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# Nutritional supplements and sports performance: Introduction and vitamins

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■ **ABSTRACT**

An increasing number of athletes are adopting vegetarian diets for ecological, economic, religious, health and ethical reasons. Vegetarian diets (except possibly fruitarian and strict macrobiotic diets) can easily meet the nutritional requirements of all types of athletes provided they contain a variety of plant-foods. Vegetarian athletes, like most athletes, may benefit from education on food choices that benefit athletic performance and promote overall health. Sports success is dependent primarily on genetic endowment in athletes with morphologic, psychologic, physiologic and metabolic traits specific to performance characteristics vital to their sport. Such genetically-endowed athletes must also receive optimal training to increase physical power, enhance mental strength and provide a mechanical advantage. However, athletes often attempt to go beyond training and use substances and techniques, often referred to as ergogenics, in attempts to gain a competitive advantage.

■ **Key Words :** Sport nutrition, Dietary supplements, Vitamins, Sports performance

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Dietary supplements are used by athletes worldwide. In the United States, the Dietary Supplement Health and Education Act has defined dietary supplements as something added to the diet, mainly (1) vitamins, (2) minerals, (3) amino acids, (4) herbs or botanicals, and (5) metabolites/constituents/ extracts, or combination of any of these ingredients. In addition to actual food products targeted to athletes and physically-active individuals, numerous companies have marketed dietary supplements to athletes, often with the claim that sports performance may be enhanced. This is the first in a series of six articles to discuss the major classes of dietary supplements listed above. The major focus will be on efficacy of such dietary supplements to enhance exercise or sport performance, with brief coverage of safety, legality, and ethicality.

**Vitamins: Ergogenic theory:**

Vitamins function in the human body as metabolic regulators, influencing a number of physiological processes important to exercise or sport performance. For example, many of the B-complex vitamins are involved in processing carbohydrate and fats for energy production, an important consideration during exercise of varying intensity. Several B vitamins are also essential to help form hemoglobin in red blood cells, a major determinant of oxygen delivery to the muscles during aerobic endurance exercise. Additionally, vitamins C and E function as antioxidants, important for preventing oxidative damage to cellular and subcellular structure and function during exercise training, theoretically optimizing preparation for competition. Complete details of vitamin functions and requirements are available in several recent treatises from the National Academy of Science (1999).

Vitamin deficiencies can certainly impair exercise performance. A daily intake of less than one-third of the RDA for several of the B vitamins ($B_1$, $B_2$ and $B_6$) and vitamin C, even when other vitamins are supplemented in the diet, may lead to a significant decrease in $VO_2$max and the anaerobic threshold in less than four weeks. However, most studies report that athletes who consume high-calorie diets that contain the RDA of all nutrients have few vitamin or mineral deficiencies. Nevertheless, recent survey data indicate that vitamins are the most commonly used dietary supplements among various athletic groups. Can vitamin supplementation above that provided by an adequate, healthy, balanced diet enhance sport or exercise performance.

**Vitamin supplements: Efficacy:**

Studies have been conducted to evaluate the ergogenic potential of virtually every individual vitamin, as well as clusters of vitamins and related substances, including the B-complex vitamins, multivitamin/mineral compounds and antioxidants.

*B vitamins and choline:*

As many of the B vitamins are involved in the metabolism of carbohydrate, fat and protein, their ergogenic potential has been studied individually and in combination. In general, although a deficiency of the B vitamins may impair both aerobic and anaerobic exercise performance, supplementation has not been shown to enhance performance in well-nourished individuals. Niacin supplementation may influence fat metabolism, blocking the release of free fatty acids (FFA) from adipose tissue and increasing reliance on carbohydrate utilization, possibly leading to premature depletion of muscle glycogen. Some research has indicated that excess niacin supplementation may actually impair aerobic endurance performance. Vitamins $B_1$, $B_6$ and $B_{12}$ are believed to affect the formation of serotonin, an important neurotransmitter involved in relaxation. Some research with large doses (60–200 times the RDA) of these vitamins has shown increases in fine motor control and performance in pistol shooting. Others have suggested that the beneficial effect was related to the role of these vitamins in promoting the development of neurotransmitters that induce relaxation. Additional research is merited to evaluate these effects on performance in precision sports dependent on fine motor control. However, it should be noted that such doses could exceed the Tolerable Upper Intake Level (UL) for vitamin $B_6$.

Choline, an amine, is found naturally in a variety of foods and its RDA is grouped with the B vitamins. 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 marathon running, choline supplementation has been theorized to prevent fatigue. 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. For example, choline supplementation, although increasing plasma free choline in marathon runners, had no effect on predicted or actual marathon time.

*Multivitamin/Minerals:*

The overall review of the literature supports the viewpoint that multivitamin/mineral supplements are unnecessary for athletes or other physically active individuals who are on a well-balanced diet with adequate calories. For example, several studies have provided multivitamin/mineral supplements over prolonged periods and reported no significant effects on both laboratory and sport-specific tests of physical performance. In one of the most comprehensive studies, Telford and others evaluated the effect of long term (7–8 months) vitamin/mineral supplementation (100 to 5,000 times the RDA) on exercise performance of nationally ranked athletes in training at the Australian Institute of Sport. The athletes were tested on a variety of sport-specific tasks as well as common tests of strength, anaerobic power, and aerobic endurance. They reported no significant effect of the supplementation protocol on any measure of physical performance when compared to athletes whose vitamin and mineral RDA were met by normal dietary intake.

*Antioxidants:*

Antioxidant vitamins include vitamins C, E and beta-carotene, while coenzyme $Q_{10}$ ($CoQ_{10}$) is a lipid with vitamin characteristics. Antioxidant vitamins have been studied individually and collectively for their potential to enhance exercise performance or to prevent exercise-induced muscle tissue damage.

**Antioxidants and exercise performance:**

Vitamin C supplementation has been shown to improve physical performance in vitamin C-deficient subjects, but several major reviews support the general conclusion that vitamin C supplementation does not enhance physical performance in well-nourished individuals.

Vitamin E has been shown to enhance oxygen utilization during exercise at altitude, but does not appear to be an effective ergogenic under sea level conditions. A contemporary review indicated that although vitamin E supplementation may increase tissue or serum vitamin E concentration, most evidence suggests there is no discernable effect on training, performance, or rate of post-exercise recovery in either recreational or elite athletes. $CoQ_{10}$, also known as ubiquinone, is an antioxidant and may improve oxygen uptake in the mitochondria of the heart, and has been used therapeutically for the treatment of cardiovascular disease. Theoretically, improved oxygen usage in the heart and skeletal muscles could improve aerobic endurance performance. Only limited data are available, but these studies have shown that $CoQ_{10}$ supplementation to healthy young or older subjects did not influence lipid peroxidation, heart rate, maximal oxygen uptake, anaerobic threshold, or cycling endurance performance. One study reported that $CoQ_{10}$ supplementation was associated with muscle tissue damage and actually impaired cycling performance compared to the placebo treatment. Overall, a recent review concluded that there is limited evidence that dietary supplementation with antioxidants improves human performance.

**Antioxidants and muscle tissue damage:**

Sen (2001) indicated that strenuous exercise may generate reactive oxygen species (ROS) to a level to overwhelm tissue antioxidant defense systems. The result is oxidative stress, and one possible outcome is oxidative damage to muscle tissues. Preventing muscle tissue damage during exercise training may help optimize the training effect and eventual competitive sports performance. Numerous studies have evaluated the potential of antioxidant vitamin supplementation to prevent exercise-induced muscle tissue damage, and several extensive reviews have evaluated the available literature. However, the viewpoints of the reviewers vary somewhat.

Several reviewers conclude that antioxidant vitamin supplementation does not appear to prevent exercise-induced muscle tissue damage. Goldfarb (1999) concluded that research findings, mostly conducted with vitamin C, vitamin E, and beta carotene, have indicated that clear evidence for their prophylactic effect on various types of muscle damage following exercise is lacking. Other reviews have indicated that although animal studies have shown some promising effects of antioxidant supplementation to lessen exercise-induced oxidative stress damage, studies with humans are less convincing.

Contrarily, Dekkers *et al.* (1996) and others concluded that dietary supplementation with antioxidant vitamins has favorable effects on lipid peroxidation and exercise-induced muscle damage and recommend vitamin supplementation to individuals performing regular heavy exercise. Evans noted that several antioxidants, including vitamin C and especially vitamin E, have been shown to decrease the exercise-induced increase in the rate of lipid peroxidation, which could help prevent muscle tissue damage. Other researchers are convinced that vitamin E contributes to preventing exercise-induced lipid peroxidation and possible muscle tissue damage, and recommend that athletes supplement with 100–200 milligrams of vitamin E daily to help prevent exercise-induced oxidative damage. Ji indicates that the delicate balance between pro-oxidants and antioxidants suggests that supplementation of antioxidants may be desirable for physically active individuals under certain physiological conditions by providing a larger protective margin. In particular, Ji notes that the aging process lessens the exercise training-induced improvement in natural antioxidant enzymes and suggests exercise training in older athletes might be assisted with antioxidant supplementation in attempts to optimize antioxidant defense.

Sacheck and Blumberg (2001) concluded that the use of dietary antioxidants like vitamin E to reduce exercise-induced muscle injury have met with mixed success, which seems to be the prevailing viewpoint. All reviewers indicate more research is needed to address this issue and to provide guidelines for recommendations to athletes.

**Vitamin supplements: Safety, legality and ethicality:**

Vitamin supplementation, particularly when limited to 100 percent of the RDA for each vitamin, is generally regarded as safe. However, excess amounts of several vitamins may contribute to serious health problems and tolerable upper limits (UL) have been established for many vitamins. For example, excessive amounts of vitamin A consumed by women who are pregnant may cause birth defects. Excessive amounts of niacin may contribute to liver damage. For complete details, consult the treatises by the National Academy of Science (2000 a and b).

The use of pure vitamin supplements by athletes is legal and ethical. However, some vitamin sports supplements marketed by unscrupulous entrepreneurs may contain banned substances. At the present time the dietary supplement industry is poorly regulated, and some preparations for athletes may be adulterated with banned substances, such as ephedrine. Athletes who consume vitamin supplements should purchase them only from reputable companies, such as those whose products that carry the USP (United States Pharmacopeia) certification on the label.

**Vitamin supplements and sport\exercise performance: Summary:**

In general, health professionals indicate that vitamin supplements are not necessary for the individual on a well-balanced diet, but they may be recommended for certain individuals, such as the elderly, vegans, and women of childbearing age. Moreover, some health professionals note that most people do not consume an optimal amount of vitamins by diet alone and indicate that it appears *prudent* for all adults to take vitamin supplements. In such cases, there is no need to take more than 100–150 per cent of the RDA.

Obtaining adequate vitamins, including use of supplements, may also be prudent behaviour for some athletes. Melinda Manore noted that athletes involved in heavy training may need more of several vitamins, such as thiamin, riboflavin and $B_6$ because they are involved in energy production, but the amount needed is only about twice the RDA and that may be easily obtained through increased food intake associated with heavy training. However, in a recent scientific roundtable exchange , several sport nutrition experts indicated that some athletes may be at risk for a vitamin deficiency, such as those in weight-control sports and those who for one reason or another do not eat a well-balanced diet. Others note that the prudent use of antioxidant supplementation can provide insurance against a suboptimal diet and/or the elevated demands of intense physical activity, and thus may be recommended to limit the effects of oxidative stress in individuals performing regular, heavy exercise.

**Nutrition before, during and after exercise:**

*Pre-event meal:*

Nutritional intake in the meal before a competition or exercise session should increase fuel stores, provide adequate hydration and prevent both hunger and gastrointestinal distress. Studies have shown that consumption of between 1 and 5g of CHO/kg BW one to four hours before endurance exercise has the potential to improve endurance performance by as much as 14 per cent (20) and is also thought to benefit high-intensity performance. Vegetarian athletes should be encouraged to consume familiar, well tolerated, high-CHO meals that are low in sodium, simple sugars and fiber. Studies looking at CHO supplementation during the 30-60 min prior to exercise, however, have indicated that CHO may need to be avoided during this period. To avoid the possibility of rebound hypoglycemia and decreased performance seen in some athletes. Interestingly, recent studies have suggested that consumption of CHO (1g/kg) with a low glycemic index (lentils vs. glucose or potatoes)1 hour before exercise may prolong endurance during strenuous exercise by maintaining higher blood glucose concentrations towards the end of exercise, and may also confer an advantage by providing a slow-release source of glucose without an accompanying insulin surge. On the other hand, ingestion of a liquid CHO supplement immediately before exercise (5 min) is appropriate and has been found to improve performance during endurance and resistance exercise.

Specific pre-event food choices, however, may need to be individualized. Athletes sensitive to gastroesophageal reflux should avoid caffeine, chocolate, sulfur-containing vegetables and concentrated sources of fat. Those experiencing frequent nausea, cramps and vomiting should pay attention to meal timing and not eat within 3 or 4 hours before exercise. Those experiencing diarrhea often benefit from a low residue diet 24-36 hours before a major event. Also, liquid meals are more easily digested and may be helpful for avoiding the pre-game nausea sometimes associated with solid foods. Guidelines for fluid consumption include consuming at least 2 cups fluid about 2 hours before exercise, followed by another 2 cups approximately 15-20 min before endurance exercise.

*Supplementation during exercise:*

Carbohydrate ingestion at levels between 45 and 75g/h have been shown to benefit prolonged, moderate intensity exercise (2 h) and variable intensity exercise of shorter duration presumably by maintaining blood glucose levels as endogenous glycogen stores become depleted. Ingestion of fluid replacement beverages easily provide CHO requirements while simultaneously meeting fluid needs. For example, consumption of 4-8 oz of 7 per cent CHO drink (level of most commercial beverages) every 15 minutes , would supply 34-50g CHO/h. Even more CHO can be provided when fluid is ingested in accordance with ACSM recommendations. While commercial sports drinks work well, vegetarian athletes may prefer diluted fruit juice (4 oz juice in 4 oz water = 6% solution) or low sodium vegetable juices such as carrot juice (7% solution). Solid CHO supplements are found to work equally as well providing they are ingested with water. Foods that are well absorbed and easily-carried include bananas, grapes, orange section, baked potatoes, bagels and sport bars.

*Post-exercise nutrition*:

Glycogen and fluid replacement are the immediate concern after prolonged or strenuous exercise. This is particularly important during heavy training. To facilitate rapid muscle glycogen synthesis, research has found that athletes should consume CHO immediately after and at frequent intervals following exercise. According to Sherman , the rate of CHO consumption should be approximately 1.5 g CHO/kg BW at 2 hour intervals for up to 4 hours. Hence, an 80 kg runner should consume about 120 g at 0, 2 and 4 hours post-exercise. Other glycogen replenishing regimens have also been suggested (6, 19) Two recent studies have suggested that ingestion of foods with a high glycemic index and protein (~1 g protein:3 g CHO) may increase the rate of muscle glycogen storage after exercise by stimulating greater insulin secretion. In the latter study, however, it is difficult to tell whether greater insulin secretion resulted from increased protein or increased energy intake. Current recommendations for post-exercise fluid requirements are to consume at least a pint of fluid for every pound of body weight deficit. Consuming water with the recovery meal should be sufficient providing the meal contains adequate sodium and potassium. However, if food is not available or desirable, ingested fluid should contain sodium chloride and other electrolytes. When sodium is provided in fluids or foods, the osmotic drive to drink is maintained and urine production is decreased.

**Of special concern for the female athlete:**

The prevalence of amenorrhea among exercising women is reported to be between 3.4 and 66 per cent with higher prevalence in runners as opposed to cyclists and swimmers.

The cause of this secondary hypothalamic amenorrhea is unknown, but may be related to training level, nutritional status, body composition changes, stress, and hormone changes with exercise. While some studies have noted higher prevalence of secondary amenorrhea among "vegetarians", other have not come to the same conclusions. By definition, however, "vegetarians" in these studies consumed low-meat and not necessarily vegetarian diets. In nonathletic females, Goldin *et al.*, () found lower circulating estrogen levels in vegetarians compared to nonvegetarians which were associated with higher fiber and lower fat intakes, higher fecal outputs and 2-3 times more estrogens in feces. This may suggest that nutrient composition of some vegetarian diets may be predisposing to amenorrhea. In athletes, several studies have generally found lower intakes of energy, protein, fat, and zinc, and higher intakes of fiber and vitamin A in amenorrheic compared to eumenorrheic athletes.

Given the high prevalence of amenorrhea among athletic women, nutritionists should take a menstrual cycle history as part of screening procedure and if appropriate refer the athlete for medical evaluation and treatment. Nutritional evaluation and education of vegetarian athletes needs to focus on adequacy of energy, protein, fat, zinc and fiber intakes. If appropriate, eumenorrheic athletes can increase energy intake and decrease fiber by consuming 1/3 to 1/2 of their cereal/ grain servings from refined rather than whole grain sources and by replacing some high fiber fruit/vegetable servings with fruit/vegetable juices.

**Conclusion:**

Nutritionists can play an essential role optimizing the health and athletic performance of vegetarian athletes of all ages and abilities. Sports nutritionists who work with vegetarian athletes and their coaches and trainers, however, need to be sensitive to and knowledgeable about vegetarian issues. In this setting, the role of the nutritionist is to work with the athlete to ensure adequate nutritional status given his/her vegetarian beliefs, income and lifestyle. While athletes should be encouraged to eat a wide variety of plant foods, this does not mean convincing the vegetarian athlete that they need poultry, fish or dairy products in the diet. The American Dietetic Association's position on vegetarian diets states that "vegetarian diets are healthy and nutritionally adequate when appropriately planned".

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