single amino acids are consumed in large quantities, absorption of others may be affected; there is also a risk of toxic effects

*Legality:* amino acid supplements are legal

#### **4.1.6 HMB (beta-hydroxy-beta-methylbutyrate)**

*Claimed action:* This metabolite of the amino acid leucine is said to help decrease muscle breakdown.

*Research:* HMB was studied in a group of serious weight lifters (1.5 hours a day, 3 days a week) on their usual diet of 117 grams of protein per day (twice the Recommended Daily Allowance) and a high protein diet of 175 grams per day. HMB (1.5 and 3.0 grams per day) decreased the products of muscle breakdown (muscle damage) found in the urine during the training period, and increased the amount of weight lifted in each week of the study when compared to a control group not using the supplement. There was a dose related effect, i.e. the 1.5 gram per day dose of HMB was beneficial but greater improvement was noted on 3.0 grams per day. There was no benefit of a high protein diet compared to a normal protein diet (117 grams per day) either in the control (no HMB) or HMB groups. Lower body strength improved more than upper. The average increase in overall (averaged) strength compared to the control (no HMB) group at week 3 was 13% for the 1.5 gram per day HMB supplement and 18% for the 3.0 gram per day HMB supplemented group.

HMB is of use in a program of regular resistance training and appears to work by minimizing the muscle damage that normally occurs. Its role in aerobic conditioning or cycling where strength is less of a factor has not been studied ([www.pponline.co.uk](http://www.pponline.co.uk))

*Adverse effects:* No adverse effects were noted during the study period

#### 4.1.7 Carbohydrates

*Claimed action:* While fat stores constitute the largest reservoir of stored energy, carbohydrates are the body's main source of rapidly available energy. It has been suggested that taking proper quantities of carbohydrates at the right time could improve athletic performance by ensuring adequate energy stores are available.

*Research:* Loading, or increasing the carbohydrate content of the diet for several days before an event, has been promoted as a means to prolong exercise endurance. One study (Hawley et al, 1997) evaluated its impact on continuous, short-term events of less than one hour and found no benefit, because muscle glycogen content was not depleted at the end of the exercise.

A meal prior to exercise will ensure that muscle and liver glycogen stores are maximized. Studies (Schabort et al, 1999 and Wee et al, 1999) investigating a meal two to four hours prior to exercise have shown positive effect, regardless of the glycemic index of the foods ingested. Evaluation of six endurance athletes ingesting carbohydrates only 45 minutes prior to a two-hour exercise test revealed no benefit (Febraio and Stewart, 1996).

Replenishment with carbohydrate-containing fluids during an endurance event may help to delay fatigue. Thirty marathon runners in a double-blind study (Utter et al, 1997) described decreased subjective exertion when ingesting 60 g per hour of a liquid carbohydrate solution during a two and one-half hour run. Another study (Jeukendrup, 1997) found that ingesting a carbohydrate-electrolyte drink during one hour of high-intensity exercise improved performance in 19 bicyclists. Many studies have demonstrated similar results. One study (Robergs et al, 1998) that evaluated solid versus liquid carbohydrate replenishment showed no difference, as long as adequate water intake was maintained. Eating a mixture of carbohydrates and protein within two hours after an activity has also been associated with benefits, including replenishment of depleted muscle and liver glycogen stores and decreased muscle catabolism. A study (Chandler et al, 1994) of nine weight lifters showed increased levels of plasma growth hormone and insulin when athletes ingested protein and carbohydrate immediately and two hours after exercise, which would theoretically provide a physiologic environment favorable for muscle growth. Another placebo-controlled study (Tarnopolsky et al, 1997) of endurance athletes ingesting a carbohydrate-containing solution after exercise reported increased glycogen resynthesis.

*Adverse Effects:* Theoretic disadvantages have been reported with carbohydrate supplementation. Increased insulin levels after carbohydrate consumption were shown to significantly decrease blood glucose levels in some athletes, though not all athletes seem to be subjectively sensitive to these decreased levels (Sherman, 1995). Fructose-containing solutions have been associated with adverse gastrointestinal effects in some studies (Murray et al, 1989).

*Legality:* Carbohydrate supplements are legal.

#### **4.1.8 Honey**

*Claimed action:* Honey mainly consists of a mixture of sugars, together with various trace elements. The sugars are glucose, fructose and sucrose. All brands of honey contain fructose at higher levels than glucose. Over the past 10 years, information has been accumulating to suggest honey is a good way to boost the carbohydrate level of your diet.

*Research:* Greek researchers recently undertook the first randomised investigation of incomplete carbohydrate absorption after eating honey. Twenty students and staff from Athens University were given differing amounts of honey after an overnight fast. Breath hydrogen measurements were used as a way of diagnosing whether the carbohydrate had been completely absorbed or not; subjects were also asked to report any intestinal discomfort or diarrhoea after eating the honey. When given a 100g dose (equivalent to 3 tablespoons), 65 per cent of people showed signs of incompletely absorbed carbohydrate, and 30% reported loose stools. For a 50g dose, 40% didn't fully absorb the sugars, and 15% reported loose stools

They found no ergogenic link between honey and exercise ([www.pponline.co.uk](http://www.pponline.co.uk)). In any case, the fructose must be first converted to glucose before catabolism for energy production.

*Adverse effects:* Fructose that is not absorbed from the small intestine into the bloodstream passes on into the large intestine, where it is consumed by the resident bacteria. The result was flatulence and diarrhoea (Ladas et al, 1990)

*Legality:* honey intake is legal

#### 4.1.9 Sodium bicarbonate

*Claimed action:* anaerobic glycolysis decreases the pH inside the muscle cells and the blood which leads to fatigue. Sodium bicarbonate decreases the acidity of the blood thus delaying the onset of fatigue.

*Research :* Bird and colleagues (Bird et al, 1995) persuaded 12 middle- and long distance runners to compete in a total of six 1500m races. The three different conditions were: after bicarbonate ingestion, after placebo ingestion, and after ingestion of neither of these. The bicarbonate ingestion trial produced race times between 3 and 5 seconds faster than the other two conditions.

Hauswirth and colleagues found that eight subjects were able to improve local muscle endurance of the quadriceps during a sustained contraction at 35 per cent of maximal force after ingestion of sodium citrate (sodium citrate raises blood bicarbonate by a similar amount as sodium bicarbonate itself), (Hauswirth et al, 1995)

Callier and colleagues had 12 male subjects perform five 1-minute bouts of cycling with 2-minute rest intervals at an intensity equivalent to 100% VO<sub>2</sub>max after placebo or citrate ingestion. The fifth bout of cycling was in fact longer than one minute and continued until exhaustion. Citrate ingestion delayed fatigue in the fifth exercise period, adding an average of 20 seconds to exercise capacity that was determined largely by anaerobic function (Callier et al, 1994)

*Research against:* Five male and four female trained track athletes, between the ages of 18 and 30, participated in a total of four competitive 1600 m races scheduled at least three days apart. Ss ingested a treatment (400 mg/kg NaHCO<sub>3</sub> or 500 mg/kg sodium citrate) or placebo (calcium carbonate) 2 hours prior to three of the races; one race was used as a control. Order of treatments was randomized. The buffering agents had no effect on racing time (Avedisian et al, 1995).

Cox and Jenkins used eight moderately-active male subjects to evaluate the effects of sodium citrate ingestion on repeated 60-second sprints on a cycle ergometer. Despite changes in blood bicarbonate and lactate measures which suggested that the supplementation was working correctly, performance (work done cycling) was no different between supplementation and placebo trials (Cox and Jenkins, 1994)

Kozak-Collins and colleagues found no significant improvement in performance, although their raw data did suggest some improvement which may have been significant if a larger sample size

had been used. After ingestion of sodium bicarbonate or a placebo, seven competitive female cyclists performed intermittent exercise of one minute at 95% VO<sub>2</sub>max, the next minute at just 60 watts, until exhaustion after an average of nine bouts at each intensity. Once again, blood measures of bicarbonate and 'buffering capacity' had increased but had not been reflected sufficiently in the all-important performance measure (Kozak-Collins et al, 1995)

*Adverse effects:* One possible reason why there has been such conflicting research both recently and earlier is the fact that many subjects suffer short-term stomach complaints after ingesting sodium bicarbonate. These took the form of pain, cramping, diarrhoea or a feeling of being bloated. Individuals who feel nauseous cannot perform better than they normally do. Thus, some potential benefits of supplementation may be neutralised by the effects of nausea in some subjects.

*Legality:* bicarbonate supplements are legal

#### **4.1.10 Citrate (Sodium Citrate)**

*Claimed action:* same as the bicarbonate

*Research:* Sodium citrate was evaluated in a 30 km high intensity time trial event at a dose of 0.5 grams per kg body weight. Total power output, but not peak power output, was greater in this treated group. At 30 km, the riders using sodium citrate had an average 100 second lead. The cyclists using the sodium citrate had a higher venous blood pH throughout the ride, and it is presumed that this buffering effect led to the improved performance (by optimizing the pH within the muscle cell and enhancing contractility).

Sodium citrate has also been shown to increase peak power over a placebo control group during short, high intensity cycle ergometry of 120 and 240 seconds duration. Again, this is thought to be related to optimizing the pH within the active muscle cell ([www.runnersworld.com](http://www.runnersworld.com))

*Adverse effects:* possible gastrointestinal discomfort at high doses

*Legality:* it is legal

#### 4.1.11 Aspartates

*Claimed action:* Aspartic acid salts may improve aerobic endurance - perhaps by sparing muscle glycogen utilization.

*Research:* the studies were conflicting. One reported no effect of 3 grams of aspartate ingested 24 hours before a ride to exhaustion at 75% VO<sub>2</sub>max. Another reported 15% increase in endurance at 75% VO<sub>2</sub>max after 10 grams of aspartate over the 24 hr period before the ride. But about 50 percent of the available studies have indicated enhanced performance (Williams, 1998A). Additional research is needed to study their potential ergogenicity and underlying mechanisms.

*Adverse effects:* Low doses are considered safe

*Legality:* it is legal

#### 4.1.12 Boron compounds

*Claimed action:* Commonly advertised as testosterone boosters, some manufacturers refer to a study published in 1987 to back up their claims.

*Research:* Anyone actually looking up the study might well be disappointed, as it documents the effects of various minerals on hormone levels in post-menopausal women. Aluminium and magnesium reduced circulating levels of testosterone - boron appeared to return these levels to normal. The researchers did not extrapolate their results to any other group of people. In a more recent study, young male bodybuilders were divided into two groups and given boron or placebo for seven weeks. There was no difference between the groups for plasma testosterone, lean mass or strength ([www.pponline.co.uk](http://www.pponline.co.uk)). Ferrando and Green in their review concluded the limited data available do not support an anabolic effect of boron (Ferrando and Green, 1993)

*Adverse effects:* Use of boron supplements may not just be ineffective - there have been reports of increased infertility in parts of the previous Soviet Union, where drinking water contained high concentrations of boron. ([www.pponline.co.uk](http://www.pponline.co.uk))

*Legality:* boron is legal

#### 4.1.13 Zinc

*Claimed action:* Zinc is a cofactor for over 300 enzymes in the human body. Zinc is vital to healthy immune function, and previous studies have shown that people with severe zinc deficiency are prone to a range of disorders linked with compromised immunity. It has been suggested that regular intense exercise may reduce blood zinc concentrations, so posing a threat to health, hence the advocacy for zinc supplements

*Research:* The researchers put this hypothesis to the test in a study of 10 male runners, who increased their normal training volume of long slow distance running over four weeks, then reduced it to recovery levels for a further two weeks. Blood samples taken from the athletes before and after the four weeks' intensified training, and again after the two weeks' recovery, were analysed for plasma zinc concentration and immune system markers and compared with samples taken from a group of seven sedentary male controls.

Key findings were as follows:

- The athletes generally had lower plasma zinc concentrations than the non-athletes both before and during the four weeks of intensified training, but these remained within the clinically normal range and were unchanged in response to the moderate increase in training volume;
- Although cell counts for some lymphocytes were lower in the athletes than the controls, they were unaffected by training and lymphocyte responsiveness was similar or higher in the athletes than the controls. Thus plasma zinc concentrations generally correlated poorly with the immune parameters under investigation;
- Five out of 10 athletes experienced varying degrees of illness during the study, compared with two out of seven controls.

The researchers concluded that their results do not support the use of zinc supplements among well-trained athletes during a period of moderately increased training volume.

([www.pponline.co.uk](http://www.pponline.co.uk))

*Side effects:* unknown

*Legality:* zinc supplements are legal

#### 4.1.14 Iron

*Claimed action:* Iron is important as a component of hemoglobin in red blood cells which transports oxygen from the lungs to the muscle cells. Iron deficiency can cause fatigue and weakness.

*Research:* Athletes involved in contact sports (including runners) are more likely to be anemic as a result of iron deficiency than cyclists, but even regular cyclists have an additional need of around 18 mg of iron per month (equal to one menstrual period). Iron deficiency is more of a problem in women athletes because of monthly menstrual blood loss. When the US Olympic team was studied, it was found that 20-30% of the female athletes did not get enough iron from diet alone. If you ride regularly, taking a multivitamin with iron will help to prevent anemia. An alternative is to eat extra portions of iron containing foods (dark green vegetables, prune juice, figs, and raisins).

Although some riders use iron supplements to alleviate the beat feeling they experience after a long ride, a balanced diet easily meets the RDA for iron (10 mg for men and 15 mg for women). Four ounces of red meat contains 8 - 10 mg.

*Adverse effects:* As excess iron can be toxic, any questions of a deficiency state are best resolved with a screening blood test before resorting to supplements - any self prescription has definite risks.

Legality: it is legal.

#### 4.1.15 Selenium

*Claimed action:* Thought to have a possible role as an antioxidant,

*Research:* There is little evidence this mineral plays a significant role in minimizing the harmful effects of free radicals. It almost certainly plays a less significant role than Vit C or Vit E, and the occurrence of specific selenium deficiency in humans is quite rare. It is found naturally in seafood, meats, and grains, and specific supplementation is not recommended.

*Adverse effects:* unknown

*Legality* : it is legal

#### **4.1.16 Calcium**

*Claimed action:* Calcium metabolism in the athlete is still not completely understood. The question of an increased calcium requirement is linked to concerns about osteoporosis in women athletes who, because of the intensity of their training, have become amenorrheic. The hormonal changes that occur with amenorrhea (associated with intense training programs) affect bone formation and are thought to be one of the causes of osteoporosis.

*Research:* Recent evidence has suggested that the positive effects of weight bearing exercise on bone formation may counteract and cancel out bone loss. At this time, there is no consensus on the need for calcium supplements.

*Adverse effects:* overdoses may lead to abnormal bone metabolism, blood clotting etc.

*Legality:* it is legal

#### **4.1.17 Magnesium**

*Claimed action:* Magnesium is an essential nutrient with multiple metabolic roles, including its involvement in protein synthesis and muscle contraction.

*Research:* In a 1988 review, McDonald and Keen did not find any data showing an ergogenic effect of magnesium supplementation in individuals who had normal body magnesium levels. These findings are supported by a study by Terblance in 1992 who noted no effect of magnesium supplementation on quadriceps muscle strength and fatigue during 6 weeks of recovery from a marathon. However, Brilla and Haley (1992) reported that magnesium supplementation to untrained males and females involved in 7 weeks of weight training increased quadriceps muscle torque significantly more than in the placebo group. Currently, there are too few data to justify magnesium supplementation for strength athletes, but more research appears to be warranted

*Adverse effects:* unreported

*Legality:* it is legal

#### 4.1.18 Chromium picolinate

*Underlying theory:* chromium is said to be effective in building lean body mass and shedding of fat

*Research:* In one unpublished study (Evans, 1989) Evans found that male athletes increased lean mass while taking in 400 daily ug of chromium. An especially interesting aspect of this third study was that they were able to link chromium supplementation with higher DHEA (dehydroepiandrosterone) concentrations and lower insulin levels.

The DHEA connection is an interesting one. DHEA is a steroid hormone having anabolic effects similar to those claimed for chromium picolinate.

However, the key aspect of this story is that higher insulin levels seem to lead to lower DHEA concentrations, while reduced insulin permits greater DHEA. Since chromium enhances the potency of insulin, it allows the body to get by with a lowered insulin output. Evans contended that the consequent upswing in DHEA may be one reason why chromium supplementation enhances muscle mass.

In another research carried out at Wright State University in Dayton, Ohio, 40 collegiate swimmers were divided into two groups, with one group (10 males and 10 females) ingesting 400 mcg of chromium picolinate per day for 24 weeks and the other group (also 10 males and 10 females) following a normal, non-supplemented diet. The two groups trained in identical fashion..After 24 weeks, the chromium-rich swimmers had increased lean mass by 3.3 per cent and decreased per cent body fat by 6.4 per cent, compared to the placebo swimmers. The improvement was actually greatest in the chromium-supplementing female swimmers, who carved body fat by over 8 per cent. Anecdotally, chromium swimmers tended to report more performance improvements and less muscle soreness, compared to non-supplemented athletes (Pringle et al, 1996). Unfortunately, Pringle's group used underwater weighing to assess body-composition changes, a method which is considered less reliable.

But another point to consider is that many chromium supplements are actually not pure chromium picolinate but combinations of chromium with some pretty potent other stuff. In fact, one of the most popular chromium supplements sold in health-food stores and nutrition shops actually contains chromium and a very potent herbal extract called 'Ma Huang'

([www.pponline.co.uk](http://www.pponline.co.uk))

*Adverse effects:* chromium doses above 400 ug daily is potentially dangerous

*Legality:* it is legal

#### 4.1.19 Vanadyl sulfate:

*Claimed action:* Vanadyl sulfate (VS) is a compound derived from the trace mineral vanadium. Bodybuilders are reporting that vanadyl sulfate has made their muscles bigger, harder, and denser, and endurance athletes are regaling their friends with stories about how VS has helped them run longer and faster..

*Research:* the precise metabolic action of vanadyl sulfate is not actually known, but scientists have recognised for years that the trace mineral vanadium has some insulin-like effects. Insulin is the body's most important anabolic hormone, packing energy into muscle cells, the liver, and other key organs and stimulating the synthesis of new tissues. Most relevant to endurance athletes is the fact that insulin promotes the passage of carbohydrate into muscle cells, leading to greater glycogen storage. Well, the truth is that there aren't that many scientific studies concerning VS and glycogen storage, and there are no studies carried out with real athletes.

*Adverse effects:* gastrointestinal problems . More troubling was the fact that haemoglobin dropped by about 7% after VS supplementation, and haematocrit went down by around 5 % . Those are effects no athlete would be thrilled about.

*Legality:* it is legal

#### 4.1.20 Vitamins

*Claimed action:* Research indicates that a vitamin deficiency may adversely affect physical performance.

*Research:* the overall review of the literature supports the viewpoint that vitamin supplements are unnecessary for physically-active individuals who are on a well-balanced diet with adequate calories. Most studies report that athletes who consume high calorie diets containing the RDA of all nutrients have few vitamin or mineral deficiencies (Armstrong and Maresh, 1996). Several excellent studies have shown that multivitamin/mineral supplementation over prolonged periods, up to eight months, have no significant effects on both laboratory and sport-specific tests of physical performance (Singh et al., 1992; Telford et al., 1992). Nevertheless, vitamin/mineral supplementation may be recommended for athletes consuming a low-calorie diet for weight control sports (Williams, 1998).

Some studies have shown that specific vitamins supplements may benefit sports performance in events where excess anxiety may be disruptive. For example, thiamin (B1), pyridoxine (B6), and cobalamin (B12) supplementation has been shown to enhance performance in pistol shooting, possibly because of beneficial effects on brain neurotransmitter functions (Bonke, 1986). Additional research is merited.

Supplementation with several antioxidant vitamins (beta-carotene; vitamin C; vitamin E) has been theorized to prevent muscle tissue damage associated with generation of oxygen free radicals during high-intensity exercise. However, recent reviews suggest that research regarding the value of antioxidant therapy for athletes is ambivalent. Some reviewers (Goldfarb, 1993; Kanter, 1995) note that further investigations are needed to determine the viability of antioxidant supplements in preventing exercise-induced lipid peroxidation and muscle damage. Conversely, other reviewers (Dekkers et al., 1996; Packer, 1997) indicate substantial research suggests that dietary supplementation with antioxidant vitamins has favorable effects on lipid peroxidation and exercise-induced muscle damage. All reviewers indicate more research is needed to address this issue and to provide guidelines for recommendations to athletes.

Antioxidant vitamins, particularly vitamins C and E, have also been theorized to enhance sport performance. Although vitamin C supplementation has been shown to improve physical performance in vitamin C-deficient subjects, research supports the general conclusion that vitamin C supplementation does not enhance physical performance in well-nourished individuals (Gerster, 1989). Vitamin E supplementation may increase tissue or serum vitamin E concentration, but a recent review indicates that there is no discernable effect on training or performance in either recreational or elite athletes (Tiidus and Houston, 1995). Nevertheless, Packer (1997) indicates that if antioxidant supplementation ameliorates exercise-induced muscle tissue damage, such supplementation may be beneficial in the long term. Additionally, some studies have shown that vitamin E supplementation may enhance exercise performance at altitude, but confirming research is needed (Williams, 1998B).

*Adverse effects:* none reported

*Legality:* vitamins are legal

#### 4.1.21 Pangamic acid (vitamin b15, d15)

*Claimed action:* this is touted by many athletes as a performance enhancer - increasing aerobic capacity and endurance, and decreasing blood lactate levels.

*Research:* there is no evidence from controlled studies as to any benefits in athletic performance.

*Adverse effects:* Concern has been expressed as to possible harmful effects to humans.

*Legality:* the FDA (USA) has made it illegal to sell this as a diet supplement or drug.

#### 4.1.22 Creatine

*Claimed action:* During brief, high intensity exercise, adenosine diphosphate is rephosphorylated to adenosine triphosphate (ATP) by muscle phosphocreatine stores. As muscle phosphocreatine stores become depleted, performance decreases. Oral creatine supplementation can increase muscle phosphocreatine stores by 6 to 8 percent. Increasing the available muscle stores of phosphocreatine causes faster regeneration of ATP, allowing decreased rest time between activities and increased energy for repeated bouts of exercise. Increased muscle creatine also buffers the lactic acid produced during exercise, delaying muscle fatigue and soreness. As with any ergogenic aid, increased motivation can spring from expected or perceived benefits, causing increased effort (placebo effect).

*Research:* Creatine research shows generally positive results. A short-term, double-blind, placebo-controlled study (Kreider et al, 1998) examined the effects of 28 days of creatine supplementation on 25 football players. Diet and exercise were tightly controlled, and strength and body composition were measured. Body weight, dual-energy radiograph absorptiometry-scanned body mass, fat-free and bone-free mass, and bench-press strength all increased in the athletes taking creatine. Overall lifting volume (sum of all lifts) was increased by 41 percent in this group. A five-week study (Stone et al, 1999) of 42 football players also showed gains in strength and mass. Another report (Vandenbergh et al, 1997) of 19 women who took supplements for 10 weeks also described increases in strength and mass. Some researchers (Urbanski et al, 1999 and Volek et al, 1997) have seen strength gains with as little as five to seven days of supplementation. Studies (Bermon et al, 1998) examining the effects of creatine in older individuals (60 to 82 years of age) have found no effect on body composition or strength.

Investigations (Kreider et al, 1998 and Englehardt et al, 1998) of the benefits on short-term sprint performance have shown increases in endurance time. A summary of 31 studies on sprint performance showed that supplemental creatine is associated with some improvement in athletic performance in laboratory settings, but most findings indicated no benefit on the field.

*Adverse Effects:* Weight gain is the most consistent adverse effect reported. In studies that investigated side effects, no other adverse effects were found, including no changes in electrolyte concentrations, muscle cramps or strains (Kreider et al, 1998). Researchers (Poortmans and Francaux, 1993) examined the renal function of patients who had been using creatine for as long as five years and found no detrimental effects (Poortmans and Francaux, 1993). Some studies have shown improved cholesterol profiles in persons taking creatine (Kreider et al, 1998). It must be noted, however, that most research to date has examined creatine use of three months or less, leaving questions about long-term use unanswered.

*Legality:* Creatine is legal.

#### **4.1.23 Choline**

*Underlying theory:* Choline is a precursor of acetylcholine, a neurotransmitter. In case of acetylcholine insufficiency, the muscles would cease functioning. Careful studies carried out with Boston-Marathon participants in 1985 and 1986 revealed that their blood-choline levels bottomed out at up to 50-per-cent-below normal levels by the end of the race. Some exercise scientists believe that this is behind at least a portion of the devastating fatigue which strikes near the end of a marathon, hence the advocacy for supplementation.

*Research:* To check on the performance part of the equation, researchers recently asked 10 trained runners (eight males and two females) to run 20 miles as fast as possible after taking 2.8 grams of choline citrate one hour before the run and the same amount (adding up to 5.6 total grams of choline) at the half-way (10-mile) point of their efforts. On a second occasion, the athletes ran the same distance without taking choline. Seven of the 10 subjects ran better times after taking choline, and average time for the 20-miler was five minutes faster when choline was utilised (2:33 versus 2:38).

However, a few studies have failed to link choline with any gains in performance. In one investigation, 20 well-trained cyclists (average training volume > 100 miles per week, VO<sub>2</sub>max between 58 and 81) tried either pedalling as long as possible at a supra-maximal intensity (150%

VO<sub>2</sub>max) or at a moderate level of exertion (70% VO<sub>2</sub>max, or about 80% of max heart rate), with and without choline. In both cases (during near-maximal and moderate-intensity exercise), the use of choline supplements caused a big upswing in blood-choline levels. However, there was no difference in performance between choline and placebo groups, either during short- or long-duration exercise. Surprisingly, only three of the cyclists were able to exercise longer than 100 minutes (most exercised for 'only' 70 to 80 minutes) during the moderate-intensity test. In a second study which was carried out in Dave Costill's laboratory at Ball State University, athletes cycled for 105 minutes at 70% VO<sub>2</sub>max and then rode for the following 15 minutes, with and without pre-ride choline supplementation. Choline supplements did raise blood-choline levels in this investigation, but they failed to improve performance at all (www.pponline.co.uk)

*Side effects:* The only potential problems identified so far are occasional bouts of diarrhoea or foul flatulence.

*Legality:* choline supplements are legal

#### **4.1.24 Lecithin**

*Underlying theory:* its believed to be a good source of choline

*Research:* lecithin (phosphatidylcholine) is not such a great source of choline. Choline makes up only a small percentage of the molecule.

*Adverse effects:* none as yet discovered

*Legality:* it is legal

#### **4.1.25 Ribose**

*Underlying theory:* Ribose forms part of the adenosine triphosphate (ATP) molecule and that ATP, the universal currency of energy in the body, is what makes our muscles work, the claims that ribose supplementation can deliver more power and energy and faster recovery seem pretty plausible.

*Research:* One study examined the effects of ribose supplementation on a one-week period of intense intermittent exercise (Wagemakers, 2003 ) In a randomised double-blind crossover experiment, eight athletes performed cycle training, comprising 15 sets of 10-second sprinting, twice daily for seven days. At the end of the study period, the subjects took either ribose (200mgs per kg of body weight) or a placebo three times a day for three days, after which an

exercise test was carried out and muscle ATP measured. After a washout period, the groups changed places and the experiment was repeated.

Analysis of the results showed that three days after the training period those taking ribose had regenerated their ATP to pre-training levels, while those taking placebo did not recover their ATP quite as rapidly. However, mean and peak power outputs observed in the post-training exercise test did not differ between the groups; in other words, the slower ATP regeneration seen in the placebo group made no difference to their actual performance.

In another double-blind randomised clinical trial, 19 trained men were initially tested for their anaerobic power by performing two 30-second sprint tests on a cycle ergometer, separated by three minutes of rest ( William, 2003 ) At the end of these practice sessions, blood samples were taken, and subjects were then matched for body mass and anaerobic capacity and assigned to ingest capsules containing either a dextrose placebo or ribose twice daily for five days, repeating the same tests on the sixth day. Although there was some evidence that total work performed in the second post-supplementation sprint was less in the placebo group than in the ribose group, further analysis showed that there were no significant differences in peak power, average power, torque, fatigue index, blood lactate or other blood metabolites between the groups. The researchers concluded that that oral ribose supplementation did not increase anaerobic exercise capacity or affect any of the measured metabolic markers.

Another recent study appears to provide some weak evidence that ribose can enhance sprinting performance (Poortmans, 2003 ) .In this randomised controlled double-blind clinical trial, subjects were asked to perform two bouts of repeated cycle sprint exercise in a single day, each bout consisting of six 10-second sprints, separated by 60-second rest periods. After the second bout, the subjects ingested either 32g of ribose or cellulose (an inert placebo) over the next 36 hours, and then returned to the lab to repeat the sprinting test. After a five-day washout period, the groups changed places and the whole procedure was repeated.

The results showed an increase in mean and peak power in sprint 2, and higher absolute values – although too small to be statistically significant – in sprints 1, 3 and 4. The researchers concluded that, because supplementation did not show reproducible increases in performance across all six sprints, ribose did not have a consistent or substantial effect on anaerobic cycle sprinting.

Yet another randomised double-blind controlled trial appears to pour cold water on the notion that ribose supplementation can enhance performance (Lemon, 2001). In this study, muscle power output was measured during dynamic knee extensions on an isokinetic dynamometer before and after a six-day training period, during which subjects were supplemented with either ribose (16g per day divided into four doses) or placebo. The exercise protocol consisted of two bouts of maximal contractions, separated by 15 seconds of rest. Each bout consisted of 15 series of 12 contractions each, separated by a 60-min rest period, and the subjects performed the same exercise protocol twice daily, with 3-5 hours of rest between sessions.

At the end of the test, knee extension power outputs were approximately 10% higher in both groups, but there were no differences between the groups. Neither were there any differences between the groups in blood lactate and plasma ammonia concentrations.

*Adverse effects:* none

*Legality:* ribose is legal

#### **4.1.26 Inosine.**

*Underlying theory:* Inosine is a nucleoside with a variety of proposed ergogenic effects, including enhancement of aerobic endurance performance by facilitating the delivery of oxygen to the muscles during exercise.

*Research:* scientific research is limited. Two well-controlled studies did use the recommended supplementation protocol for endurance athletes and reported no beneficial effects of inosine on cardiovascular-respiratory or metabolic functions during exercise, nor was there any effect on time to complete a simulated three mile race on a treadmill. Both studies actually suggested inosine could be ergolytic for certain athletic endeavors involving anaerobic glycolysis (Starling, R., et al., 1996; Williams, M., et al., 1990).

*Adverse effects:* Prolonged supplementation may have an ergolytic effect.

*Legality:* it is legal.

#### **4.1.27 Ornithine $\alpha$ -ketoglutarate**

*Claimed action:* this is a recent addition to the list of anabolics available to athletes. This compound, known as OKG, purportedly increases insulin output and action (Cynober et al., 1984), thereby attenuating protein degradation in skeletal muscle (Gelland et al., 1987). There is

also a preliminary report of a large OKG-induced increase in insulin-like growth factor I (IGF-I) and stature in six prepubertal children afflicted with bowel disorders (Moukarzel et al., 1993).

*Research:* apparently no complete peer-reviewed reports of well-controlled experiments on OKG effects on resistance-trained subjects as of this writing.

*Adverse effects:* none reported

*Legality:* it is legal

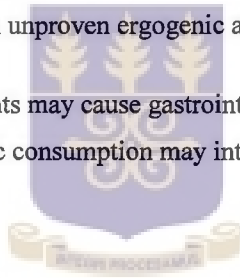
#### **4.1.28 Phosphate**

*Claimed action:* A blood phosphate compound (2,3 diphosphoglycerate, DPG) binds with hemoglobin to facilitate the release of oxygen at the level of the muscle capillary. Thus oral phosphate, a building block of DPG, has been investigated as a performance enhancer.

*Research:* results have been conflicting and although there is some suggestive evidence, this compound should be considered as an unproven ergogenic aid at this time

*Adverse effects:* Phosphate supplements may cause gastrointestinal distress unless consumed with ample fluids or food, and chronic consumption may interfere with calcium balance.

*Legality:* it is legal



#### **4.1.29 DHAP (dihydroxyacetone pyruvate)**

A metabolic byproduct of glycolysis which includes dihydroxyacetone and pyruvate in a 3:1 ratio. Several studies have suggested that 100 grams per day of DHAP for 7 days increased arm ergometer endurance at 60% VO<sub>2</sub>max and cycle ergometer endurance time at 70%VO<sub>2</sub>max. These studies are yet to be confirmed in well trained athletes (Anderson, 1997; Williams, 1998B). According to Swensen, other metabolites, such as fructose 1,6-diphosphate and lactate salts (polylactate) do not provide any ergogenic effect beyond that provided by more natural carbohydrate sources, such as glucose (Swensen, et al., 1994; Williams, 1998B).

#### 4.1.30 Cytochrome C

Cytochromes are iron containing cellular enzymes which facilitate energy transfer. The only controlled study of this compound examined the effects of a supplement containing 500 mg cytochrome C on eleven trained triathletes. The performance test included a treadmill for 90 minutes at 70% VO<sub>2</sub> max. followed by cycling to exhaustion again at 70% VO<sub>2</sub> max. There was no significant improvement over the placebo (Irvin et al, 2002)

#### 4.1.31 CoQ10 (coenzyme Q10; ubiquinone)

*Claimed action:* Coenzyme Q10 (CoQ10), also known as ubiquinone, is a lipid with characteristics common to a vitamin. CoQ10 is found in the mitochondria in all tissues, particularly the heart and skeletal muscles. CoQ10 is also an antioxidant. CoQ10 supplementation has been used therapeutically for the treatment of cardiovascular disease because it may improve oxygen uptake in the mitochondria of the heart. Theoretically, improved oxygen usage in the heart and skeletal muscles could improve aerobic endurance.

*Research:* Although research data suggests CoQ10 supplementation may benefit cardiac patients, several studies have shown that CoQ10 supplementation to healthy young or older physically-active subjects did not influence lipid peroxidation, heart rate, VO<sub>2</sub>max, or cycling endurance performance (Braun, et al., 1991; Laaksonen, et al., 1995; Snider, et al., 1992; Weston, et al., 1997). One study reported that CoQ10 supplementation was associated with muscle tissue damage and actually impaired cycling performance compared to the placebo treatment (Malm, et al., 1996). This study examined the effects of the Coenzyme Athletic Performance System (CAPS) on endurance performance to exhaustion. CAPS contains 100 mg coenzyme Q10, 500 mg cytochrome C, 100 mg inosine, and 200 IU vitamin E. Eleven highly trained male triathletes were given three daily doses of either CAPS or placebo (dicalcium phosphate) for two 4-week periods using a double-blind crossover design. A 4-week washout period separated the two treatment periods. An exhaustive performance test, consisting of 90 minutes of running on a treadmill (70% VO<sub>2</sub>max) followed by cycling (70% VO<sub>2</sub>max) until exhaustion, was conducted after each treatment period. The mean time to exhaustion for the subjects using CAPS (223 +/- 17 min) was not significantly different ( $p = 0.57$ ) from the placebo trial (215 +/- 9 min). Blood glucose, lactate, and free fatty acid concentrations at exhaustion did

not differ between treatments ( $p < 0.05$ ). CAPS had no apparent benefit on exercise to exhaustion (Malm et al, 1998)

*Adverse effects:* One study reported that CoQ10 supplementation was associated with muscle tissue damage and actually impaired cycling performance compared to the placebo treatment (Malm, et al., 1996).

#### **4.1.32 Medium-chain triglycerides (MCT)**

*Claimed action:* Exercise scientists have long speculated that MCTs might promote improved endurance performances, primarily because MCTs can slip into the mitochondria inside muscle cells much more readily than regular fats. Since muscles create most of the energy they need by breaking down fat and carbohydrate inside their mitochondria, MCTs' ability to enter the mitochondria quickly should increase energy production and help to conserve muscles' most precious fuel – glycogen.

*Research:* Until now, however, MCTs' capacity to enhance exercise was speculative, but a new study at the University of Cape Town demonstrates that MCTs can indeed improve performances in certain situations. In the South African study, six experienced cyclists performed the same exercise test on three separate days. The test consisted of two hours of easy pedaling at just 60%  $V_{O2max}$  (about 73 per cent of maximal heart rate), closely followed by a 40-kilometre time trial completed as quickly as possible. During the three tests, the athletes consumed either a 10-per cent carbohydrate solution, a 4.3-per cent MCT beverage, or a drink which contained both 10-per cent carbos & 4.3-per cent MCTs. In all cases, the subjects consumed 400 ml (14 ounces) of drink at the beginning of the test and then 100 ml every 10 minutes thereafter.

The carbohydrate & MCT drink produced the best performances during the 40-K time trial (Buci, 1993)

*Adverse effects:* MCTs are found in 'bad' foods like coconut oil, which is 87+ % saturated fatty acid.

*Legality:* it is legal ([www.pponline.co.uk](http://www.pponline.co.uk))

#### 4.1.33 Omega-3 fatty acids

*Claimed action:* The less depressed you are, the higher will be your motivation and drive to succeed as an athlete, so inclusion of omega-3 fats in your diet may be favourable to performance from a mental standpoint.

*Research:* Only one peer-reviewed piece of research has actually looked at whether omega-3 fats can bolster exercise capacity. In that study, carried out at Western Washington University, 32 healthy young males were divided into four groups. One group acted as controls, a second group ingested four grams of omega-3 fat per day, a third group undertook a vigorous aerobic exercise programme, and a fourth group participated in the same exercise programme while taking the omega-3 supplements.

After 10 weeks, the non-exercising group which consumed omega-3s was better off than the non-exercised control group without the omegas. Their average VO<sub>2</sub>max had risen by 11 per cent, against just 4.5 per cent for the controls. In other words, starting to supplement one's diet with omega-3s is a bit like going on a moderate exercise programme; one's ability to utilize oxygen seems to increase

However, both exercising groups, the one with omega-3s and the one without, broadened VO<sub>2</sub>max by about the same amount, 20%, indicating no additional benefit of omega-3 fats when an exercise programme is undertaken. It would be interesting to see this same study carried out for a longer period of time or with a more experienced group of athletes ([www.pponline.co.uk](http://www.pponline.co.uk))

*Adverse effects:* potential weight gain problems

*Legality:* it legal

#### 4.1.34 Conjugated linoleic acid

*Claimed action:* Conjugated linoleic acid supplementation is said to have decreased body fat and increased lean muscle mass in animals.

*Research:* most human studies show no benefit to body composition or energy. Experienced resistance-trained athletes show no ergogenic effect from supplementation.

*Adverse effects:* Possible side effects include GI distress

*Legality:* it is legal.

#### 4.1.35 L-carnitine

*Claimed action.* L-carnitine facilitates the transport of fatty acids into the mitochondria for oxidation and also facilitates the oxidation of several amino acids and pyruvate, functions that theoretically could lead to a sparing of muscle glycogen during exercise and a decreased production of lactate.

*Research:* recent reviews of the available research do not support an ergogenic effect of L-carnitine supplementation on fuel utilization during exercise, maximal heart rate, anaerobic threshold, maximal oxygen uptake, time to exhaustion in various anaerobic or aerobic exercise tasks, or performance in either a marathon or 20-kilometer run (Heinonen, 1996; Wagenmakers, 1991; Williams, 1998B).

*Adversed effects:* Side effects include diarrhea and fishy breath. The D-carnitine form can cause muscle weakness.

*Legality:* it is legal

#### 4.1.36 Glycerol

*Claimed action:* Rehydration during exercise in the heat has been shown to decrease physiological stress as evidenced by a decreased heart rate response, lesser rise in the core temperature, and increased endurance performance. Hyperhydration before exercise may also be helpful, but has not been shown to be as effective as rehydration (Williams, 1998B). Glycerol (glycerin), an alcohol byproduct of fat hydrolysis, has been studied as a means to enhance the hyperhydration effect. Small amounts of glycerol are mixed with water in set proportions and the water is consumed following normal hyperhydration procedures.

*Research:* Glycerol-induced hyperhydration, when compared to water hyperhydration alone, has been shown to increase total body water in some (Freund, et al., 1995; Koenigsberg, et al., 1995), but not all (Latzka, et al., 1997) studies. Several studies have shown that glycerol-induced hyperhydration improves cardiovascular responses, temperature regulation, and cycling exercise performance under warm/hot environmental conditions (Lyons, et al., 1990; Montner, et al., 1996). However, other research has shown that both glycerol and carbohydrate supplementation improved cycling endurance compared to a placebo solution, suggesting carbohydrate

supplementation was as effective as glycerol supplementation as a means to enhance performance (Lamb, et al., 1997). Additional research is needed to resolve these equivocal findings, particularly so in sports such as distance running in which the extra body mass (water weight) must be moved as efficiently as possible.

*Adverse effects:* hyperhydration may render the athlete 'water logged' and give him excess weight

*Legality:* glycerol is legal

#### **4.1.37 Glucosamine sulfate**

*Claimed action:* An over the counter agent derived from shark cartilage, glucosamine sulfate is said to be helpful in decreasing the joint pain from degenerative or wear and tear arthritis (osteoarthritis).

*Research:* There is no evidence that it decreases the muscular pain associated with over training.

#### **4.1.38 Anabolic Steroids**

*Claimed action:* Anabolic steroids are testosterone derivatives with three mechanisms of action. First, anticatabolic effects- reverse the actions of glucocorticoids and help metabolize ingested proteins, converting a negative nitrogen balance into a positive one. Second, anabolic effects - directly induce skeletal muscle synthesis. Third, there is a "steroid rush"--a state of euphoria and decreased fatigue that allows the athlete to train harder and longer (Haupt and Rovere, 1984).

*Research:* Many early studies used physiologic doses, or doses only two to three times these amounts, and provided mixed results. More recent reviews, controlling for various measurement methods, have concluded that anabolic steroids do indeed cause increased strength and muscle mass. A randomized, double-blind, 10-week study (Bhasin et al, 1996) of 40 men examined the effect of supraphysiologic testosterone doses. The participants were divided into four groups: those given a placebo with or without weight training and those given 600-mg testosterone enanthate with or without weight training. Diet and training times were controlled. Fat-free mass, muscle size and strength increased more than placebo in both groups taking testosterone than in the groups taking placebo. The subjects in the exercise plus testosterone group had a 9 percent increase in mass and 23 percent increase in bench-press strength, compared with 3

percent and 9 percent, respectively, in the subjects in the exercise plus placebo group. These doses were comparable with the doses that many athletes, who use steroids, take.

*Adverse Effects:* Anabolic steroids have many adverse effects, most related to the unwanted androgenic effects. Some of the adverse effects are potentially serious and irreversible

*Table 1: Reported side effects of Anabolic Steroids*

<b>Reversible Side Effects</b>	<b>Serious and Irreversible Side Effects</b>
<b><i>Sexual effects:</i></b>	Hypertension from mineralocorticoid effects
Increased or decreased libido	Dysplastic changes in collagen fibrils, resulting in severe tendon ruptures
Decreased sperm production	
Scrotal pain	Liver tumors (hepatocellular carcinoma, hepatic adenoma, hepatic cholangiocarcinoma)
Gynecomastia	
Cutaneous effects	
Acne	Psychosis (i.e., "steroid rage")
Hirsutism	
Edema	Irreversible hirsutism, clitoral hypertrophy and deepening of voice in women Premature closure of growth plates, causing shorter stature in adolescents
<b><i>Psychiatric effects:</i></b>	
Euphoria	
Nervousness	
Aggression	
Personality disorders	
<b><i>Others</i></b>	
Increased transaminases	

(USDA, 1996)

*Legality:* Anabolic steroids such as testosterone and its derivatives are prescription medications with clearly defined indications. Procuring and using them without a prescription is illegal. Most sports organizations have rules that ban the use of anabolic steroids for any reason

#### **4.1.39 Dehydroepiandrosterone , Androstenedione & androsterone**

*Claimed action:* Both of these supplements are precursors in the gonadal steroid pathway. Increasing supplies of precursors theoretically cause a physiologic increase in testosterone synthesis.

*Research:* Dehydroepiandrosterone (DHEA) has been studied for its replacement role in older men and women. These studies (Flynn et al, 1999 and Morales et al, 1998) found testosterone levels increased in women, but were unchanged in men, with no changes in body composition noted. No published studies of its ergogenic benefit in younger athletes exist. One eight-week study (King et al, 1999) evaluated androstenedione supplementation in 30 men, aged 19 to 29 years, during resistance training. No differences in muscle size, strength or overall body composition were noted. One study (Leder et al, 2000) has shown transient increases in serum testosterone levels but no ergogenic benefit has been demonstrated.

*Adverse Effects:* No long-term studies of adverse effects are available. If these precursors could successfully increase testosterone production, they would likely cause the many adverse effects associated with anabolic steroids.

*Legality.* These substances are banned by the International Olympic Committee (IOC).

#### **4.1.40 Clenbuterol**

*Underlying theory:* Clenbuterol is a popular - but banned - drug used by athletes in body-building,. The chemical is attractive to athletes because it appears to have an anabolic effect on human muscles, and it may also increase fat metabolism. However, the actual effects of long-term clenbuterol intake on performance, muscle power, and overall health have been unclear ([www.pponline.co.uk](http://www.pponline.co.uk)).

*Research:* To determine some of clenbuterol's actions, scientists at the University of Melbourne in Australia gave clenbuterol to laboratory rats at dosages of 2 milligrams per kilogram of body weight per day. Some of the rats followed a completely sedentary lifestyle, while others sprinted

on treadmills or engaged in endurance swim training. Clenbuterol did have a couple of potentially positive effects: Sedentary rats which ingested clenbuterol had larger muscles than clenbuterol-free, sedentary rodents, and clenbuterol users also transformed leg-muscle cells from slow-twitch to fast-twitch fibres, a surprising change which would tend to increase anaerobic energy production and magnify muscle power during short, intense exertions (Morales, 1994). *Adverse effects:* However, clenbuterol also yielded three very negative changes. First, after just four weeks, clenbuterol-treated rats were unable to maintain their normal swimming or running training intensities, while clean rodents were quite capable of continuing. Secondly, the hearts of the clenbuterol-taking, trained rats increased dramatically in size compared to the hearts of sedentary rats, but the heart expansion was probably due to the infiltration of collagen fibres into the heart walls, not an increase in heart-muscle cells. Collagen is a tough connective tissue which doesn't augment heart-muscle power but in fact stiffens the heart, potentially leading to a decrease in cardiac output. Increases in collagen may also produce cardiac arrhythmias. Thirdly, clenbuterol rats suffered from noticeable cardiac-cell degeneration.

In addition, although sedentary, clenbuterol-treated rats were more muscular than clenbuterol-free, sedentary rats, clenbuterol was unable to boost muscle mass among either the swim- or treadmill-trained rodents. It appears that, in spite of its popularity, clenbuterol is a potentially dangerous drug which offers very few positive effects for either the power or endurance athlete (King, 1994).

*Legality:* Clenbuterol is banned by the IOC and many other sports governing bodies.

#### **4.1.41 Albuterol and salbuterol**

*Underlying theory:* Albuterol (salbutamol) holds a similar quandary as clenbuterol.

*Research:* In a 3-week study (Martineau et al, 1992) of an oral form of albuterol, it seemed to increase, though inconsistently, the voluntary strength of young men. A study (Caruso et al, 1995) in which healthy young men took oral albuterol (4 mg four times daily for 6 weeks) suggests that resistance exercise may augment any strength gain from albuterol. In two other studies (Robertson et al, 1994 and Morton et al, 1996), however, long-acting inhaled salmeterol had no ergogenic effect on maximal or endurance cycling in asthmatic men. For now, all long-acting beta2 agonists are banned, but some authors are calling for legalizing salmeterol for asthmatic athletes (Morten et al, 1996).

Whether the legal inhaled form of albuterol is ergogenic remains controversial. As reviewed in four studies (Meeuwisse et al, 1992; Morten et al, 1993; Lemmer et al, 1995 and Norris et al, 1996), the weight of evidence suggests that single doses of albuterol are not ergogenic for asthmatic or nonasthmatic athletes. Two early studies in cyclists suggested that albuterol was ergogenic, but their design has been faulted, and six other studies (three in cyclists, two in runners, one in power athletes) found no immediate ergogenic effect for albuterol on either power or endurance. Researchers do caution, however, that albuterol is conceivably ergogenic at higher or prolonged dosage (Norris et al, 1996).

In spite of the confusing research picture regarding albuterol, the peculiar epidemic of "asthma" among elite athletes suggests that they think albuterol is ergogenic. The declared prevalence of exercise-induced asthma (EIA) among American Olympians shot up from just over 10% at the 1984 Summer Games to nearly 60% at the 1994 Winter Games (P.Z. Pearce, MD, personal communication, 1994). Though some of this increase could be ascribed to the contribution of cold weather to EIA, the size of the increase suggests that more and more Olympians want to be approved to use albuterol in order to level the playing field.

*Adverse effects:* similar to clenbuterol

*Legality:* Legal only in inhaled form for exercise-induced asthma.

#### **4.1.42 Caffeine**

*Claimed action:* Caffeine enhances the contractility of skeletal and cardiac muscle, and helps metabolize fat, thereby sparing muscle glycogen stores. It is also a central nervous system stimulant, which can aid in activities that require concentration.

*Research:* Many small studies (Graham and Spreit, 1991 and Kalmar and Cafaralli, 1999) using randomized, double-blind design have associated caffeine use with increased endurance times. The smallest dose linked to positive results was 250 mg (approximately 3.0 to 3.5 mg per kg) (Anselme et al, 1992). Other studies have used doses of 6 to 9 mg per kg.

*Adverse Effects:* Ergogenic doses of caffeine may cause restlessness, nervousness, insomnia, tremors, hyperesthesia and diuresis. Caffeine use has no adverse effects on body temperature or sweating (Dunagan et al, 1998).

*Legality:* Caffeine is part of a regular diet for most people and is legal to a certain level. The legal urine level for athletes is 12 µg per mL (IOC standards) or 15 µg per mL (NCAA standards). The ergogenic dose is approximately one half of this--250 to 500 mg (three cups of coffee or six to eight sodas). Many athletes take caffeine in pill form.

#### **4.1.43 Guarana**

A South American herb used as a natural source of caffeine. Used in the energy gel “*Pocket Rocket*”, which contains the equivalent of 50 mg of caffeine per 1.2 ounce packet. The caffeine effect of one teaspoon (100 mg) of guarana is equivalent to one cup of coffee (www.pponline.co.uk)

#### **4.1.44 Caffeine and Ephedrine Combination**

*Claimed action:* Sympathomimetics such as ephedrine, pseudoephedrine, phenylpropanolamine and herbal ephedrine (ma huang) are used for their stimulant properties. This combination is found in many “energizing” and diet supplements and is used to increase subjective energy, decrease appetite and increase metabolism without exercise (Bell et al, 1998).

*Research:* A double-blind study (Bell et al, 1998) of eight patients showed prolonged time to exhaustion and decreased perception of exertion with a caffeine and ephedrine combination. Studies (Bell et al, 1998 and Swain et al, 1997) of sympathomimetics alone have not shown benefit.

*Adverse Effects:* The combined adverse effects of these stimulants include restlessness, nervousness, tachycardia, arrhythmias and hypertension. As of August 1998, at least 17 deaths have been linked to use of these products in combination (Gurley et al, 1998).

*Legality:* Use of ephedrine products and elevated levels of urinary caffeine, as noted above, are banned by the IOC.

#### **4.1.45 Alcohol**

*Claimed action:* Occasional articles appear touting the benefits of alcohol as an energy source for various sports activities.

*Research:* Although alcohol does contain more energy per gram (7 cal/gm) than carbohydrates, and is rapidly absorbed from the intestinal tract, the available evidence suggests these Calories are not utilized to any significant extent during exercise. Thus its negative effects outweigh any theoretical positive ones. Alcohol is a diuretic and contributes to dehydration. It impairs endogenous glucose production and release from the liver and impairs nervous coordination.

In a recent study from Penn State, 10 women were given a moderate drink. They then rode stationary bikes for 30 minutes at 70% of their maximum heart rate. Compared to their baseline performance off alcohol, cycling after alcohol required more energy, produced a higher heart rate, and stimulated a higher cardiovascular demand..

*Adverse effects:* Even moderate drinking while exercising placed increased demands on the cardiovascular system. The bottom line is a definite negative influence on performance ([www.physicallyelite.com](http://www.physicallyelite.com)).

*Legality:* Alcohol is banned by many sporting organizations

#### **4.1.46 Anti-inflammatories**

*Claimed action:* taking anti-inflammatories like aspirin before cycling or other vigorous activity can reduce muscle soreness.

*Research:* A study at the University of Georgia concluded that even at large doses (20 mg per kg or 4 standard aspirin for the average rider), aspirin did not delay the onset of muscle pain during exercise or reduce the perceived intensity when it occurred.

*Adverse effects:* there is good evidence that using agents such as motrin (ibuprofen) or aspirin on a regular basis increases the incidence of ulcers and can cause kidney and liver damage. ([www.cyclingperformancetips.co.uk](http://www.cyclingperformancetips.co.uk))

*Legality:* it is legal

#### **4.1.47 Human Growth Hormone (somatotrophin)**

*Underlying theory:* The situation of recombinant human growth hormone (hGH) seems similar to that of anabolic steroids in the early years of their use. Scientists report that hGH may not increase effective strength or performance, but some athletes, convinced it works, use it.

*Research:* Two studies (Yarasheski KE, Campbell JA, Smith K, et al, 1992 and Yarasheski et al, 1993) suggest no performance benefit from hGH. When 16 untrained men underwent a 12-week muscle-building program, receiving either hGH or placebo, the hGH increased fat-free mass and total body water, but not muscle protein synthesis, muscle size, or strength. With hGH use, insulin action was slightly impaired, and two of the men contracted Carpal Tunnel syndrome. When seven trained weight lifters were given hGH for 2 weeks as they continued training, the hGH did not increase the rate of muscle protein synthesis or reduce the rate of whole-body protein breakdown.

The early interest in hGH as a rejuvenator is fading. Now a 6-month, controlled, randomized, double-blind study (6) of hGH in healthy older men (mean age 75 years) reports slight improvements in body composition (decrease in fat mass, increase in lean mass), but *no* increase in strength, endurance, or cognitive function.

*Adverse effects:* Side effects include insulin resistance (diabetes), water retention, and Carpal Tunnel syndrome. At this time, injectable growth hormone should be considered potentially dangerous.

*Legality:* it is illegal

#### **4.1.48 Blood doping**

*Claimed action:* Another name for red blood cell reinfusion. In this procedure 1 to 4 units (one has about 10 units of whole blood circulating normally) of blood are removed, the red blood cells separated from the plasma and stored, and the plasma reinfused. Three to four weeks later (when the body has replaced the red blood cells removed) and just prior to the event, the stored red blood cells are reinfused with a rise in the hematocrit from a normal 40-45% to 60%. The increased hematocrit will persist for 14 days or so before the body readjusts through decreased red blood cell production. Since red blood cells carry oxygen from the lungs to the muscles, this increase in the total red blood cell mass is beneficial to the endurance athlete for whom oxygen transport and delivery to the muscle are often limiting factors in performance.

*Research:* generally supports. In controlled studies this translates into a 5 to 13% increase in aerobic capacity, reduced submaximal heart rate and blood lactate, and augmented endurance.

*Adverse effects:* The opposite side of this issue is the definite deterioration in performance within the training period that results from donating a unit of blood. Research has shown that both VO<sub>2</sub>max and endurance suffer after blood donation. There is an immediate drop in plasma volume of 7 to 13% which persists for up to 24 hours, and the loss of hemoglobin may not be corrected for several weeks, even with an iron supplemented diet. There is also the possibility of infection from contaminated blood sample.

*Legality:* blood doping is illegal.

#### **4.1.49 Erythropoietin (EPO)**

*Claimed action:* EPO is a hormone, produced by the kidney, which stimulates the bone marrow to produce red blood cells. It is available in injectable form and can be self administered to "hyper"stimulate the bone marrow. The result is an abnormally high hematocrit (hct) which effectively creates the same physiologic conditions as blood doping.

*Research:* generally supports

*Adverse effects:* when administered in an unmonitored manner, the hematocrit can increase above 60% increasing blood viscosity and predisposing to the formation of blood clots (also aggravated by the dehydration which occurs in competitive cycling). This clotting tendency is speculated to be the explanation for the cases of sudden death which have been reported after hard training or racing - most likely from a heart attack or a pulmonary embolism.

*Legality:* EPO is banned in sanctioned events. But as it is almost impossible to monitor for an excess of a hormone that is naturally produced, it is the hct. that is monitored, not the hormone itself. Any cyclist with a hct greater than 50% is not allowed to compete, regardless of the mechanism of the increased hct. Unfortunately this is not as fair as a test for EPO, but health concerns were felt to override those of fairness.

#### **4.1.50 Ginseng**

*Claimed action:* Ginseng is said to alleviate fatigue and increase endurance. Although ginseng contains some chemicals which probably have an impact on human physiology (most notably the 'ginsenosides,' which are known chemically as glycosylated steroids - steroids with ring-like sugar structures attached), the exact mechanism by which ginseng might influence human

performance is unknown. One popular idea is that ginseng increases the production of cortisol, a key 'anti-stress' hormone released by the adrenal glands. Another theory is that ginseng might enhance the ability of muscles to extract oxygen from the blood ([www.pponline.co.uk](http://www.pponline.co.uk))

*Research:* scientists at Wayne State University in Detroit divided 36 healthy men into three different groups. Placebo-group members received no ginseng during the eight-week study. Men in a second group ingested 200 mg of a standardized Panax ginseng preparation per day (in which 100 mg of the preparation was equivalent to 500 mg of Panax ginseng root), and a third group's members took in a very high dose - 400 mg of ginseng daily (the clinically recommended amount is 200 mg per day). Before and after the eight-week period, the subjects were assessed for oxygen consumption, respiratory exchange ratio, ventilation, blood-lactate concentration, heart rate, and perceived exertion during both submaximal and maximal exercise on a stationary bicycle. The study was carried out in double-blind (Burke et al, 1997). The research showed that ginseng did absolutely nothing. There was no effect on oxygen consumption, lactate production, perceived effort, or anything else. This same Wayne State research group has also shown that ginseng does not increase the work capacities of healthy young women

In another related studies in 1994 by Morris Jacobs and colleagues, Ginseng saponin ingested at either 8 or 16 mg/kg body weight for 7 days did not improve either submaximal or maximal cycling performance. They concluded ginseng is not an ergogenic aid (Jacobs et al, 1994).

*Side effects:* In the Wayne State work, three of the subjects in the high-dose (400 mg per day) ginseng group developed nasty bouts of diarrhoea, and other reports have linked ginseng with high blood pressure, nervousness, and sleeplessness. However, ginseng itself may not always be the culprit underlying these disorders, since investigators have determined that some 'ginseng' products contain no ginseng at all but some other potent stuff, in one case –ephedrine.

*Legality:* ginseng is legal

#### **4.1.51 Siberian ginseng**

A Chinese herb, questionably related to ginseng - as in many of these herbal products it is difficult to determine the exact chemical makeup - claimed to have benefit as a brain stimulant. A group of volunteers is reported to have shown an increase in mental alertness and work output,

while another study suggested an increase in athletic performance under stressful conditions such as heat and noise. As with other herbal products, these claims are anecdotal and there is no scientific proof of increased athletic performance.

#### **4.1.52 Echinacea**

*Underlying theory:* Echinacea is said to boost the immune system. Echinacea is a plant native to the United States which grows nowhere else in the world - except for the extreme southern portion of Canada. The word Echinacea actually comes from a Greek word 'echinos,' which means sea urchin and refers to the plant's sea-urchin-shaped, flowering head. The Cheyenne used Echinacea to soothe sore gums, the Comanches favoured the herb for sore throats, the Crows were keen on it for colic, the Delaware employed it for its anti-gonorrhoea properties, the Kiowa tried Echinacea for coughs, the Fox for fits, the Winnebago for anaesthesia, and the Sioux to cure maladies originating in either the bowels or blood. Almost all of the tribes believed there was no better medicine for infections.

*Research:* Echinacea has been used in a variety of ways with humans. In one study, individuals with far-advanced, inoperable liver cancers were given Echinacea and two other drugs - cyclophosphamide and thymostimulin. Immune system parameters improved considerably, with T-helper cells increasing significantly and suppressor cells decreasing appreciably. Natural killer (NK) cells, which actively seek out and destroy tumour cells, increased by 17 per cent, and their actual activity burgeoned by 90 per cent (Wheeler, 1990). However, it's not clear that Echinacea was the key ingredient which produced these effects, since it was mixed with two other compounds.

Athletes are often plagued by upper-respiratory-tract infections, and the research with Echinacea in that area has been fairly positive. For example, in a double-blind, placebo-controlled study carried out with 180 individuals, German researchers determined that four 'droppersful' (from a standard medicine dropper) of Echinacea extract per day were better than a placebo preparation at relieving the symptoms and duration of influenza. In the same study, however, two droppersful of Echinacea per day were not enough to alleviate symptoms.

In another double-blind, placebo-controlled study with humans, individuals who suffered from fairly frequent upper-respiratory infections such as ear infections, sinusitis, bronchitis, tonsillitis, or laryngitis were given either Echinacea or a placebo over an eight-week period. The Echinacea was given in a fairly popular commercial preparation called Echinacin, and the dosage was 4

millilitres twice a day for the eight weeks.

Compared to the control group, the Echinacea people suffered fewer infections, the time between infections was lengthened, the duration of illness was shortened, and severity of symptoms was reduced (Zeit, 1992). In addition, 36-per cent more people in the Echinacea group had no illnesses at all during the test period. The Echinacea formulation seemed to be most helpful to individuals with lowered T4/T8 ratios (T4 cells spur the immune system to activity, while T8 cells relax it).

*Adverse effects:* unknown. Extremely high doses of Echinacea extract have been given to laboratory animals, with little evidence of tumour induction or toxicity.

*Legality:* echinacea is legal

#### **4.1.53 Smilax (Smilax officinalis)**

*Claimed action:* Smilax officinalis, native to the tropics of Brazil, began as a pharmaceutical base for the production of certain anabolic steroids. It is alleged to raise the blood content of testosterone and to be equivalent to anabolic steroids in gains of lean muscle mass and defined tissue.

*Research:* these performance claims are not supported by published research studies (Grunewald & Bailey, 1993 )

*Adverse side effects:* without the chemical modifications, smilax officinalis is thought to be non-toxic and its use has no known negative side effects

*Legality:* it is legal

#### **4.1.54 Quinine**

*Claimed action:* This medication is used by cyclists as a cure for leg cramps.

*Research:* this claim is not supported by published research studies.

*Adverse effects:* it can cause a drop in blood count and has been linked to 16 deaths.

*Legality:* banned by the American Food and Drug Administration (FDA) ([www.pponline.co.uk](http://www.pponline.co.uk))

#### **4.1.55 Pycnogenol**

*Claimed action:* pycnogenol is a procyanidin extracted from the tree bark of the pine, *Pinus maritima*. It is a free radical scavenger and antioxidant when studied in the test tube.

*Research:* there have been limited animal studies and no human studies of this compound. There is no proof as to benefits of this compound compared to the antioxidant effects of Vitamins C or E. ([www.physicallyelite.co.uk](http://www.physicallyelite.co.uk))

*Adverse effects:* unknown

*Legality:* it is legal

#### **4.1.56 Oryzanol**

*Claimed action:* A plant extract claimed to have anabolic effects. This is a ferulic acid compound derived from rice bran oil.

*Research:* Although gamma oryzanol may influence lipid metabolism, there are no data supportive of an ergogenic effect in humans. Wheeler and Garleb (1991) reviewed research with animals and speculated that gamma oryzanol actually may reduce testosterone production. Any effect on performance is purely speculative.

*Adverse effects:* may decrease testosterone production

*Legality:* it is legal

#### **4.1.57 Humic acid**

Humic substances (including humic acid) are ubiquitous in the environment and may constitute as much as 95% of the total dissolved organic matter in aquatic systems. Although they have been touted as a health supplement, their use at this time should be considered risky ([www.physicallyelite.co.uk](http://www.physicallyelite.co.uk))

#### 4.1.58 Ferulic acid (frac)

Ferulic acid is derived from the natural plant sterol, frac, and has been claimed to assist the body in maintaining greater workloads. However these performance claims are not supported by published research studies. ([www.physicallyelite.co.uk](http://www.physicallyelite.co.uk))

#### 4.1.59 Astragalus

A root herb from the Mongolian wilderness. Reported to increase the body's capacity to handle stress, and help reduce fatigue and enhance endurance. There are no studies with specifics. All information is purely anecdotal. ([www.physicallyelite.co.uk](http://www.physicallyelite.co.uk))

#### 4.1.60 Yohimbine

*Claimed action:* Yohimbine is a nitrogen-containing alkaloid extracted from the bark of the yohimbe tree. It functions as an alpha2-adrenoreceptor blocker, increasing serum levels of norepinephrine (Grossman et al,1991 ). Yohimbine has been used as an adjunct in the treatment of obesity (Kucio et al., 1991) and for the treatment of impotence (Grunewald & Bailey, 1993). Comparable to Smilax, yohimbine and yohimbe bark are advertised to increase testosterone levels.

*Research:* no scientific data have been disclosed supportive of any anabolic effects.

*Adverse effects:* unknown

*Legality:* it is legal

#### 4.1.61 Glandulars

*Claimed action:* Glandulars are extracts from various animal tissues or glands, such as the pituitary, thymus, adrenal, and testes. Their use is based on the premise that they will enhance function of the glands in the body from which they are derived, e.g., orchic extract from the testes purportedly facilitates testosterone production.

*Research:* these glandular extracts are degraded during the digestive process and are inactive when absorbed as the digested components (Newsom, 1989).

*Adverse effects:* none reported

*Legality:* it is legal

#### **4.1.62 Lycopene**

*Claimed action:* it is an antioxidant that has been promoted as reducing the risk of prostate cancer, but more clinical trials need to be done. ([www.cycling performance tips - nutritional myths.htm](http://www.cyclingperformance.com/nutritional-myths.htm))

#### **4.1.63 Saw palmetto**

*Claimed action:* It is a herb advertised to reduce the risk of benign prostate hyperplasia. Due to lack of standardization of herbal products, it is difficult to test its efficacy. Side effects are rare. ([www.cycling performance tips - nutritional myths.htm](http://www.cyclingperformance.com/nutritional-myths.htm))

#### **4.1.64 Quercetin**

*Claimed action:* it is an antioxidant naturally found in foods such as onions and other vegetables, apples, and wine. Its purported as an aspirin substitute in combination supplements. There is no data to that assertion. ([www.cycling performance tips - nutritional myths.htm](http://www.cyclingperformance.com/nutritional-myths.htm))

4.2.1 Table 2: A list of 77 ergogenic aids, their legality, claimed actions & side effects

Ergogenic aid	Legality	Claimed action	Research	Side effects
1. Water	Legal	Increase endurance, cools body	Supports	None at normal hydration
2. Anabolic steroids	Illegal	Increase strength, lean muscle mass and motivation	Supports	Significant, dangerous
3. Creatine	legal	increases muscle energy, short term endurance, strength, and lean muscle mass	supports,	mild
4. Dehydroepiandrosterone	illegal	same as steroids	no benefit in healthy athlete	potentially dangerous
5. Androstenedione	illegal	same as steroids	refutes, no benefits	Significant
6. Androstenediol	illegal	same as steroids	limited, refutes	Unknown
7. Caffeine	Legal to urine level of 12 to 15 µg per mL	increases muscle contractility and aerobic endurance, enhances fat metabolism	Supports	Mild, significant at high doses
8. Ephedrine	illegal	stimulates CNS, increases energy, delays fatigue, stimulates weight loss	no benefit	potentially dangerous

<b>Ergogenic aid</b>	<b>Legality</b>	<b>Claimed action</b>	<b>Research</b>	<b>Side effects</b>
9. Protein	Legal	optimizes muscular growth and repair	supports, increased need for protein with activity, limited benefit for the well nourished	none unless underlying medical condition
10. Branched chain amino acids	Legal	limit perceptions of fatigue	limited, no ergogenic effect	none unless underlying medical condition
11. Arginine, ornithine, lysine	Legal	Stimulate growth hormone release	No benefit	None at doses used
12. Alanine	Legal	Helps keep blood sugar levels stable	limited, no ergogenic effect	none
13. Leucine	Legal	decreases muscle breakdown, spares muscle glycogen stores	limited, no ergogenic effect	None
14. Beta-hydroxy-beta-methylbutyrate (HMB)	Legal	decreases muscle breakdown	limited, no ergogenic effect	None
15. Gamma-hydroxybutyric acid	Illegal	Promoted as a steroid alternative for body-building	limited, no ergogenic effect	Unknown
16. Carbohydrates	Legal	Increase endurance, decrease fatigue	Supports	Mild at high doses

<b>Ergogenic aid</b>	<b>Legality</b>	<b>Claimed action</b>	<b>Research</b>	<b>Side effects</b>
17.Honey	Legal	Boosts carbohydrate reserve, increase endurance	limited, no ergogenic effect	Mild at high doses
18.Fructose	Legal	Increase endurance, decrease fatigue	refutes, no benefits	Mild at high doses
19.Sodium bicarbonate	Legal	Counter lactic acid buildup, prolong fatigue	Supports	Mild at high doses
20.Sodium citrate	Legal	Counter lactic acid buildup, prolong fatigue	Mixed, some positive benefits	Mild at high doses
21.Aspartates	Legal	Increase free fatty acid use, sparing muscle glycogen	Mixed, some limited positive benefits	Mild at high doses
22.Boron compounds	Legal	Boosts testosterone level	refutes, no benefits	Significant
23.Zinc	Legal	Boosts immunity	refutes, no benefits	Mild at high doses
24.Iron	Legal	Increases aerobic endurance	limited, no ergogenic effect	potentially dangerous
25.Selenium	Legal	As an antioxidant	refutes, no benefits	Unknown
26.Calcium	Legal	Increases muscle contractility, enhances glycogen metabolism	Refutes, no benefit	Mild at high doses

<b>Ergogenic aid</b>	<b>Legality</b>	<b>Claimed action</b>	<b>Research</b>	<b>Side effects</b>
27.Magnesium	Legal	Improves protein synthesis , muscle contraction	Refutes, no benefit	None
28.Chromium picolinate	Legal	Increases lean mass	Refutes, no benefit unless prior deficiency	Safe to 400 µg daily
29.Vanadyl sulfate	Legal	Improves glycogen storage, Increase muscle mass	Refutes, no benefit	Mild, significant at high doses
30.Ginseng	Legal	Alleviate fatigue and increase endurance	Refutes, no benefit	Mild at high doses
31.Siberian ginseng	Legal	Alleviate fatigue and increase endurance	Refutes, no benefit	Mild at high doses
32.Endurox	Legal	Lowers heart rate, lifts lactate threshold and helps burn 43% more fat	Refutes, no benefit	Unknown
33.Echinacea	Legal	Boosts immune system	no ergogenic effect	Unknown
34.Similax officinalis	Legal	raise the blood content of testosterone	Refutes, no benefit	Unknown
35.Quinine	Illegal	A cure leg cramps in cyclists	Mixed, limited positive benefits	Potentially dangerous

<b>Ergogenic aid</b>	<b>Legality</b>	<b>Claimed action</b>	<b>Research</b>	<b>Side effects</b>
36.Pycnogenol	Legal	As an antioxidant	Refutes, no benefit	Unknown
37.Oryzanol	illegal	As an anabolic steroid	Refutes, no benefit	Unknown
38.Gamma-oryzanol	illegal	Increase serum testosterone and human growth hormone	Refutes, no benefit	Unknown
39.Octacosanol	Legal	Improves endurance	Refutes, no benefit	Unknown
40.Humic acid	Legal	Improves endurance	Refutes, no benefit	risky
41.Guarana	Legal	As a natural source of caffeine	Supports	mild
42.Ferulic acid	Legal	Assist the body in maintaining greater workload	Refutes, no benefit	Unknown
43.Astragalus	Legal	increase the body's capacity to handle stress, and help reduce fatigue and enhance endurance	Refutes, no benefit	Unknown
44.Yohimbine	Legal	Increases endogenous steroid production	Refutes, no benefit	mild
45.Glandulars	Legal	enhance the parent gland's function	Refutes, no benefit	Unknown

<b>Ergogenic aid</b>	<b>Legality</b>	<b>Claimed action</b>	<b>Research</b>	<b>Side effects</b>
46.Cow colostrum	Legal	Contains antibodies that boost immunity	Refutes, no benefit	Unknown
47.Lycopene	Legal	As antioxidants	Refutes, no benefit	None
48.Saw palmetto	Legal	As antioxidants	Refutes, no benefit	None
49.quercetin	Legal	As antioxidants	Refutes, no benefit	None
50.Multivitamins	Legal	increase energy, endurance and aerobic capacity, enhance recovery	no benefit unless pre-existing deficiency	none at RDA, some toxicities at high doses
51.Antioxidants	Legal	Decrease muscle breakdown	Mixed, no clear benefits	none
52.Niacin	Legal	Lowers free fatty acid, improves carbohydrate metabolism	no clear benefits	None
53.Pangamic acid	Illegal	increases aerobic capacity & endurance, reduces blood lactate levels	no clear benefits	significant at high doses
54.Choline	Legal	Increases endurance	Mixed, inconclusive	None
55.Lecithin	Legal	As a source of choline	no clear benefits	None

<b>Ergogenic aid</b>	<b>Legality</b>	<b>Claimed action</b>	<b>Research</b>	<b>Side effects</b>
56.Ribose	Legal	Increase ATP synthesis	no clear benefits	None
57.Inosine	Legal	Increase protein and ATP synthesis	no clear benefits	None
58.Ornithine $\alpha$ -ketoglutarate	Legal	increases insulin output and action	Inconclusive	None
59.Phosphate	Legal	increase ATP production, energy and muscle endurance	Mixed , refutes	Mild at high doses
60.Dihydroxyacetone phosphate (DHAP)	Legal	Increase endurance	equivocal	None
61.Cytochrome C	Legal	Improves aerobic capacity	limited, no ergogenic effect	None
62.Coenzyme Q10	Legal	Improves aerobic capacity	limited, no ergogenic effect	significant at high doses
63.Medium chain triglyceride (MCT)	Legal	improves endurance performances	limited, no ergogenic effect	mild at high doses, mostly together with saturated fat
64.Omega-3 fatty acids	Legal	improves blood flow to the muscles	no ergogenic effect	significant at high doses
65.Conjugated linoleic acid	Legal	Decrease in body fat and increase in lean muscle mass	limited, no ergogenic effect	significant at high doses

<b>Ergogenic aid</b>	<b>Legality</b>	<b>Claimed action</b>	<b>Research</b>	<b>Side effects</b>
66.L-carnitine	Legal	Increases fat metabolism	Refutes, no benefits	None
67.Glycerol	Legal	Enhances hyperhydration,	Mixed, some support	Mild
68.Glucosamine sulfate	Legal	Decrease joint pain	Refutes, no benefits	unknown
69.Clenbuterol	Illegal	Increase muscle mass and increase fat metabolism	Mixed, some support	Significant
70.Albuterol	Illegal	Increase muscle strength and mass	Mixed, some support	Significant
71.Alcohol	illegal	Decreases anxiety	Mixed, No benefits	Significant
72.Amphetamines	illegal	Improve concentration, decrease fatigue	Mixed, some support	significant, dangerous
73.Anti-inflammatories	legal	Delay the onset of muscle pain	No benefits	Potentially dangerous
74.Human growth hormone	Illegal	Increase muscle mass	Refutes, no benefits	Potentially dangerous
75.Insulin	Illegal	Promote muscle development	limited, no ergogenic effect	Potentially dangerous
76.Erythropoetin	Illegal	increase aerobic capacity	Supports	Significant , dangerous
77.Blood doping	Illegal	increase aerobic capacity	Supports	dangerous

**Table 3: The efficacy of the purported ergogenic aids**

<b>Nutritional ergogenic aids with clear scientific support</b>
Alkaline salts (sodium bicarbonates, sodium citrate ,etc), Caffeine( including herbal sources), carbohydrates , creatine , water
<b>Nutritional ergogenic aids with mixed scientific support</b>
Antioxidants (Beta carotene, vitamin C, etc), Choline , dihydroxyacetone phosphate , alcohol glycerol , phosphates , vitamin E

<b>Nutritional ergogenic aids lacking substantial scientific support</b>		
Amino acids: Arginine, ornithine, lysine, Branched-chain (leucine, isoleucine, valine), Glutamine, Glycine , Tryptophan	Glucosamine sulfate	Anti-inflammatories
Bee pollen (honey)	Clenbuterol	Human Growth Hormone
Carnitine (L-carnitine)	Albuterol	Omega-3 fatty acids
Ciwujia (Endurox)	Quinine	Polylactate
Coenzyme Q10 (Ubiquinone)	Pycnogenol	Protein
Conjugated linoleic acid (CLA)	Oryzanol	Smilax officinalis
Dehydroepiandrosterone (DHEA)	Gamma oryzanol.	Vitamins : Thiamin (B1), Riboflavin (B2), Niacin, Pyridoxine (B6) , Cyanocobalamin (B12) , Folicin, Pantothenic acid, Beta carotene , Vitamin C, Vitamin B15)
Ephedrine, ephedra (Ma Huang)	Octacosanol	Fructose
Gamma oryzanol (Ferulic acid, Inosine	Humic acid ,	Yohimbine ,
Medium chain triglycerides	Guarana ,	Glandulars,
Minerals : Boron, Chromium, Iron	quercetin	ginseng,
Selenium, Vanadium		

## DISCUSSION, RECOMMENDATION & CONCLUSION

### 5.1 Discussion

Table 2 gave a general summary of the review based on their claimed actions, research position, sided effects and legality. We will discuss the available literature on the supplements in terms of efficacy, sided effects and legality.

*Efficacy:* Table 3 classified the supplements based on their efficacy while figure 1 shows the efficacy by percentage. Out of 77 substances reviewed, only 5 representing 6 % had clear research support for their ergogenic effects. Twelve percent had mixed support while the rest failed to attract any substantive scientific backing. Among the effective are alkaline salts, caffeine, carbohydrate, creatine and water. There was some data supporting anabolic steroids, blood doping, erythropoietin, and some androgenic substances but these are more pharmaceutical than nutritional. Additional research is needed to evaluate the possible ergogenic effects of aspartate salts, choline, glycerol, medium chain triglycerides, phosphates, pyruvate, and certain vitamins (antioxidants; B1, B6, B12; E), as these had mixed or weak scientific backing. They form about 9 % of the lot. Surprisingly, a whopping 85 % of the substances considered have no reliable scientific support according to this review. Some of the supplements could even be ergolytic (impair performance). E.g. honey may give flatulence and diarrhea, a nonstarter in competition.

Interestingly, some of the theories were conflicting. For example, branched chain amino acids are taken by some athletes to counter the metabolic effects of tryptophan, a precursor of serotonin in order to delay fatigue. In section 3.2.1.3, the same tryptophan is ingested by others to delay the onset of fatigue. In some cases, research on the same substance produced conflicting results, some ergogenic and others ergolytic. E.g. aspartate salts. Some of the substances also

tend to produce other effects that cancel out the ergogenic benefit. For example, caffeine is diuretic. Those who take it easily get dehydrated in competition, a situation many are unaware of.

In other circumstances, the substance produces “a nine day wonder”, leaving the athlete midway the competition to his fate. For example, carbohydrate loads with refined sugar base. These have a high glycemic index, increasing plasma glucose concentrations quickly and dropping sharply. This is a bad news for endurance athletes like those in the marathon. Yet in many cases, the “placebo effect” worked. Once you know or believe a substance will improve your performance, you tend to work harder unconsciously. This is a proven psychological phenomenon commonly employed in clinical settings.

However, research tends to support an ergogenic effect for some. Even these sometimes require individual experimentation, as in many cases, the timing; the safe and ergogenic dosages are not specified. Water is naturally safe and necessary but too much of it may lead to abdominal discomfort, frequent urination, and excess body weight.

*Adverse effects:* figure 3 shows the distribution of the supplements by side effects. Some of the supplements were found to have significant adverse effects on health, sometimes fatal. These formed 32 % of the total and include anabolic steroids, amphetamines, alcohol, clenbuterol, albuterol, quinine, androsterone, androstenedione , ephedrine, DHEA, blood doping, erythropoietin, and nutrient overdoses especially iron, boron, vanadium etc. Others have recorded mild side effects at high doses and they form 34 % of all. These include alkaline salts which give gastric distress, caffeine which is associated with restlessness among others, etc. Fourteen percent had no side effects reported while 20% of these effects are unknown or simply not researched.

*Legality:* figure 4 shows the distribution of the substances by legality. Twenty –five percent were banned by various sports organizations while 75 % were legal. The illegal ones are mostly pharmaceutical in nature than nutritional and are the most dangerous. Examples are anabolic steroids, amphetamines, alcohol, erythropoietin, blood doping, DHEA, etc. The legal ones are mainly essential nutrients and are naturally safe at physiologic doses.

So it gets confusing sometimes. One study tells you that a supplement reduces your risk of a disease. Another reveals that the same compound might increase your risk. And yet another study finds no relationship at all between this substance and the disease. But there is no doubt nothing is more important to good health and ability to perform than good nutrition. Without the right foods, even physical conditioning and expert coaching aren't enough to push one to his best.

## 5.2 Recommendations

(i) In their joint Position Statement on nutrition and athletic performance, The American College of Sports Medicine, American Dietetic Association, and Dietitians of Canada agreed that physical activity, athletic performance, and recovery from exercise are enhanced by optimal nutrition.

(ii) These organizations recommended appropriate selection of food and fluids, timing of intake, and supplement choices for optimal health and exercise performance. And that Nutritional Ergogenic Aids should be used with caution, and only after careful evaluation of the product for safety, efficacy, potency, and whether or not it is a banned or illegal substance.

(iii) They also added that Nutrition advice, by a qualified nutrition expert, should only be provided after carefully reviewing the athlete's health, diet, supplement and drug use, and energy requirements.

(iv) There is no one "miracle food" or supplement that can supply all nutritional needs. Certain foods supply mainly proteins, others contain vitamins and minerals, and so on. The key to a balanced diet is the combination of various foods so that nutrient deficiencies in some foods are made up by nutrient surpluses in others.

(v) A supplement in pill form contains only that nutrient, and nothing more. A vitamin-E capsule contains vitamin E. That is not inherently bad. However, healthy grains, fruits, and vegetables contain many nutrients, some that we know about and others that we will eventually learn about through research.

Furthermore, the evidence that every vegetable and fruit contains a variety of what are now called phytochemicals seems to suggest that the use of isolated nutrients probably lowers their

efficacy. It seems obvious that life evolved in a synergistic way with complex mixtures of biochemicals, not commercialized isolates.

(vi) Before taking a supplement, it is important to know what role it plays in the body, what current research has to say about its performance benefits, what the potential adverse effects are, and how its use might help towards the long-term goal, good health. It is a mistake to take a supplement simply because someone else has said it worked for him. All athletes are different, with different nutritional needs and responses to training.

(vii) Finally as a reminder, a well nourished person might not need any supplement. Some of the performance benefits recorded actually stemmed from the satisfaction of a hidden hunger (subclinical nutrient deficiency). Ergogenic aids are very expensive and one reasonably needs to assess the benefits and risks. In any case, man is still basically what he eats and not which drugs or supplements he takes.

**Table 4: Some foods to avoid before an event**

<b>Foods</b>	<b>Comments</b>
<i>Refined sugary beverages and bars</i>	After an initial rise, your blood-sugar level can actually drop below normal, resulting in a sudden feeling of tiredness
<i>Tea, coffee, , cola</i>	Caffeine consumption leads to dehydration
<i>Highly fatty foods</i>	Fat digests slowly
<i>Some fibrous fruits and vegetables e.g cabbage, beans</i>	Some of these foods may cause gas and/or an uncomfortable feeling of fullness during the game.
<i>Any new food</i>	Don't experiment with new foods right before an event. If you experience any adverse reactions, your body has little time to recover
<i>Fruit-flavored drinks</i>	Many drinks contain little fruit juice and a lot of sugar. Read the label

### **5.3 Conclusion**

In conclusion, except for 6% of the ergogenic aids studied, supplementation will not, in general, enhance exercise performance in well-nourished, physically-active individuals.

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