Search for the Competitive Edge: A History of Dietary Fads and Supplements[1]

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ABSTRACT The premise and promise of ergogenic aid use is rooted in antiquity and is based upon superstition and ritualistic behavior of athletes who perceive that past performances were predicated upon unique dietary constituents or dietary manipulation. Accounts from ancient times recommended that athletes and soldiers preparing for battle consume specific animal parts to confer agility, speed or strength associated with that animal. Scientific understanding of the chemical and physiological nature of muscular work in the early 20th century was followed by ergogenic aid use by athletes and rationalized as ''scientific'' justification. Ergogenic aids such as alkaline salts, caffeine, carbohydrate and protein have been used by athletes with variable success. As nutritionists and exercise physiologists discovered and perfected the scientific understanding of metabolic reactions, athletes in turn experimented with the amount, form and timing of administration in the search for optimal performance. Anabolic steroids and blood doping enhance athletic performance, but health risks, ethics and sportsmanship contravene their use. Popularity and use of ergogenic aids often have preceded scientific substantiation of claims. Current products such as protein isolates and antioxidant nutrients commonly are used by athletes, and many ergogenic aids available today differ little from those used long ago. J. Nutr. 127:869S–873S, 1997

KEY WORDS: • *athletic training* • *dietary supplements* • *ergogenic aids*

We pay tribute today to the Olympic athletes of 100 years ago and will look at the history of nutrition science and exercise science. The athletes of 100 years ago can be compared with athletes assembling in Atlanta in the summer of 1996. Although the athletes in 1996 have very sophisticated training methods that stem from advances in exercise physiology as well as sports nutrition, they share with their historical counterparts the same quest: success and victory at the Olympic Games. In addition to paying tribute to Olympic athletes of the past 100 years, it also is appropriate to note another commemorative event taking place in Boston (Patriots' Day, Monday, April 15, 1996) marks the 100th anniversary of the Boston Marathon. About noon today, approximately 38,000 runners will begin their quest for gold and cross the starting line. Only the "seeded," elite runners will cross the starting line quickly; for others it will take an hour or more to reach the starting line—but they will have run at Boston, and will have done so on this special anniversary date (Higdon 1995).

Many of the runners assembled at Boston will have practiced nonscientific rituals involving specific behaviors. Some will have manipulated their diet in the months, weeks anddays before the event, manipulations based more upon "magic" than science, in attempts to mirror or repeat outstanding past performances. Some will have practiced carbohydrate loading, others will have "tanked-up" on caffeine, or tested other products and (perceived) ergogenic aids, in their attempts to enhance performance. Contemporary Boston marathon runners and ancient Greek Olympic athletes both have embraced the ideal of participation in sport, the quest for success through hard work and unaided effort, to do the best with "what you've got."

This is the ideal, however, not reality.

The reality is that many athletes, ancient and modern, elite and Olympic caliber and "weekend warrior" and back-of-the-pack runners, embark upon a quest to improve performance, to accomplish more than what is attainable through their own efforts alone. This search for dietary supplements and ergogenic aids, or substances that enhance work performance, is as ancient as sports themselves. 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 (Mayer and Bullen 1960, Reed 1977, Van Itallie et al. 1956, Williams 1989b). Most evidence for relationships between diet and supplements and improved performance, however, stems 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

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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.

PROTEIN AND AMINO ACID SUPPLEMENTS

Protein is perhaps the most common ergogenic aid or dietary supplement used today. It was known by the turn of the 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 mention 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). Strength athletes today, knowledgeable about nutrition, regularly state that they use protein supplements many grams above the RDA because they perceive the recommendation to be insufficient. Although protein supplementation is the vehicle of choice today, in the 1950s and 1960s athletes increased their protein intakes through diet and "training tables" and focused their intakes 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 through fitness and running magazines "extended" the findings and interpreted them to indicate that supplements of isoleusine, leucine and valine would translate into improved performance and maintenance of muscle mass (Applegate 1991, Williams 1994). Such accounts "extending" research findings are easy to read and not couched in scientific jargon and therefore are commonly embraced and implemented by athletes, whether or not the supposed effects are real. 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). Athletes now commonly consume these beverage supplements during exercise, a distinct shift from past practices when carbohydrate intake during exercise was more common. Strength athletes interested in optimizing nitrogen retention and enhancing protein gains have utilized these products, and intensive marketing campaigns by various companies suggest that protein and amino acid beverages should be consumed during exercise and for 1–2 h following intensive strength-exerting exercise (Applegate 1992).

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 (**Fig. 1** and **2**) 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 as a fuel, there evolved commercial marketing of carbohydrate products during the 1960s and 1970s and various manipulations of the

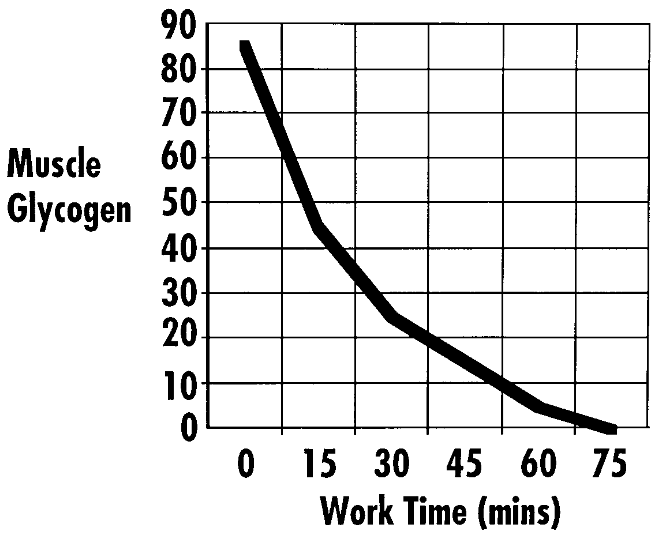

FIGURE 1 The breakdown of muscle glycogen during intense exercise (cycling) (adapted from Borgström et al. 1967).

activity known collectively today as "carbohydrate loading." This dietary manipulation was popularized by running magazines and adopted by noted elite runners and other athletes. In the classical "carbohydrate loading" manipulation, the athlete exercises to exhaustion to deplete glycogen stores, then ingests a carbohydrate-free diet for 2–5 d. The depletion phase is followed by an intake pattern that is ~70–85% carbohydrate, up to 600 g or more of carbohydrate, for 1–2 d (Bergström and Hultman 1972, Sherman and Costill 1984). This classical scheme, however, was challenging for many endurance athletes and presented difficulty in weight maintenance. At the completion of the classical manipulation (d 7), athletes typically had gained 2 to 3 kg of water, felt poorly, and were apprehensive (Sherman and Costill 1984). A modified carbohydrate manipulation was then developed in which athletes merely depleted glycogen stores through intense, exhaustive exercise and then consumed a high carbohydrate diet for several days before competition (Sherman and Costill 1984). Recently there has been a further carbohydrate manipulation pattern, sometimes called "loaf-loading" by athletes, in which

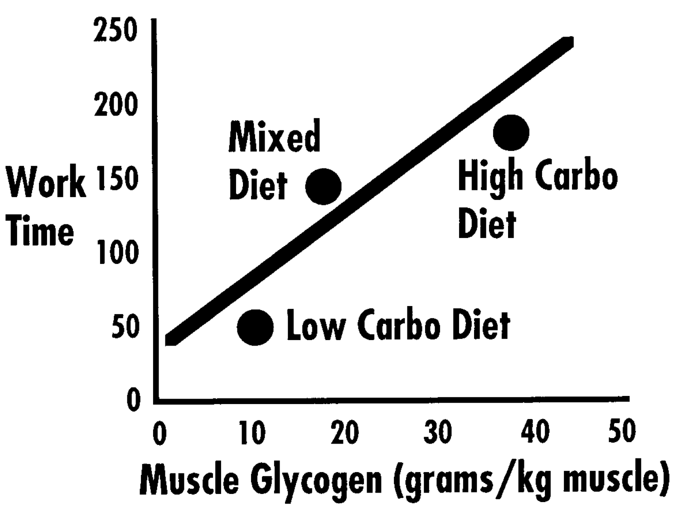

FIGURE 2 The relationship of muscle glycogen content, work time and dietary carbohydrate intake (adapted from Borgström et al. 1967).

practitioners do not exercise at all before an event, do not deplete glycogen storage to enhance glycogen deposition, and simply increase the quantity of carbohydrate in the diet (Sherman and Costill 1984, Applegate 1988).

The Scandinavian research on carbohydrate led to the development and application of the first sports nutrition product, Gatorade®, in the 1960s. Evidence that carbohydrate feedings could delay fatigue was implemented by researchers at the University of Florida, Gainsville, with the objective of improving the "Gators" football team performance (Cade et al. 1972). Gatorade, a mixture of glucose and sucrose in water at approximately 6% solution, ultimately spawned a multimillion dollar sports beverage industry. Other beverages, among them ERG®, were developed in the 1970s. At present, there are more than 20 different sports drinks creatively marketed in the United States and abroad under labels as diverse as Powerade® and All Sport®. These products are utilized by athletes and nonathletes alike and are readily available to the general public. Some, such as All Sport and Sport Toddy®, are fortified with vitamins.

With the increased attention on adequate carbohydrate in the diet, athletes, particularly those involved in endurance sports, struggled with meeting recommended levels of carbohydrate intake at ≳60% or total energy intake (Burke and Read 1993). 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, with names such as Cliff Bar®, VO_2Max® and Powerbar® to captivate and catch prospective consumers.

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—those at the front of the pack—reportedly performed better after taking vitamin supplements (Mayer and Bullen 1960, Horstman 1972). Still, 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

TABLE 1

Partial list of presumed ergogenic aids and supplements used by athletes

Acetyl choline	Ginseng
Amino acids (individual and mixtures)	Glandulars
Bee pollen	Glucose polymers
β-Sitosterol	Inosine
Boron	Medium-chain triglycerides
Branched-chain amino acids	Octacosanol
Caffeine	(n-3) Fatty acids
Chromium picolinate	Pangamic acid
Citrulline	RNA
Coenzyme Q10	Royal jelly
Creatine	Smilax
Desiccated liver	Sodium bicarbonate
Eicosanoids	Spirulina
Ferulic acid	Succinate
γ-Hydroxybutyrate	Vitamins (mixtures and individual)
Gamma oryzanol	Wheat germ oil

et al. 1993, Clarkson 1995, Nieman et al. 1989). This has led to the development of commercial products designed to enhance antioxidant intake and to prevent antioxidant damage due to endurance and high intensity exercise.

MISCELLANEOUS PRODUCTS

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, 1940s and 1950s (Barron and Vanscoy 1993, Burke and Read 1993, Cureton 1954, Cureton and Pohndorf 1955, Grunwald and Bailey 1993, Williams 1989b 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).

Among the more commonly used ergogenic products since the 1970s, however, has been caffeine. 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), yet athletes, whether Olympic or casual, use caffeine in an effort to aid performance.

IS ANYTHING NEW?

The number of ergogenic aids used by athletes since the 1950s is staggering (**Table 1**). Whether or not these aids work, athletes will try almost anything in their search for the competitive edge, even products with demonstrated health risks, such as amphetamines and anabolic steroids or controversial behaviors such as blood doping. What is less realized today, however, is that the fatigue-masking effect of caffeine was known at the turn of the century (Williams 1992 and 1994), amphetamine use by athletes was documented in the early 1900s (Golding 1972), blood doping was used to improve endurance of World War II pilots in the 1940s (Boje 1939, Williams 1989a) and anabolic steroids were tested for their effect on improving muscle mass and athletic performance in the 1950s (Golding 1972).

Although modern athletes have surpassed their ancient and 19th century counterparts in running and swimming faster, throwing farther, and lifting heavier weights, athletes through the centuries have striven for the same objective: success and victory. The dual search, the quest for success and a personal best, has also been accompanied by the search for a nutritional competitive edge. There has been long, historical road through countless attempts at dietary manipulations, dietary supplements and ergogenic aids. Sometimes the quest has been successful, sometimes not. Sometimes the ergogenic aids have worked on a scientific basis; at other times the placebo effect brought improvement. It is the quest for an "edge," however, that poses an ethical dilemma, one that challenges both athlete and scientific researcher alike.

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