The Athlete's Diet: A Current View

Malcolm L. McCutcheon, MD
Duluth, Minnesota

As a result of new interest in prescribing individual athletic programs and healthy life styles, the average participant and the health care provider are faced with confusing information on what constitutes optimal nutrition. Not only has the efficacy of dietary supplements (high-protein, "megadose" vitamins and minerals) for improved athletic performance not been demonstrated, but these supplements can also have undesirable effects. A diet of adequate calories and composition remains the optimal source of good nutrition and must be balanced with energy output. While most mineral supplements are unnecessary, iron supplements for female athletes and for male long-distance runners may be advisable. Carbohydrate loading is the only dietary manipulation shown to affect athletic performance and then only in the endurance athlete. Conscious water replacement is needed during and after competition.

With the new surge of active life styles and individual-oriented athletic programs, good nutrition has in many instances remained a murky and poorly understood aspect of getting in shape. The concern of the average American with proper nutrition is reflected by the proliferation of diet books that are consistently among the bestsellers in this country. Most of these books give only partly helpful advice. Proper nutrition is often lost to food fads, quackery, and superstition, and this is at least as true for athletes as it is for the general population.

Although coaches, trainers, and athletes usually well understand the principles of physical training, they often neglect the equally well-developed principles of nutrition. Thus, many an athlete engaged in competitive sports, from the trained professional to the weekend warrior, ascribes special properties to foods and food supplements that seem to improve athletic performance but have little nutritional merit. In their eager search for the magic combination that will propel them to the pinnacle of their ability, many athletes assume a mystic, quasi-religious attitude toward certain foods and food supplements. As a result nutritional science takes on a mystique that is based on feelings and beliefs with little basis in fact. Consequently, the athlete may come to believe in protein supplements or vitamins but have little understanding of what the body needs or how these nutrients are used. Coaches and trainers may fall into the same trap, so that advice given to athletes becomes a mixture of tradition, superstition, and science.

Most physicians have only recently been thrust into the sports medicine scene and lack sound nutritional information with which to counsel their patients. This paper is an attempt to apprise primary care physicians of current scientific information regarding nutrition in athletes as reflected in the current literature.

Metabolic Considerations

Each tissue system of the body is in a unique dynamic metabolic equilibrium. Manipulation of

From the Student Health Services and Department of Clinical Sciences, School of Medicine, University of Minnesota–Duluth, Duluth, Minnesota. Requests for reprints should be addressed to Dr. Malcolm L. McCutcheon, University of Minnesota–Duluth, Student Health Services, 1215 University Health Circle, Duluth, MN 55812.

this equilibrium from the natural state is rarely beneficial, and balanced nutrition is aimed at providing basic essential nutrients in amounts that meet the body's needs without overloading the system. All foods can serve as fuel for energy, but no one food provides all the essential nutrients; therefore, a balance of protein, carbohydrates, and fat, plus vitamins and minerals, is necessary.

Protein Metabolism

Protein is the basic component of all body tissue and constitutes about 15 to 20 percent of body weight in the nonobese human. Since amino acids are not stored in the body, the protein compartment must be maintained by daily intake. A typical adult requires approximately 0.5 g of protein per kilogram per day, and the athlete in rigorous training needs 0.8 g/kg/d. Most people in well-fed nations consume about four times this minimum, more than meeting any increased need for athletic performance.[1] The quality of the protein (the number of essential amino acids it provides) is guaranteed to be high if it comes from a variety of sources.

Excess protein that is not used for energy production is converted to fat and stored. Bathing body tissue in excess protein does not build more muscle tissue. Once growth is complete, only vigorous muscle exercise will increase muscle mass, and the basic diet supplies more than enough protein to accomplish this. Protein supplements are expensive ways to produce fat.

If necessary, the body's protein can be broken down into component amino acids and metabolized for energy. About one third of the body's total protein is potentially available as an energy source in case of extreme need, which can actually occur with overzealous dieting.

Carbohydrate Metabolism

The body prefers carbohydrate in the form of glucose for immediate energy. The central nervous system is totally dependent on glucose as a source of energy. This simple sugar is manufactured by the healthy body from two major nutrients, carbohydrates and protein. In more demanding conditions, it can also be obtained from ingested or stored lipids by hydrolysis of glycerol and by gluconeogenesis. Small amounts of carbohydrates can be stored as glycogen in the liver and muscles. Liver glycogen is used to replenish blood glucose as necessary; muscle glycogen is used almost exclusively by the muscles themselves. The total energy reserve in the form of glycogen is about 500 g (200 g in the liver) and equals about one day's energy needs for the body.[1]

To protect the glycogen reservoir for emergencies, the body does not call on it immediately when the glucose level is temporarily insufficient. Instead, glucose is manufactured from hydrolytic products of lipids (glycerol) and protein (amino acids). Free fatty acids and amino acids can also be burned directly for energy.

During periods of more prolonged increased energy needs (fasting, endurance events), liver glycogen is converted to glucose (gluconeogenesis). The legendary "hitting the wall" occurs when glycogen stores are depleted, and the athlete must depend entirely on less-efficient fat metabolism. When the glycogen storage space is filled, excess carbohydrate is converted to lipid for economical storage as fat or triglyceride.

Lipid Metabolism

Lipid (fat and triglyceride) is a component of all body tissue, as is protein, and it is the chief stored energy substance in the body. As an energy fuel, fat supplies 9 kcal/g compared with 4 kcal/g of carbohydrate and protein. One pound of fat equals 3,500 kcal of energy. The typical 70-kg man stores 100,000 kcal (less than one month's supply of energy) as fat compared with 2,000 kcal as glycogen.[1] Normal fat reserves constitute 18 to 20 percent of body weight in women and 12 to 15 percent in men.

Carbohydrate Loading

Glycogen stores can be increased, thus increasing the capacity for prolonged strenuous exercise, by carbohydrate loading. Carbohydrate loading is the only dietary manipulation shown to affect endurance. It does not affect strength. In the classic experiment of Bergstrom et al[2] in 1967, six days before competition, athletes ate a high-protein, high-fat, low-carbohydrate (15 percent) diet for three days and exercised vigorously to deplete the glycogen stores as demonstrated on needle biopsy of muscles. This was followed by three days of high-carbohydrate (70 percent) diet and minimal exercise. Repeat biopsy showed a doubling of muscle glycogen. Moore[3] has demonstrated that extreme carbohydrate deprivation is not necessary to achieve good loading and achieved the same results with three days of 50 percent carbohydrate diet and usual exercise, followed by three days of 70 percent carbohydrate diet. He further demonstrated that glycogen stores were reduced only a little more than one half after a 13-mile run, and concluded that carbohydrate loading is not necessary for this degree of energy output but is of value only in the endurance athlete who is exercising continuously for two to three hours.

There are some possible disadvantages to carbohydrate loading:

1. With each gram of glycogen stored, the muscle stores 3 g of water; some runners complain that this extra weight and a feeling of muscle tightness impair performance early in the race.
2. Some people develop diarrhea after the loading phase, especially if they rely too heavily on simple and refined sugars.
3. The heart muscle also participates in the loading phenomenon, and there has been reported an increase in arrhythmias and angina,[4] although some physicians dispute this.[3]
4. There is some speculation that muscle cell damage can occur as a result of carbohydrate loading and myoglobinuria has occurred.[4] The empirical recommendation is that loading not be used more than four times a year, since there are no data yet available on possible long-term effects.

While carbohydrate loading is of no value other than to endurance athletes, it is important that all athletes replace glycogen burned in training. This can generally be accomplished with a 50 to 55 percent carbohydrate diet, but some people recommend that the athlete working out heavily for several days in a row eat a diet higher in carbohydrates. Muscle glycogen stores can be repleted to previous levels within 24 hours when a 70 percent carbohydrate diet is consumed.[4] High-carbohydrate diet can be achieved more easily and is often better tolerated if taken as a liquid supplement. Polycose and Gatorlode 280 are two such supplements that have been successfully used.[3]

Optimal Diet for Athletes

Diet is a highly subjective matter, and appetizing, nutritious diets can vary widely to satisfy individual tastes. "Good" diets are made up of a wide variety of foods from each of the four basic food groups (dairy products, meats, vegetables and fruits, and grain and cereals) balanced to provide approximately 15 percent of daily calories as protein, 35 percent as fat, and 50 percent as carbohydrates. Total food requirements vary with activity level; as a rule of thumb, 15 kcal/lb of body weight will maintain present weight. To this basic requirement add 50 percent for light activity, 75 percent for moderate, and 100 percent for strenuous activity.[5] Adding an additional 500 kcal/d without increasing activity will result in a 1 lb/wk weight gain; conversely, eating 500 kcal/d less will yield a 1 lb/wk weight loss. Intake must be balanced with output.

Table 1 shows the approximate number of calories used per minute in various activities. Caloric intake for the 170-lb athlete in training with vigorous energy output may exceed 5,000 kcal/d compared with 2,850 kcal/d between seasons. Athletes who want to avoid obesity must be careful not to continue the habit of high-calorie intake when they decrease their workouts between seasons. Attempting to lose weight by exercising without modifying caloric intake is difficult. Jogging 20 minutes each day for 10 days will produce a 1-lb fat loss as well as the fringe benefits of increased vitality and improved muscle tone.

Vitamins

Seventy-five percent of American households use vitamin supplements, resulting in a $100 million business in the United States.[6] A balanced diet supplies all of the essential vitamins and minerals in adequate amounts. The question is, are additional vitamins really beneficial?

Table 1. Calories Used per Minute

Activity	Calories
Walking upstairs	20
Jogging	17
Skating	12
Swimming	12
Basketball	9
Bowling	8
Bicyling	8
Tennis	7
Walking outside	6
Dancing	4
Horseback riding	3
Resting in bed	1

There are two styles of vitamin users. Many take one vitamin pill each day, including the required daily allowance for each vitamin, as a kind of nutritional insurance. In most cases there is no serious objection nutritionally or financially to this practice, although there are no data to support the impression that vitamin supplements added to a well-balanced diet provide any nutritional advantage.

Then there is the vitamin user who takes megadoses of individual vitamins, often in addition to the once-daily multivitamin preparation. This person may take 500 mg of vitamin C, 1,000 units of vitamin E, several tablespoons of nutritional yeast, some kelp tablets, a capsule of vitamin A and D, trace minerals plus dessicated liver, powdered bone meal, and wheat germ sprinkled on Granola. Such a person is using vitamins as a medication rather than as an essential nutrient, and there is considerable controversy over this kind of use. When taken in excess of the required daily allowance, vitamins have no clearly demonstrated advantages, and some may have significant disadvantages. One example is the fat-soluble vitamins A and D, which are stored in body fats. Excess intake of vitamin A can cause increased intracranial pressure, whereas excess vitamin D can cause increased serum calcium leading to renal stones, cataracts, increased blood pressure, and related sequelae.

Water-soluble vitamins have been thought to be relatively safe, although not particularly advantageous, in megadoses because those portions ingested in excess to nutritional needs are simply eliminated in the urine. Excess vitamin B_3 (niacin), however, can produce diabetes, gout, and liver disease, and smaller amounts inhibit uptake of free fatty acids by cardiac muscle (ie, the heart's main immediate energy source).[4]

Much has been written about the benefits of megadoses of vitamin C, and much of it remains unproven. There is evidence that chronic use over many months tends to increase the body's rate of degrading vitamin C, and there is risk of developing deficiency states (scurvy) when the excessive dose is decreased, especially for the newborn whose mother took high doses of vitamin C during pregnancy.[6,7] Increased risk of kidney stones and impaired bacteria-killing ability by white blood cells has also been reported.[6]

Athletes require higher thiamine, riboflavin, and niacin because their requirements relate to total caloric intake. Vitamin C requirements vary from person to person, but normal variations do not justify use of large quantities of vitamins in concentrated form. Such use at worst can cause disease and at best makes for expensive urine. For the healthy athlete eating an adequate diet, extra or special vitamins are not indicated.

Iron

Daily iron intake needed to maintain body stores is thought to be achieved with intakes of 10 mg/d for men and 14 mg/d for women. Normally 5 to 10 percent of ingested iron is absorbed to replace daily losses, which in men is 1 mg/d through stool, urine, sloughed skin, and nails, and in women is up to 1 mg more per day in menstrual loss. Training tends to increase red blood cell mass (18 percent) and plasma volume (31 percent), thus sometimes resulting in a decreased hematocrit. Because muscle mitrochondria in the trained athlete takes up oxygen with greater efficiency, this apparent anemia is probably not consequential, and the male athlete does not need supplemental iron.[8]

An exception is the long-distance runner. Although Clement and Asmundson[8] in their study of 52 long-distance runners found no women with hemoglobin levels less than 12 g and only 10 percent of men with hemoglobin levels less than 14 g (the respective levels considered to indicate clinical anemia), 82 percent of the women and 29 percent of the men had decreased serum ferritin, thus suggesting decreased bone marrow iron stores.

Several mechanisms may contribute to this subclinical deficiency:

1. Using $^{59}FeSO_4$ and a whole body counter, iron absorption in top male runners with iron deficiency was 16.4 percent compared with 30 percent in control groups of blood donors also with deficiency.

2. Thirty percent of women and 2.5 percent of men had iron intake below the required daily allowance.

3. Twenty-six percent of men and 91.1 percent of women had lowered heptoglobin levels, suggesting hemolysis. The resulting hemoglobinuria may account for increased iron loss. Mechanical damage of the red blood cells from the impact of the foot on the running surface is speculated to be the cause of the erythrocyte hemolysis. Once the binding capacity of heptoglobin for free hemoglobin is exceeded, hemoglobin may be excreted in the urine.

4. Increased sweat loss may contribute to iron loss. In 100 cc of sweat is contained 10 mg of iron; 0.4 to 1 mg of iron per day may be thus lost.

Testing for serum ferritin is a better basis for detecting latent iron deficiencies than are the traditional hemoglobin or hematocrit values, and latent deficiency without anemia can reduce physical work capacity and impair performance.[9]

Because a large number (75 to 90 percent) of female athletes do not meet their daily iron requirement, they should receive supplemental iron.[6,8]

Other Minerals

Adequate zinc, chloride, sodium, copper, and cobalt are important to good health, but because they are adequately supplied by a diet rich in vegetables, fruits, and cereals, deficiency is unlikely to occur. Despite its popularity with some nutrition counselors, hair analysis of trace minerals is expensive and does not significantly contribute to general nutritional counseling.[6]

Salt and Water

Satisfying water requirements is essential for health and physical performance. A rapid water loss of 5 percent of body weight can reduce work capacity by 20 to 30 percent.[6] Hard exercise in hot, humid weather and prolonged practices, as experienced by runners and football players, dramatically increase water requirements. A hockey player loses 2.5 to 4 L of water during a game. Replenishing that loss is not easy, and the thirst mechanism alone does not satisfy it.

Dill's classic work involving donkeys and men exercising in the desert showed that donkeys would replace almost all the water they lost but that humans would not voluntarily do so.[9] Long-distance runners lose weight on a run because they do not replace their water loss even though they are provided water as often as they want it.

Precompetition athletes should choose fluids that will pass through their stomachs rapidly and will not cause gastrointestinal distress. Caffeine-containing liquids, including cola drinks, may improve reflex time slightly, but they are diuretic, may further agitate an already nervous athlete, and should be avoided for three to four hours before competition. Beer decreases performance skills and concentration, increases calories, and releases gas into the gut, as do other carbonated drinks. Immediately before and during competition, liquids high in sugar should be avoided, since sugars increase absorption time and tend to give a heavy feeling in the gut.

Taking fluids frequently during competition is important, especially during long events or in hot, humid weather. Diluted juice, such as 1 part orange juice and 4 parts water, or plain water is the best replacement fluid during competition.[6] The correct way to replace water losses and maintain normal body temperature is to replace with water the weight lost during exercise. A weigh-in before and after exercise is, therefore, important. After competition, extra fluids should be taken over a period of several hours. A person who sweats heavily (eg, 2 L) during competition cannot replace the lost fluid rapidly by drinking that much because the stomach cannot absorb more than 1 L/h.[6] Apple juice, orange juice, lemonade, and skim milk are good rehydrating fluids.

An athlete should begin replacing salt as well as water after having drunk more than four quarts of water to replace salt lost in heavy sweating. Replacement need not be immediate, however, and should not be with salt tablets. Since most Americans normally eat 10 to 20 times their daily requirement of salt, it is not difficult to replace salt losses with normal eating. If weight control is important to the sport, an excess of salt should be avoided.[6]

Even when weight is restored, it takes four to five hours to restore fluid distribution. For instance, a wrestler who dehydrates himself to a desired weight cannot restore physiologic equilibrium in the three hours between weigh-in and competition.

Pregame Meals

It is desirable to have an empty stomach at game time. Pregame emotional tension is frequently translated into digestive upset, with slowing of the digestive process. If food has not evacuated the stomach by game time, nausea, vomiting, and abdominal cramps often occur. The pregame meal should be eaten about four hours before the event. Large pregame meals yield increased blood flow to viscera and away from muscle, increasing anaerobic metabolism and lactic acid formation in the muscles. Anaerobic metabolism is 25 times less efficient in energy release than is aerobic metabolism.[10] It takes about two hours for food to become liquid and leave the stomach and another two hours before it leaves the small intestine. Since it is desirable to have an empty stomach and maximum blood flow available to the muscles, it is inadvisable to eat excessively before a game. A light meal high in complex carbohydrates, but not free sugars, is desirable and helps avoid rebound low blood sugars at game time. Excess free sugar increases insulin production and decreases liver glycogen stores. Increased insulin further retards fat metabolism.[6] Excess free sugar is hypertonic and draws fluid into the gut.[11] One should avoid extremely large meals or meals high in fats or proteins, which are more slowly digested and tend to result in abdominal distention, cramps, or vomiting during competition. Excess protein can enhance mild dehydration through production of end products such as urea and ammonia that require increased urinary excretion.[4] Also to be avoided are foods that are gas producers or known to be laxative or excessive bulk producers.

Liquid Pregame Meals

Liquid pregame meals can minimize all of the above problems. There are a number of liquid dietary supplements available, but not all of them are palatable. Sustagen, containing 68 percent carbohydrate, 24 percent protein, and 8 percent fat, furnishes 925 calories per 16 oz. It is best taken mixed with milk, flavored with chocolate or strawberry, and chilled. Polycose is another product that meets the requirements. These products pass through the stomach rapidly and have low residue. Hunger feelings can be decreased by combining these preparations with modest amounts of high-carbohydrate solid foods such as toast and honey, pasta, rice, or potatoes.

Weight has been demonstrated to remain steady even when liquid meals are used for two meals per day. Nausea and vomiting and pregame cramps during competition are completely eliminated, diarrhea does not occur, and general strength and endurance are well maintained. Liquid meals do not replace conditioning or all the other factors involved in superior performance, but they have a useful place in athletic nutrition.

References

1. Fundamentals of Nutritional Support. Deerfield, Ill, Travenol Laboratories, 1979, pp 8-15
2. Bergstrom J, Hermansen L, Hultman E: Diet, muscle glycogen and physical performance. Acta Physiol Scand 71:140, 1967
3. Moore M: Carbohydrate loading: Eating through the wall. Physician Sports Med 9(10):102, 1981
4. Nelson RA: Nutrition and physical performance. Physician Sports Med 10(4):55, 1982
5. Gundersen K (ed): Are You Really Serious About Losing Weight? Rochester, NY, Pennwalt, 1982, pp 18, 25
6. Hamilton E, Whitney E: Concepts and Controversies in Nutrition. St. Paul, Minn, West Publishing, 1982, pp 45-49, 279
7. Nelner RA: "Exceptional" Nutritional Needs of the Athlete: Nutrition for Athletes—Handbook for Coaches. Washington, DC, American Association for Health, Physical Education and Recreation, 1971
8. Clement DB, Asmundson RC: Nutritional intake and hematologic parameters in endurance runners. Physican Sports Med 10(3):37, 1982
9. Ryan AJ: Weight reduction in wrestling. Physician Sports Med 9(9):78, 1981
10. Stokes PG (ed): Guide to Sports Medicine. New York, Churchill Livingstone, 1979, pp 20-23
11. Domenquez R: Complete Book of Sports Medicine, New York, Scribner, 1979, pp 21-31