

PCPFS Research Digests

Nutritional Erogogenics & Sports Performance

A Note From The Editors

Over the past few years, The President's Council on Physical Fitness and Sports Physical Activity and Fitness Research Digest has focused primarily on physical activity as it relates to good health and fitness. In this issue, we deviate a bit from that traditional theme. We have asked Dr. Mel Williams to write about nutritional ergogenics and sport performance. We did this because the use of nutritional products in attempts to increase performance has become so widespread. We thought it was important to provide a review of the latest evidence to provide readers with the latest evidence on these various products alleged to enhance performance.

This review will show that there is evidence to support the performance enhancement of a few supplements, but to use Dr. William's words, "...supplementation with various essential nutrients or commercial dietary supplements will NOT, in general, enhance exercise performance in well-nourished and physically active individuals."

As editors, we solicited this paper for a second reason. Many non-athletes interested in increasing muscle mass or reducing body fat levels look to athletes for advice on dietary supplements. Even though they are not particularly interested in performance enhancement, they will mimic the behaviors of high profile athletes using the strategy "...if they use it, it must be good." This paper allows teachers, coaches, fitness leaders, and all other readers to find out the facts about dietary supplements. While some of the information in this paper is somewhat technical, Dr. Williams has made every effort to provide the information in a format that is easy to understand. Table 1 provides a good summary of the evidence available for the dietary supplements discussed in this paper.

Introduction

Most individuals participate in mild to moderate physical activity to improve their physical appearance or health. Many others, however, engage in high-intensity physical activity to prepare for sport performance. They are athletes. Whatever the level of competition, be it for an Olympic gold medal or an age-group award in a local road race, the two major keys to successful athletic performance are genetic endowment and proper training. In order to optimize the genetic potential of the elite athlete, scientists at the United States Olympic Training Center design specific individualized physiological training programs to increase physical power, psychological training programs to enhance mental strength, and biomechanical training programs to provide a mechanical edge. Many of these training strategies are increasingly available to nonelite athletes to help increase their ability to perform their best athletically within their genetic potential.

Although there are multiple purposes for engaging in sport, one of the primary objectives of athletic competition is supremacy, to win the contest. The most appropriate means to achieve this objective is optimal physiological, psychological, and biomechanical training. However, some athletes believe that they have maximized their ability to improve their

sport performance through training and may seek other methods to gain a competitive edge on their opponents.

Ergogenic aids, or ergogenics, are substances, strategies or treatments that are theoretically designed to improve physical performance above and beyond the effects of normal training. Some ergogenics are used during training to enhance the training effect over time, while others are used just before or during the sport event to provide an immediate competitive edge. In general, ergogenics are designed to enhance the athlete's physical power (physiological ergogenics), mental strength (psychological ergogenics), or mechanical edge (mechanical ergogenics).

Physiological ergogenics, particularly pharmacological and nutritional substances, are designed to increase physical power by enhancement of metabolic processes involved in energy production during exercise. For example, anabolic/androgenic steroids (drugs) and creatine monohydrate (nonessential nutrient) have both been used in attempts to increase strength and power.

Psychological ergogenics are devised to enhance mental strength by favorably affecting psychological processes before or during competition. For example, hypnosis and mental imagery have been used to induce psychological sensations of relaxation or stimulation, depending on the nature of the sport.

Mechanical ergogenics are used to provide a mechanical edge by improving energy efficiency. For example, a skintight racing suit will reduce wind resistance and help increase velocity at a given energy expenditure during sports such as downhill skiing and speed skating.

Within the regulations of the specific sport, use of most psychological and mechanical ergogenics is legal. However, use of many physiological ergogenics, particularly drugs and methods such as blood doping, is prohibited because they may provide an unfair competitive advantage or pose serious health risks to the athlete. A comprehensive list of prohibited substances and methods is available from the United States Olympic Committee (1996). Conversely, use of most nutritional substances is legal, and literally hundreds of dietary supplements have been promoted as ergogenic aids for sports performance. Table 1 provides a partial listing of individual nutrients or nutritional products that have been studied or marketed for their ergogenic potential. However, some commercial products include multiple ingredients. For example, Up Your Gas, advertised as a natural energy pill, includes the following among its many ingredients: Bee pollen, Cayenne Pepper, Ginkgo Biloba, Guarana, Inosine, Kola Nut, Korean ginseng, Niacin, Octacosanol, Spirulina blue-green algae, Vitamin E, and Yerba Mate.

First and foremost, a varied, healthful diet balanced in energy and nutrient content is the nutritional mainstay for most athletes. Sports nutritionists contend that athletes should obtain the energy and nutrients they need through wise selections within and among the various food groups, including whole grains, fruits, vegetables, and meat and milk products. Dietary supplements are designed to complement a balanced, healthful diet, not substitute for it.

The purpose of this review is to provide a broad overview of selected individual nutrients and dietary supplements purported to possess ergogenic properties. Space does not permit a detailed analysis of all specific studies, so most of the references cited are either principal studies or review papers that may provide the interested reader with more detail.

Table 1. Efficacy of some purported nutritional ergogenics

Nutritional ergogenics may be used in attempts to enhance physical power, mental strength, and mechanical edge for various sports. Research support for nutritional ergogenics may be classified as strong (meaning studies generally support effectiveness), uncertain (meaning some positive findings are available, but confirming research is needed), or weak (meaning little or no positive data are available). The following is a brief summary of the research-based efficacy of some purported nutritional ergogenics on physical

power (PP), mental strength (MS), or mechanical edge (ME) in well-nourished subjects.

Strong evidence	
Alkaline salts:	PP - aerobic endurance
Caffeine:	PP - aerobic endurance
Carbohydrates:	PP - aerobic endurance
Creatine:	PP - muscular strength
Water:	PP - aerobic endurance during heat stress conditions

Uncertain evidence	
Alcohol:	MS - neuromuscular relaxation
Antioxidants	ME - muscle tissue damage prevention
Antioxidants	PP - aerobic endurance
Choline:	PP - aerobic endurance
Dihydroxyacetone pyruvate:	PP - aerobic endurance
Glycerol:	PP - aerobic endurance
Phosphates:	PP - aerobic endurance
Vitamin E:	PP - aerobic endurance at altitude
Vitamins B1,B6, B12	MS - neuromuscular relaxation

Weak evidence:

Amino acids:

- Arginine, ornithine, lysine
- Branched-chain (leucine, isoleucine, valine)
- Glutamine
- Glycine
- Tryptophan

Bee pollen
Carnitine (L-carnitine)
Ciwujia (Endurox)
Coenzyme Q10 (Ubiquinone)
Conjugated linoleic acid (CLA)
Dehydroepiandrosterone (DHEA)
Ephedrine, ephedra (Ma Huang)
Fructose 1,6-diphosphate
Gamma oryzanol (Ferulic acid, FRAC)
Ginkgo biloba
Ginseng
Inosine
Medium chain triglycerides (MCTs)

Minerals

- Boron
- Chromium
- Iron
- Selenium
- Vanadium

Octacosanol
Omega-3 fatty acids
Polylactate
Protein
Smilax officianalis
Vitamins

- B-complex
  - Thiamin (B1)
  - Riboflavin (B2)
  - Niacin
  - Pyridoxine (B6)
  - Cyanocobalamin (B12)
  - Folacin
  - Pantothenic acid
- Antioxidants
  - Beta carotene
  - Vitamin C

Vitamin B15
Wheat germ oil
Yohimbine (Yohimbe)

Carbohydrate and carbohydrate metabolites

Carbohydrate is the primary dietary energy source for high-intensity aerobic endurance exercise (> 65-70% VO2max), but endogenous supplies such as muscle and liver glycogen are limited and may become suboptimal within 90 minutes. Carbohydrate loading procedures may elevate endogenous glycogen stores, postponing fatigue and improving performance in which a set distance is covered as quickly as possible (such as a marathon) by 2-3 percent (Hawley et al., 1997). Additionally, numerous studies support the efficacy of carbohydrate supplementation prior to and/or during such prolonged aerobic exercise tasks to improve performance (Williams, 1998B).

Metabolic by-products of carbohydrate are theorized to provide a more efficient fuel than other carbohydrate sources. Several well-controlled studies by researchers at the University of Pittsburgh have shown that pyruvate, administered as dihydroxyacetone and pyruvate (DHAP), may increase muscle glycogen levels or blood glucose uptake by exercising muscles and enhance exercise performance in untrained subjects. However, these findings have not been duplicated by other scientists and the ergogenic effect of pyruvate for trained athletes is questionable (Anderson, 1997; Williams, 1998B). 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).

Lipids and lipid metabolites

Lipids represent an energy source for mild-to-moderate intensity aerobic endurance exercise (less than 50-65% VO2max), but unlike carbohydrate, endogenous stores of lipids as adipose and muscle tissue triglycerides are abundant. Triglycerides provide free fatty acids (FFA), the primary lipid energy source during exercise. Lipid dietary strategies or supplements attempt to increase FFA oxidation and reduce reliance on endogenous carbohydrate stores, sparing muscle glycogen use and delaying fatigue during prolonged exercise. Other supplements, such as L-carnitine and caffeine supplementation (discussed below) are theorized to exert similar effects.

Fat loading is a dietary strategy involving increased consumption of dietary fats, up to 70 percent of daily energy intake, in attempts to increase the contribution of endogenous fats as an energy source during exercise. Several preliminary studies have shown some beneficial effects of fat loading, but either the experimental design was not appropriate or the exercise tasks used do not appear to have any application to contemporary sports events (Williams, 1998B). In a major review, Sherman and Leenders (1995) noted that although the fat loading hypothesis is intriguing, the current scientific literature is not supportive. Medium-chain triglycerides (MCT), oral water soluble supplements that may enter the circulation more readily than normal dietary fats, have been theorized to be a more efficient lipid energy source during exercise. However, recent research by scientists from the Netherlands has not shown any significant contribution of oral MCT to energy metabolism during exercise, and two recent studies have shown that MCT supplementation could actually impair 40-kilometer cycling performance (Williams, 1998B). Nevertheless, in a recent review, Berning (1996) noted that some preliminary research findings were promising, particularly when MCT were ingested with carbohydrate supplements during exercise. Confirming research is needed.

Proteins, amino acids, and related metabolites

Protein supplements have been recommended to athletes to enhance nitrogen retention and increase lean body (muscle) mass, to prevent protein catabolism during prolonged exercise, and to support an increased synthesis of hemoglobin, myoglobin, oxidative enzymes, and mitochondria during aerobic training. Current research suggests that athletes may need slightly more protein than the Recommended Dietary Allowance (RDA). Values suggested for strength-type athletes approximate 1.6-1.8 grams per kilogram body weight, while recommended amounts for endurance athletes approximate 1.2-1.6 grams per kilogram body weight (Lemon, 1996; 1995). Such values may be obtained easily in a typical western diet with adequate

animal and plant protein. In general, research with protein supplements in excess of these dietary quantities has shown no beneficial effects on strength, power, hypertrophy of muscle, or physiological work capacity (Williams, 1998B). Amino acid supplements have also been marketed to increase muscle mass and enhance aerobic endurance capacity via various mechanisms.

Arginine and ornithine have been used in attempts to increase human growth hormone (HGH) and/or insulin production, the theory being to increase muscle mass and strength via enhanced hormonal activity. Limited data are available, but a number of well-controlled studies, including several with experienced weightlifters, reported that amino acid supplementation elicited no significant increases in serum HGH, insulin levels, or various measures of muscular strength or power (Fogelholm, 1993; Kreider et al., 1993; Williams, 1998B).

Potassium and magnesium aspartates are salts of aspartic acid, an amino acid. They have been used as ergogenics, possibly by mitigating the accumulation of ammonia during exercise. The effect of aspartate supplementation on physical performance is equivocal, 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.

Tryptophan (TRYP) and branched chain amino acids (BCAA) are thought to affect the formation of serotonin, a neurotransmitter believed to be involved in the etiology of central nervous system (CNS) fatigue during exercise. However, according to proponents of either TRYP or BCAA supplementation, the hypotheses underlying the serotonin effect on the development of fatigue are diametrically opposite.

In one hypothesis, TRYP serves as a precursor for serotonin, a brain neurotransmitter theorized to suppress pain. Free tryptophan (fTRYP) enters the brain cells to form serotonin. Thus, TRYP supplementation has been used to increase fTRYP and serotonin production in attempts to increase tolerance to pain during intense exercise, thus delaying fatigue. Limited data involving TRYP supplementation are available, but one study reported significant improvements in time to exhaustion at 80 percent VO2max, accompanied by significant reductions in the psychological rating of perceived exertion (RPE). However, research with a more appropriate experimental design did not replicate these findings when subjects ran to exhaustion at 100 percent VO2max. Moreover, other investigators reported no effect of TRYP supplementation on aerobic endurance performance at 70-75 percent VO2max (Williams, 1998B). In a recent review, Wagenmakers (1997) concluded that TRYP supplementation had no effect on endurance performance.

Relative to the second hypothesis, some investigators believe that increased levels of serotonin may induce fatigue by depressing central nervous system functions (Newsholme et al., 1992). During prolonged aerobic endurance exercise, muscle glycogen may become depleted and the muscle may increase its reliance on branched chain amino acids (BCAA) for fuel, decreasing the plasma BCAA:fTRYP ratio. Because BCAA compete with fTRYP for entry into the brain, a low BCAA:fTRYP ratio would facilitate the entry of fTRYP to the brain, increasing serotonin formation and inducing fatigue. Hypothetically, BCAA supplementation may delay fatigue in prolonged aerobic endurance events by maintaining a high BCAA:fTRYP ratio to mitigate the formation of serotonin. Although several studies support this hypothesis both Wagenmakers (1997) and Davis (1996), in recent reviews, concluded not enough evidence indicates BCAA supplementation is ergogenic. Davis also noted that carbohydrate supplementation during exercise, by delaying the reliance on BCAA as a fuel, would serve the same purpose as BCAA supplementation.

Vitamins

Research indicates that a vitamin deficiency may adversely affect physical performance, but 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, 1998B).

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).

Minerals

As with vitamins, research indicates that a mineral deficiency may adversely affect physical performance. Iron deficiency is the most common mineral deficiency among athletes, particularly female athletes in weight-control sports, and curing an athlete's iron-deficiency anemia with iron supplementation will return performance to normal. However, in general, research also indicates that mineral supplements, including multivitamin/mineral compounds, are unnecessary for physically-active individuals who are on a well-balanced diet with adequate calories.

Several minerals have been marketed as potent anabolic agents. Chromium is an insulin cofactor, and its theorized ergogenic effect is based on the role of insulin to facilitate BCAA transport into the muscle. Chromium has been advertised for strength-type athletes. The available research with chromium is limited, and the data available have not been subjected to a critical scientific review. Some early research data do suggest an increase in lean body mass and decreased body fat with chromium picolinate supplementation (Evans, 1989). However, this report was based on flawed studies. More contemporary research with better experimental protocols replicated these studies and have shown that chromium picolinate supplementation does not increase lean muscle mass or decrease body fat (Clancy et al., 1994; Hallmark et al., 1996; Trent and Thieding-Cancel,

1995). Other research also indicated different forms of chromium, such as chromium chloride, had no effect on body composition (Lukaski et al., 1996). Boron and vanadium have also been advertised for their anabolic potential. However, the limited data available do not support an anabolic effect of either boron (Ferrando and Green, 1993) or vanadium (Fawcett et al., 1996).

Phosphorus is an essential nutrient present in the diet as a phosphate salt, or phosphate. Phosphate is a component of several high energy compounds, is essential for the functioning of several B vitamins, and is part of 2,3-DPG, essential for oxygen release from hemoglobin. An increased 2,3-DPG level is the prevalent theory underlying phosphate supplementation to endurance athletes. Current research is equivocal as to whether or not phosphate loading may improve physiological functions important to endurance performance. However, no study has reported decreases in performance, and several recent studies from independent laboratories have shown remarkable similarities relative to increased levels of VO2max (about 10%) following phosphate supplementation. Increases in physical performance have also been documented in four of these studies (Cade et al., 1984; Kreider et al., 1990; Kreider et al., 1992; Stewart et al., 1990). However, a number of confounding variables in previous research have been identified and more controlled research has been recommended (Tremblay et al., 1994).

Food drugs

Although doping (the use of pharmacological ergogenics to improve sports performance) is prohibited, the International Olympic Committee does permit limited use of several nutritionally-related drugs, such as caffeine, alcohol, and alkaline salts.

Caffeine, found naturally in certain foods or beverages, such as cocoa, coffee, and cola drinks, consumed by athletes, has been studied extensively for its ergogenic potential. Caffeine is a stimulant that may improve various metabolic and psychological functions during exercise, and several recent reviews indicate that legal doses of caffeine may enhance performance in a variety of exercise tasks (Graham and Spriet, 1996; Spriet, 1995). Many studies that have evaluated the ergogenic effect of caffeine on prolonged aerobic endurance tasks greater than one hour have shown beneficial effects. For example, a series of studies from Guelph University in Canada has suggested caffeine may enhance prolonged aerobic endurance performance through increased levels of epinephrine and sparing of muscle glycogen (Graham and Spriet, 1991; Spriet, et al., 1992). Other recent research suggests caffeine may exert an ergogenic effect in shorter endurance events through neurological mechanisms. For example, caffeine supplementation has been shown to improve performance in a 1,500-meter run, an event which is not dependent on muscle glycogen sparing (Wiles et al., 1992), and caffeine supplementation also has increased work output on a cycle ergometer at a set RPE (Cole, et al., 1996). Because caffeine appears to be an effective ergogenic in legal doses, some investigators have suggested the IOC should reconsider the legal limits determinant for a positive drug test (Spriet, 1995)

Alkaline salts, such as sodium bicarbonate and sodium citrate, are described as antacids in the United States Pharmacopeia (USP) and have been studied as nutritional ergogenics. Taken orally prior to high-intensity anaerobic exercise, alkaline salts may increase the alkaline reserve and help buffer lactic acid in the muscle cell, an effect that theoretically could improve performance in exercise tasks dependent primarily on anaerobic glycolysis. Research indicates that alkaline salt supplementation will increase the serum pH and may enhance performance in exercise tasks, particularly repetitive exercise tasks, that maximize energy production for 1-6 minutes. Numerous laboratory and field studies support a positive ergogenic effect of sodium bicarbonate supplementation, and several comprehensive reviews (Linderman and Fahey, 1991; Williams, 1992), including a meta-analysis reporting an effect size greater than 0.40 favoring sodium bicarbonate when compared to placebo conditions (Matson and Tran, 1993), conclude that sodium bicarbonate is an effective ergogenic. Studies conducted subsequent to these reviews have provided mixed results but, in general, about half of

these more recent studies have revealed ergogenic effects of sodium bicarbonate or sodium citrate on exercise performance. Some beneficial effects have even been noted on prolonged aerobic endurance tasks, a finding that merits additional research (Williams, 1998B)

Dietary supplements

Numerous dietary supplements are marketed to physically-active individuals. Advertisements insinuate that such supplements may improve energy production, increase muscle mass, decrease body fat, or induce some other possible ergogenic outcome. By and large, many commercial products have not been studied scientifically to validate such advertising claims. However, some data are available for several specific ingredients marketed individually or as part of a multiple-ingredient product. Choline - Choline, an amine, is found naturally in a variety of foods. A sports drink powder containing carbohydrates, electrolytes, and choline has been marketed recently.

Choline is involved in the formation of acetylcholine, a neurotransmitter whose reduction in the nervous system may be theorized to be a contributing factor to the development of fatigue. Because plasma choline levels have been reported to be significantly reduced following events such as marathon running, choline supplementation has been theorized to prevent fatigue in aerobic endurance tasks. Research has shown that choline supplementation will increase blood choline levels at rest and during prolonged exercise, and some preliminary field and laboratory research has suggested increased plasma choline levels are associated with a significantly decreased time to run 20 miles. However, other well-controlled laboratory research has revealed that choline supplementation, although increasing plasma choline levels, exerted no effect on either brief, high-intensity anaerobic cycling tests or more prolonged aerobic exercise tasks (Williams, 1998B). These findings are equivocal and reviewers have recommended more research with choline supplementation, particularly research involving prolonged aerobic endurance exercise tasks (Kanter and Williams, 1995).

Coenzyme Q10 (Ubiquinone) - 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 performance.

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, VO2max, 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).

Creatine - Creatine is a nitrogen-containing substance, found naturally in small amounts in animal foods. Acute oral creatine supplementation, daily as creatine monohydrate for approximately 5-7 days, has been reported to increase muscle concentrations of total creatine, both as free creatine and creatine phosphate, a high-energy phosphagen. Several reviews indicate creatine supplementation may be an effective sport ergogenic (Balsom, et al., 1994; Greenhaff, 1995). Subsequent to these reviews, numerous studies have reported a positive ergogenic effect of creatine supplementation, particularly in repetitive, short-duration, high-intensity, short-recovery isokinetic and isometric resistance tests or cycle ergometer protocols. However, in such tests, although some body parts are exercising, the total body mass is stationary. Thus, the ergogenic effect of acute creatine supplementation may be limited to laboratory tasks in which the body mass does not need to be moved. Acute creatine supplementation also appears to increase body mass (Williams and Branch, 1998). In exercise tasks in which the body mass is moved, research generally has not supported an ergogenic effect of creatine supplementation on sprint swim

performance (Burke, et al., 1996) or sprint run performance (Redondo, et al., 1996), and actually may be ergolytic (impair performance) in endurance running because of the acute increase in body mass (Balsom et al., 1993), which may simply be water associated with the oncotic effect of creatine in the muscle. Creatine supplementation has been shown to improve rowing performance (Rossiter et al., 1996), an exercise task in which the body mass is supported, and may theoretically enhance performance in cycling tasks for similar reasons.

Although acute creatine supplementation may enhance exercise performance under certain laboratory conditions, more research is needed to evaluate its efficacy to enhance actual sports performance. Additionally, well-controlled research is needed to evaluate the effect of chronic creatine supplementation on the training response and subsequent competitive sport performance.

Ginseng - Extracts derived from the plant family Araliaceae contain numerous chemicals that may influence human physiology, the most important being the glycosides, or ginsenosides. Collectively, these extracts are referred to as ginseng. Numerous commercial forms of ginseng products are available, including Chinese or Korean (Panax ginseng), American (Panax quinquefolium), and Russian/Siberian (Eleutherococcus senticosus), but the ginseng content may vary considerably (Cui et al., 1994).

Ginseng supplementation has been theorized to mitigate the stress of exercise and possess ergogenic qualities, but the underlying mechanisms have not been determined. Although some earlier studies reported ergogenic effects of ginseng supplementation on exercise performance, a recent comprehensive review by Bahrke and Morgan (1994) indicated that ginseng research with humans has been characterized by numerous methodological and statistical shortcomings. They concluded, in 1994, that there is an absence of compelling research evidence demonstrating the ability of ginseng to consistently enhance physical performance in humans, and that there remains a need for well-designed research.

Several well-controlled studies subsequent to the review by Bahrke and Morgan reported no significant effect of either Panax ginseng, Eleutherococcus senticosus Maxim L (regarded to be Siberian Ginseng), or a standardized ginseng extract on cardiovascular, metabolic, or psychologic responses to either submaximal or maximal exercise performance, or on maximal performance capacity (Dowling, et al., 1996; Engels and Wirth, 1997; Morris, et al., 1996).

Glycerol - Water ingestion is essential to help optimize body water balance and body temperature regulation during exercise under warm environmental conditions. 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. Glycerol capsules and a glycerol-containing sports drink are marketed to athletes.

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.

Inosine - 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. Although 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 submaximal or maximal 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).

L-carnitine - L-carnitine is a vitamin-like compound found naturally in animal foods, particularly meats, and may also be formed in the liver from various amino acids. 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. However, 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).

Summary

Adequate dietary intake of carbohydrate, essential fatty acids, protein, vitamins, minerals and water is necessary to insure optimal physical performance, because a deficiency of any essential nutrient associated with energy production may impair physiological or psychological functions during exercise. As may be discerned from this review, supplementation with various essential nutrients or commercial dietary supplements will not, in general, enhance exercise performance in well-nourished, physically-active individuals. However, research tends to support an ergogenic effect for some nutritional ergogenics (including alkaline salts, caffeine, carbohydrate loading, and creatine) under certain conditions or for some athletes. Additional research is needed to evaluate the possible ergogenic effects of aspartate salts, choline, glycerol, MCT, phosphates, pyruvate, and certain vitamins (antioxidants; B1, B6, B12; E) for specific conditions mentioned above.

Caution is advised when using any nutritional ergogenic in an attempt to enhance sport performance. As noted above, some products may impair performance. Also, improper amounts may cause various health problems. For example, supplements such as alkaline salts may cause gastrointestinal distress and diarrhea while others, such as ephedrine, have been associated with fatalities. Individuals who desire to use specific nutritional ergogenics should consult a sports nutrition expert or physician, and also experiment with their use in training before use in compe

Please note that the appropriate language for the citation of this resource is: *The President's Council on Physical Fitness and Sports Research Digest.*

The President's Council on Physical Fitness and Sports

The President's Council on Physical Fitness and Sports (PCPFS) was established in 1956 through an Executive Order by President Dwight D. Eisenhower as part of a national campaign to help shape up America's younger generation. Today, the PCPFS serves as an advisory council to the President and Secretary of the Department of Health & Human Services on matters involving physical activity, fitness and sports to enhance and improve the health of Americans of all ages.

The PCPFS enlists the active support and assistance of individual citizens, civic groups, private enterprise, and voluntary organizations to

promote and improve the physical activity and fitness of all Americans and to inform the public of the important link which exists between regular activity and good health.

Twenty (20) individuals from the sports, fitness and health fields are appointed by the President to serve as members of the Council. They are:

200 Independence Avenue, S.W., Washington, DC 20201· (202) 690-9000· FAX (202) 690-5211

Published quarterly by the

President's Council on Physical Fitness and Sports Washington, D.C.

Melvin H. Williams, PhD Eminent Scholar Emeritus Department of Exercise Science, Physical Education and Recreation Old Dominion University, Norfolk, VA

Co-edited by Drs. Chuck Corbin and Bob Pangrazi Arizona State University

References

1. Anderson, O. (1997). Pyruvate: Good for the alcoholic, the diabetic, the obese person - and the marathon runner? Running Research News, 13 (10), 1, 9-11.
2. Armstrong, L., and Maresh, C. (1996). Vitamin and mineral supplements as nutritional aids to exercise performance and health. Nutrition Reviews, 54, S148-S158.
3. Bahrke, M., and Morgan, W. (1994). Evaluation of the ergogenic properties of ginseng. Sports Medicine, 18, 229-248. Balsom, P., et al. (1994). Creatine in humans with special reference to creatine supplementation. Sports Medicine, 18, 268-280.
4. Balsom, P., et al. (1993). Creatine supplementation per se does not enhance endurance exercise performance. Acta Physiologica Scandinavica, 149, 521-523.
5. Berning, J. (1996). The role of medium-chain triglycerides in exercise. International Journal of Sport Nutrition, 6, 121-133.
6. Bonke, D. (1986). Influence of vitamin B1, B6 and B12 on the control of fine motoric movements. Bibliotheca Nutritio et Dieta, 38, 104-109.
7. Braun, B., et al. (1991) The effect of coenzyme Q10 supplementation on exercise performance, VO2max, and lipid peroxidation in trained cyclists. International Journal of Sport Nutrition, 1, 353-365.
8. Burke, L., et al. (1996). Effect of oral creatine supplementation on single-effort sprint performance in elite swimmers. International Journal of Sport Nutrition, 6, 222-233.
9. Cade, R., et al. (1984). Effects of phosphate loading on 2,3-diphosphoglycerate and maximal oxygen uptake. Medicine and Science in Sports and Exercise, 16, 263-268.
10. Clancy, S., et al. (1994). Effects of chromium picolinate supplementation on body composition, strength, and urinary chromium loss in football players. International Journal of Sport Nutrition, 4, 142-153.
11. Cole, K., et al. (1996). Effect of caffeine ingestion on perception of effort and subsequent work production. International Journal of Sport Nutrition, 6, 14-23.
12. Cui, J., et al. (1994). What do commercial ginseng preparations contain? Lancet, 344, 134.
13. Davis, J. M. (1996). Carbohydrates, branched-chain amino acids and endurance: The central fatigue hypothesis. Sports Science Exchange, 9 (2), 1-5.
14. Dekkers J., et al. (1996). The role of antioxidant vitamins and enzymes in the prevention of exercise-induced muscle damage. Sports Medicine, 21, 213-238.
15. Dowling, E., et al. (1996). Effect of Eleutherococcus senticosus on submaximal and maximal exercise performance. Medicine and Science in Sports and Exercise, 28, 482-489.
16. Engels, H., and Wirth, J. (1997). No ergogenic effects of ginseng (Panax ginseng C. A. Meyer) during graded maximal aerobic exercise. Journal of the American Dietetic Association, 97, 1110-1115.

17. Evans, G. (1989). The effect of chromium picolinate on insulin controlled parameters in humans. International Journal of Biosocial Medicine, 11, 163-180.
18. Fawcett, J., et al. (1996). The effect of oral vanadyl sulfate on body composition and performance in weight-training athletes. International Journal of Sport Nutrition, 6, 382-390.
19. Ferrando, A., and Green, N. (1993). The effect of boron supplementation on lean body mass, plasma testosterone levels, and strength in male bodybuilders. International Journal of Sport Nutrition, 3, 140-149.
20. Fogelholm, G. M., et al. (1993). Low dose amino acid supplementation. No effects on serum human growth hormone and insulin in male weightlifters. International Journal of Sport Nutrition, 3, 290-297.
21. Freund, B., et al. (1995). Glycerol hyperhydration: Hormonal, renal, and vascular fluid responses. Journal of Applied Physiology, 79, 2069-2077.
22. Gerster, H. (1989). Review: The role of vitamin C in athletic performance. Journal of the American College of Nutrition, 8, 636-643.
23. Goldfarb, A. (1993). Antioxidants: Role of supplementation to prevent exercise-induced oxidative stress. Medicine and
Science in Sports and Exercise, 25, 232-236.
24. Graham, T., and Spriet, L. (1996). Caffeine and exercise performance. Sports Science Exchange, 9, (1), 1-5.
25. Graham, T., and Spriet, L. (1991). Performance and metabolic responses to a high caffeine dose during prolonged exercise. Journal of Applied Physiology, 71, 2292-2298.
26. Greenhaff, P. (1995). Creatine and its application as an ergogenic aid. International Journal of Sport Nutrition, 5, S100-S110
27. Hallmark, M., et al. (1996). Effects of chromium and resistive training on muscle strength and body composition. Medicine and Science in Sports and Exercise, 28, 139-144.
28. Hawley, JA, et al. (1997). Carbohydrate-loading and exercise performance. An update. Sports Medicine, 24, 73-81. Heinonen, O. Carnitine and physical exercise (1996). Sports Medicine, 22, 109-132.
29. Kanter, M. (1995). Free radicals and exercise: Effects of nutritional antioxidant supplementation. Exercise and Sport Sciences Reviews, 23, 375-398.
30. Kanter, M., and Williams, M. (1995). Antioxidants, carnitine, and choline as putative ergogenic aids. International Journal of Sport Nutrition, 5, S120-S131.
31. Koenigsberg, P., et al. (1995). Sustained hyperhydration with glycerol ingestion. Life Science, 57, 645-653.
32. Kreider, R., et al. (1993). Amino acid supplementation and exercise performance. Sports Medicine, 16, 190-209.
33. Kreider, R., et al. (1992). Effects of phosphate loading on metabolic and myocardial responses to maximal and endurance exercise. International Journal of Sport Nutrition, 2, 20-47.
34. Kreider, R., et al. (1990). Effects of phosphate loading on oxygen uptake, ventilatory anaerobic threshold, and run performance. Medicine and Science in Sports and Exercise, 22, 250-256.
35. Laaksonen, R., et al. (1995). Ubiquinone supplementation and exercise capacity in trained young and older men. European Journal of Applied Physiology, 72, 95-100.
36. Lamb, D., et al. (1997). Prehydration with glycerol does not improve cycling performance vs 6% CHO-electrolyte drink. Medicine and Science in Sports and Exercise, 29, S249 (abstract).
37. Latzka, W., et al. (1997). Hyperhydration: Thermoregulatory effects during compensable exercise-heat stress. Journal of
Applied Physiology, 83, 860-866.
38. Lemon, P. (1996). Is increased dietary protein necessary or beneficial for individuals with a physically active lifestyle? Nutrition Reviews, 54, S169-S175.
39. Lemon, P. (1995). Do athletes need more dietary protein and amino acids International Journal of Sport Nutrition, 5,
S39-S61.
40. Linderman, J., and Fahey, T. (1991). Sodium bicarbonate ingestion and exercise performance. Sports Medicine, 11, 71-77
41. Lukaski, H., et al. (1996). Chromium supplementation and resistance training: Effects on body composition, strength, and trace element status of men. American Journal of Clinical Nutrition, 63, 954-965.
42. Lyons, T., et al. (1990). Effects of glycerol-induced hyperhydration prior to exercise in the heat on sweating and core temperature. Medicine and Science in Sports and Exercise, 22, 477-483.
43. Malm, et al. (1996). Supplementation with ubiquinone-10 causes cellular damage during intense exercise. Acta Physiologica Scandinavica, 157, 511-512.
44. Matson, L., and Tran, Z. (1993). Effects of sodium bicarbonate ingestion on anaerobic performance: A meta-analytic review. International Journal of Sport Nutrition, 3, 2-28.
45. Montner, P., et al. (1996). Pre-exercise glycerol hydration improves cycling endurance time. International Journal of Sports Medicine, 17, 27-33.
46. Morris, A., et al. (1996). No ergogenic effect of ginseng ingestion. International Journal of Sport Nutrition, 6, 262-271.
47. Newsholme, E., et al. (1992). Physical and mental fatigue: Metabolic mechanisms and importance of plasma amino acids. British Medical Bulletin, 48, 477-49
48. Packer, L. (1997). Oxidants, antioxidant nutrients and the athlete. Journal of Sports Sciences, 15, 353-363.
49. Redondo, D., et al. (1996). The effect of oral creatine monohydrate on running velocity. International Journal of Sport Nutrition, 6:213-221.
50. Rossiter, H., et al. (1996). The effect of oral creatine supplementation on the 1000-m performance of competitive rowers. Journal of Sports Sciences, 14, 175-179.
51. Sherman, WM, and Leenders, N. (1995). Fat loading: The next magic bullet. International Journal of Sport Nutrition, 5, S1-S12.
52. Singh, A., et al. (1992). Chronic multivitamin-mineral supplementation does not enhance

physical performance. Medicine and Science in Sports and Exercise, 24, 726-732.
53. Snider, I., et al. (1992). Effects of coenzyme athletic performance system as an ergogenic aid on endurance performance to exhaustion. International Journal of Sport Nutrition, 2, 272-286.
54. Spriet, L. (1995). Caffeine and performance. International Journal of Sport Nutrition, 5, S84-S99.
55. Spriet, L., et al. (1992). Caffeine ingestion and muscle metabolism during prolonged exercise in humans. American Journal of Physiology, 262, E891-E898.
56. Starling, R., et al. (1996). Effect of inosine supplementation on aerobic and anaerobic cycling performance. Medicine and Science in Sports and Exercise, 28, 1193-1198.
57. Stewart, I., et al. (1990). Phosphate loading and the effects on VO2max in trained cyclists. Research Quarterly for Exercise and Sport, 61, 80-84.
58. Swensen, T., et al. (1994). Adding polylactate to a glucose polymer solution does not improve endurance. International Journal of Sports Medicine, 15, 430-434.
59. Telford, R., et al. (1992). The effect of 7 to 8 months of vitamin/mineral supplementation on athletic performance. International Journal of Sport Nutrition, 2, 135-153.
60. Tiidus, P., and Houston, M. (1995). Vitamin E status and response to exercise training. Sports Medicine, 20, 12-23.
61. Tremblay, M., et al. (1994). Ergogenic effects of phosphate loading: Physiological fact or methodological fiction? Canadian Journal of Applied Physiology, 19, 1-11.
62. Trent, L., and Thieding-Cancel, D. (1995). Effects of chromium picolinate on body composition. Journal of Sports medicine and Physical Fitness, 35, 273-280.
63. Wagenmakers, A. (1997). Branched-chain amino acids and endurance performance. In T. Reilly and M. Orme (eds.), The Clinical Pharmacology of Sport and Exercise. Amsterdam: Excerpta Medica.
64. Wagenmakers, A. (1991). L-carnitine supplementation and performance in man. Medicine and Sport Sciences, 32, 110-127.
65. Weston, S., et al. (1997). Does exogenous coenzyme Q10 affect aerobic capacity in endurance athletes? International Journal of Sport Nutrition, 7, 197-206.
66. Wiles, J., et al. (1992). Effect of caffeinated coffee on running speed, respiratory factors, blood lactate and perceived exertion during 1500-meter treadmill running. British Journal of Sport Medicine, 26, 116-120.
67. Williams, MH. (1998A). The Ergogenics Edge: Pushing the Limits of Sports Performance. Champaign, IL: Human Kinetics.
68. Williams, MH. (1998B). Nutrition for Health, Fitness, and Sport. Dubuque, IA: WCB/McGraw-Hill.
69. Williams, M. (1992). Bicarbonate loading. Sports Science Exchange 4, (1), 1-4.
70. Williams, M. H., and Branch, J. D. (1998). Journal of the American College of Nutrition, 17 (3): In press.
71. Williams, M., et al. (1990). effect of oral inosine supplementation on 3-mile treadmill run performance and VO2 peak.
72. Medicine and Science in Sports and Exercise, 22, 517-522.

Physical Activity and Fitness Quote

First and foremost, a varied, healthful diet balanced in energy and nutrient content is the nutritional mainstay for most athletes. Although research suggests that a few forms of nutrient supplementation may enhance physical performance under specific circumstances, such supplements should complement a healthful diet, not substitute for it.

Melvin H. Williams, PhD
Eminent Scholar Emeritus Department of Exercise Science,
Physical Education and Recreation Old Dominion University,
Norfolk, VA 23529-0196
Office (757) 683-3355 Fax (757) 683-4270 Home (757) 464-3044
E-mail Mwilliam@odu.edu

Back to top

Home | Help | Contact Us | Privacy | Disclaimer | Site Map | Accessibility | FOIA | USA.gov | The White House

Last updated on 04/23/2008