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ABSTRACT

Nutrition is well-recognized as a necessary component of educational programs for physicians. This is to be valued in that of all factors affecting health in the United States, none is more important than nutrition. This can be argued from various perspectives, including health promotion, disease prevention, and therapeutic management. In all cases, serious consideration of nutrition related issues in the practice is seen to be one means to achieve cost-effective medical care. These modules were developed to provide more practical knowledge for health care providers, and in particular primary care physicians. This module is designed to help the primary care physician to identify the relationship between nutrition and physical activity. Efforts are made to examine health maintenance aspects as well as the physical development aspects of the relationship. Diet and fitness fads are explored to assist the physician in counseling patients regarding such fads. Included are learning goals and objectives, a self-check of achievement with regard to goals, references, and lists of resources for patients and physicians. Appendices include sample menus, daily food requirements for training and endurance, and sample menus for a high calorie diet, including a set for ovolactovegetarians. (CW)

The Nutrition in Primary Care Series Contains These Modules:

1. Nutrient Content of Foods, Nutritional Supplements, and Food Fallacies
2. Appraisal of Nutritional Status
3. Nutrient and Drug Interactions
4. Normal Diet: Age of Dependency
5. Normal Diet: Age of Parental Control
6. Normal Diet: Adolescence
7. Normal Diet: Pregnancy and Lactation
8. Normal Diet: Geriatrics
9. Dietary Management in Obesity
10. Dietary Management in Diabetes Mellitus
11. Dietary Management in Hypertension
12. Dietary Management in Hyperlipidemia
13. Dietary Management in Gastrointestinal Diseases
14. Dietary Management for Alcoholic Patients
15. Nutritional Care of Deteriorating Patients
16. An Office Strategy for Nutrition-Related Patient Education and Compliance

The Nutrition in Health Promotion Series Contains These Modules:

17. Individual and Social Factors
18. Metabolic Principles
19. Risk Factors and Disease Prevention
20. Decoding Fad Diets
21. Protecting Bone and Teeth
22. Exercise and Physical Activity
23. Vitamins and Trace Minerals
24. Behavioral and Neurological Disorders
25. Preventing Hospital and Home Malnutrition
26. Questions About Common Ailments

Faculty Guide (includes comprehensive index for Modules 1-26)

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22 Nutrition in Health Promotion: Nutrition and Physical Activity

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Introduction

More Americans are involved in exercise than ever before. The primary care physician is being called upon with greater frequency not only to assess the fitness of patients for participation in a variety of exercise programs, but also to advise patients as to appropriate nutrition as such programs are undertaken. Questions range from concerns about diet, exercise, and weight loss to the effectiveness of carbohydrate loading before an athletic event. The primary care physician, therefore, must develop a sound understanding of the interrelationship of nutrition and physical activity. This module explores this interrelationship.

Goal

The goal of this module is to assist the physician in identifying the relationship of nutrition and physical activity. Efforts are made to examine the health maintenance aspects as well as the physical development aspects of the relationship. Where appropriate, diet and fitness fads are explored to assist the physician in counseling patients regarding such fads.

Objectives

Upon completion of this module, you will be able to:

1. *Counsel the broad spectrum of patients who might wish to engage in an exercise program.*
2. *Identify the dietary needs associated with various forms of exercise.*
3. *Advise patients regarding the interrelationship of diet and exercise in health maintenance.*
4. *Assist athletes in approaching the nutritional aspects of competitive sports in a healthy and productive manner.*

The Role of Diet in Physical Performance - An Overview

Many athletes and exercising individuals are interested in how diet can influence their performances. Therefore, they are often susceptible to nutrition misinformation and myths, sometimes promoted by other athletes, the media, coaches, and trainers. Nutritional conditioning is a continuous process that needs to be maintained throughout the individual's lifetime, not simply during the training period.

A 1977 Gallup Poll indicated that more Americans are involved in regular exercise than ever before. Although young, well-educated, affluent men are the most likely to follow an exercise program, the frequency of involvement of people in sports and/or regular exercise is increasing in all age and economic groups. This increase in interest has been influenced not only by the recognition of the health benefits of regular exercise, especially as a means of weight control, but also by the renewed competitive philosophy of society in general.[1]

The increased interest in competition and winning has enhanced the desire of athletes to have a training program that will maximize athletic performance. Consequently, many athletes and exercising individuals are interested in how diet can influence their performances. "What is best for me to eat to achieve top performance?" is a question often asked by competitors as well as casual athletes of their physicians, coaches, trainers, or peers. The majority of athletes worry about what they eat. The fact that they do not have time to eat is a common concern. They often feel insecure about the quality of their diets and want to know how to eat healthfully during training without spending a lot of time and effort. Therefore, these people are susceptible to nutrition misinformation promoted by other athletes, health food enthusiasts, and even coaches or trainers who claim that megavitamins, protein, quick-energy supplements, crash diets, fluid and electrolyte solutions, wheat germ oil, and other "nutritional snake oils" are advantageous to performances. Some of these practices, or substances consumed in moderation, may not pose a threat to health but do tend to be expensive. However, more drastic measures, such as steroid use, laxative abuse, and partial starvation, are dangerous and only hamper overall performance. Athletes who engage in these practices are successful in spite of these practices, not because of them.[1] Talent, dedication, and creative training are the athletes' most effective means of achieving success. Nothing can substitute for these qualities. "However, optimal nutrition is a basic training component necessary for the development and maintenance of top physical performance."[1] The primary care physician should be prepared to advise athletes and exercising patients about proper nutrition to help dispel some of the common myths.

The individual must first realize that nutritional conditioning, as with physical conditioning, is a continuous process and not simply "what is the best pre-game meal?" The athlete needs to maintain an adequate nutritional regimen during the course of the entire training/competitive session.

The best nutritional preparation for peak performance is still the well-balanced diet. However, given the well-balanced diet there are adjustments of some essential nutrients such as carbohydrates and fluids, as well as timing of feeding, which may result in improved performance.

The Basic Diet

A nutritionally adequate diet is one that provides sufficient nutrients, including water and energy, to meet metabolic needs for the functioning of the body. When basic energy needs for increased physical activity are obtained from a variety and balance of foods, all other basic nutrient requirements will be met for most individuals. Ideally, the athlete should obtain 10-15% of total calories from protein, 50% from carbohydrates, and 30-35% from fat.

It is critical to ensure the overall "essentiality" of the diet. A nutritionally adequate diet is one that provides sufficient nutrients, including water and energy, to meet metabolic needs for optimal functioning of the body. As a result of their increased physical activity, athletes must first increase their energy intake to meet the needs of their activities. If the increased energy needs are met by a well-balanced diet from a variety of foods, all other basic nutritional requirements will be met for most individuals.

Ideally, the athlete should obtain 10 to 15% of total calories from protein, 50% from carbohydrates, and 30 to 35% from fat.[1-4] The Basic Four Food Groups is still an excellent guideline for athletes and exercising individuals as well as others for achieving a "balanced" diet (Table 22-1).[5] Within the Basic Four food plan, individual food preferences should be taken into account in selecting food to be eaten. The diet of the athlete should be palatable and appealing or it will not be consumed. Table 22-2 describes a sample of a suggested diet plan using the Basic Four Food Groups as the guideline.[1] Since the Basic Four provides only 1000 to 1300 kcal/day, the remaining required energy, which can be as much as 2500 additional calories, must be made up by consumption of extra servings from the four food groups. Moderate amounts of fat, such as butter, margarine, oils, and salad dressings, and other foods, such as sugar and desserts, can be used as additional sources of calories. Further increases in calorie intake are best provided by complex carbohydrates, such as breads, cereals, potatoes, rice, and pasta. Foods high in fat should be limited, since they do not support the level of readily available energy derived from high-carbohydrate foods and may be atherogenic to susceptible individuals.[6]

Meal Distribution

Athletes and exercising individuals, especially adolescents and teens, should be encouraged to consume their daily caloric requirements in a consistent pattern, such as three meals per day. Often frequent snacking may be necessary to achieve the necessary energy intake and avoid weight loss. Although conclusive research is not available, common sense suggests that a significant proportion of food energy should be consumed prior to the initiation of daily exercise or training; i.e., in the breakfast and/or lunch meal. This often presents a problem for the swimmer or runner who may have an early morning training period. Some research has been conducted on the use of liquid supplements, such as Polycose or Ensure, to provide additional nutrition for athletes with high energy requirements. These types of products may be easier for the athlete to consume, but no specific performance benefits have been demonstrated. They can be useful for snacks between events during a day-long meet. Consuming most of the calories in a large evening meal, often after exercise is completed, may promote lipogenesis and may lead to unwanted fat accumulation.[1]

Fuel Requirements of Muscle

Storage Forms of High-Energy Phosphate in Muscle

In addition to ATP itself, high-energy phosphate is stored in creatine phosphate which can be used to regenerate ATP from ADP. The terminal phosphate bond on ADP also has a high free-energy of hydrolysis and can be transferred from one ADP to another to form ATP and leave AMP. All three storage forms of high-energy phosphate are readily depleted upon initiation of muscle contraction.

Muscle cells, like all other cells of the body, must maintain a minimum level of ATP just to maintain cellular integrity. Most of this ATP is required for ion pumping; i.e., to maintain a low concentration of sodium ion and a high concentration of potassium ion inside the cell. In addition, ATP is required by the working muscle to provide the energy for muscle contraction.

Several sources of high-energy phosphate are available to the muscle cell. First, a very small amount of ATP is present in the resting muscle which would rapidly be depleted upon initiation of muscle contraction. The muscle cell also has a storage form of high-energy phosphate in the form of creatine phosphate. Creatine kinase catalyses the reversible formation of ATP:

Creatine Phosphate + ADP <-----> Creatine + ATP

Creatine can be dehydrated non-enzymatically to form creatinine, which is excreted in the urine. Thus, the quantity of urinary creatinine reflects muscle mass except that its excretion is elevated during loss of muscle mass as in a debilitating disease. The amount of high-energy phosphate available through the creatine kinase reaction is greater than that directly available from ATP stores, but this source is also rapidly depleted upon initiation of muscle contraction.

Another source of pre-formed, high-energy phosphate is ADP, produced as ATP is depleted. The enzyme adenylate kinase catalyses the reversible formation of ATP from ADP:

ADP + ADP <----> ATP + AMP

During vigorous exercise, when ATP is being used for

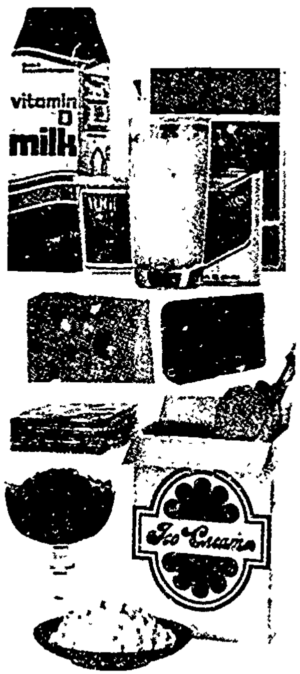
Table 22-1 Guide to Good Eating

Milk Group

2 Servings/Adults
4 Servings/Teenagers
3 Servings/Children

Foods made from milk contribute part of the nutrients supplied by a serving of milk.

Calcium
Riboflavin (B_2)
Protein



Meat Group

2 Servings

Dry beans and peas, soy extenders, and nuts combined with animal protein (meat, fish, poultry, eggs, milk, cheese) or grain protein can be substituted for a serving of meat.

Protein
Niacin
Iron
Thiamin (B_1)

Fruit-Vegetable Group

4 Servings

Dark green, leafy, or orange vegetables and fruit are recommended 3 or 4 times weekly for vitamin A. Citrus fruit is recommended daily for vitamin C.

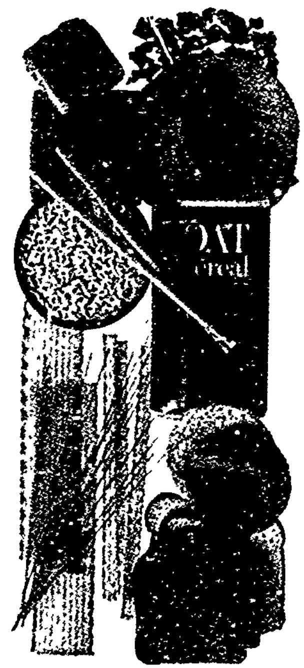
Vitamins A and C

Grain Group

4 Servings

Whole grain, fortified, or enriched grain products are recommended.

Carbohydrate
Thiamin (B_1)
Iron
Niacin



Foods and condiments such as these compliment but do not replace foods from the four groups.

Amounts should be determined by individual caloric needs.

Others

Carbohydrate
Fats

Guide to Good Eating

A Recommended Daily Pattern

Guide to Good Eating...

A Recommended Daily Pattern

The recommended daily pattern provides the foundation for a nutritious, healthful diet.

The recommended servings from the Four Food Groups for adults supply about 1200 Calories. The chart below gives recommendations for the number and size of servings for several categories of people.

Food Group	Recommended Number of Servings				
	Child	Teenager	Adult	Pregnant Woman	Lactating Woman
Milk 1 cup milk, yogurt, OR Calcium Equivalent: 1½ slices (1½ oz) cheddar cheese* 1 cup pudding 1¾ cups ice cream 2 cups cottage cheese*	3	4	2	4	4
Meat 2 ounces cooked, lean meat, fish, poultry OR Protein Equivalent: 2 eggs 2 slices (2 oz) cheddar cheese* ½ cup cottage cheese* 1 cup dried beans, peas 4 tbsp peanut butter	2	2	2	3	2
Fruit-Vegetable ½ cup cooked or juice 1 cup raw Portion commonly served such as a medium-size apple or banana	4	4	4	4	4
Grain, whole grain, fortified, enriched 1 slice bread 1 cup ready-to-eat cereal ½ cup cooked cereal, pasta, grits	4	4	4	4	4

*Count cheese as serving of milk OR meat, not both simultaneously

"Others" complement but do not replace foods from the Four Food Groups. Amounts should be determined by individual caloric needs.

Nutrients for Health

Nutrients are chemical substances obtained from foods during digestion. They are needed to build and maintain body cells, regulate body processes, and supply energy.

About 50 nutrients, including water, are needed daily for optimum health. If one obtains the proper amount of the 10 "leader" nutrients in the daily diet, the other 40 or so nutrients will likely be consumed in amounts sufficient to meet body needs.

One's diet should include a variety of foods because no *single* food supplies all the 50 nutrients, and because many nutrients work together.

When a nutrient is added or a nutritional claim is made, nutrition labeling regulations require listing the 10 leader nutrients on food packages. These nutrients appear in the chart below with food sources and some major physiological functions.

Nutrient	Important Sources of Nutrient	Some major physiological functions		
		Provide energy	Build and maintain body cells	Regulate body processes
Protein	Meat, Poultry, Fish Dried Beans and Peas Egg Cheese Milk	Supplies 4 Calories per gram	Constitutes part of the structure of every cell, such as muscle, blood, and bone; supports growth and maintains healthy body cells.	Constitutes part of enzymes, some hormones and body fluids, and antibodies that increase resistance to infection.
Carbohydrate	Cereal Potatoes Dried Beans Corn Bread Sugar	Supplies 4 Calories per gram Major source of energy for central nervous system.	Supplies energy so protein can be used for growth and maintenance of body cells.	Unrefined products supply fiber—complex carbohydrates in fruits, vegetables, and whole grains—for regular elimination. Assists in fat utilization.
Fat	Shortening, Oil Butter, Margarine Salad Dressing Sausages	Supplies 9 Calories per gram	Constitutes part of the structure of every cell. Supplies essential fatty acids.	Provides and carries fat-soluble vitamins (A, D, E, and K).
Vitamin A (Retinol)	Liver Carrots Sweet Potatoes Greens Butter, Margarine		Assists formation and maintenance of skin and mucous membranes that line body cavities and tracts, such as nasal passages and intestinal tract, thus increasing resistance to infection.	Functions in visual processes and forms visual purple, thus promoting healthy eye tissues and eye adaptation in dim light.
Vitamin C (Ascorbic Acid)	Broccoli Orange Grapefruit Papaya Mango Strawberries		Forms cementing substances, such as collagen, that hold body cells together, thus strengthening blood vessels, hastening healing of wounds and bones, and increasing resistance to infection.	Aids utilization of iron.
Thiamin (B_1)	Lean Pork Nuts Fortified Cereal Products	Aids in utilization of energy		Functions as part of a coenzyme to promote the utilization of carbohydrate. Promotes normal appetite. Contributes to normal functioning of nervous system.
Riboflavin (B_2)	Liver Milk Yogurt Cottage Cheese	Aids in utilization of energy		Functions as part of a coenzyme in the production of energy within body cells. Promotes healthy skin, eyes, and clear vision.
Niacin	Liver Meat, Poultry, Fish Peanuts Fortified Cereal Products	Aids in utilization of energy		Functions as part of a coenzyme in fat synthesis, tissue respiration, and utilization of carbohydrate. Promotes healthy skin, nerves, and digestive tract. Aids digestion and fosters normal appetite.
Calcium	Milk, Yogurt Cheese Sardines and Salmon with Bones Collard, Kale, Mustard, and Turnip Greens		Combines with other minerals within a protein framework to give structure and strength to bones and teeth.	Assists in blood clotting. Functions in normal muscle contraction and relaxation, and normal nerve transmission.
Iron	Enriched Farina Prune Juice Liver Dried Beans and Peas Red Meat	Aids in utilization of energy	Combines with protein to form hemoglobin, the red substance in blood that carries oxygen to and carbon dioxide from the cells. Prevents nutritional anemia and its accompanying fatigue. Increases resistance to infection.	Functions as part of enzymes involved in tissue respiration.

From National Dairy Council: *A Guide to Good Eating,* 4th edition. Rosemont, Illinois, 1977. Used with permission of the National Dairy Council.

Table 22-2 Basic Diet Utilizing the Basic Food Groups

5 Meal Plan

Breakfast
- 1/2 grapefruit
- 2/3 cup bran flakes
- 1 cup skim or low-fat milk or other beverage

Snack
- 1 small package raisins
- 1/2 bologna sandwich

Lunch
- 1 slice pizza
- carrot sticks
- 1 cup skim or low-fat milk
- 1 apple

Snack
- 2 oatmeal cookies

Dinner
- baked fish with mushrooms (3 oz)
- baked potato
- 2 tsp margarine
- 1/2 cup broccoli
- 1 cup tomato juice or skim or low-fat milk

Total calories: about 1400

3 Meal Plan

Breakfast
- 1/2 cup orange juice
- 1 soft-boiled or poached egg
- 1 slice whole wheat toast
- 1-1/2 tsp margarine
- 1 cup skim or low-fat milk or other beverage

Lunch
- 1-1/2 cup Manhattan clam chowder
- 2 rye wafers
- 1/2 cup cottage cheese (uncreamed)
- 1 medium bunch grapes or 1 medium apple
- 1 granola cookie

Dinner
- oven barbecued chicken (3 oz, no bone)
- 1/2 cup green beans
- 1/2 cup cabbage and carrot salad
- 2/3 cup mashed potatoes
- 1/2 cup applesauce
- 1 cup skim or low-fat milk or other beverage

Total calories: about 1200

From Hecker, A.. "Nutritional Conditioning and Athletic Performance." *Primary Care*, 9(3). 545. Philadelphia: W. B. Saunders Company, 1982. Reprinted by permission.

muscle contraction faster than it is being produced, this reaction will result in the build-up of AMP, which, along with lactic acid, is thought to be the major chemical reason for post-exercise soreness. In addition, vigorous exercise also causes soreness because of actual tissue damage.

Substrate for the Generation of ATP in Muscle During Exercise

ATP can be generated in muscle by the anaerobic glycolysis pathway and by aerobic metabolism. The importance of each pathway depends upon the rate of ATP utilization for muscle contraction relative to the availability of oxygen to the muscle cell to support aerobic metabolism. The adrenergic response that occurs during vigorous physical activity increases oxygen available to the muscle to support aerobic generation of ATP. Carbohydrate (from glycogen stores and blood glucose), amino acids (from protein degradation), and fatty acids (from triglyceride stores) serve as oxidizable substrates.

All three stored high-energy phosphate sources (ATP, creatine phosphate, and ADP) together provide a very limited amount of ATP, hardly enough to get you out of a chair during an emergency and certainly not enough to get you out of the building. Sufficient ATP to sustain muscle contraction for more than a few seconds must come from metabolic generation of ATP. Skeletal muscle, like other tissues of the body, has two ways to generate ATP: anaerobic glycolysis and aerobic metabolism. Aerobic generation of ATP requires oxidation of substrates in the citric acid cycle, followed by oxidative phosphorylation with oxygen as the final electron acceptor.

At rest, most of the ATP is generated in muscle cells by aerobic metabolism. Not very much ATP is being formed, but not very much is needed. An adrenergic response or initiation of muscle contraction will activate the enzyme that regulates glycogen hydrolysis, phosphorylase, which produces glucose-6-phosphate to generate ATP via glycolysis. Phosphorylase is activated by phosphorylation (see Module 18, Metabolic Principles) by a sequence of reactions, either in response to an increase in cyclic-AMP or free calcium ion in the muscle cell. Cyclic-AMP is elevated in response to occupation of a beta-adrenergic receptor, and calcium ion can be elevated either because of the occupation of an alpha-adrenergic receptor or because calcium ion is released from a bound form when the muscle fiber contracts.

In the early stages, after initiation of an adrenergic response of voluntary muscle contraction, much of the glucose-6-phosphate entering the glycolytic pathway is converted to lactate because there is insufficient oxygen at the tissue level to reoxidize NADH produced by the citric acid cycle. The increase in NADH inhibits pyruvate oxidation to acetyl CoA by pyruvate dehydrogenase. Thus, at this stage, most of the ATP formed in muscle is anaerobically produced by glycolysis.

As physical activity continues, adrenalin secretion increases, which results in a series of events which increases the oxygen supply to the muscle. These include increased heart rate, increased respiration rate, and increased oxygen-carrying capacity of myoglobin. As oxygen becomes more available to the muscle mitochondria to act as a final electron acceptor in the oxidative phosphorylation-electron transport pathway, more of the ATP utilized by muscle is generated aerobically. Since the rate of production of NADH may still exceed the rate of its oxidation, pyruvate dehydrogenase is partially inhibited so that a portion of the pyruvate produced from glycolysis may still be converted to lactate rather than be oxidized to acetyl CoA. At the same time that adrenalin affects oxygen availability to muscle, it increases mobilization of triglyceride stores to provide free fatty acids as a substrate for the production of acetyl CoA in the muscle cell. Adrenalin activates triglyceride mobilization by a direct interaction with adrenergic receptors on the fat cell as well as indirectly by increasing glucagon output from the alpha cells of the pancreas. Glucagon interacts with receptors on the fat cell resulting in triglyceride mobilization.

Lactate produced by the muscle cells can be utilized for glucose synthesis in the liver, activated by glucagon (see Module 18, Metabolic Principles). Glucose produced in the liver diffuses into blood and can be utilized by muscle and reconverted to lactate anaerobically. This cyclic sequence has been named the Cori cycle in recognition of its discoverers. The ATP required for liver gluconeogenesis comes from the oxidation of fatty acids, mobilized from adipose tissue. The net effect of the Cori cycle is to take advantage of the fact that the liver has a better blood and oxygen supply than muscle so that aerobic metabolism in the liver supports anaerobic generation of ATP in muscle. Glucose entry into muscle requires insulin, but the additional glucose uptake in muscle that occurs during the operation of the Cori cycle does not require blood insulin to be elevated. Rather, exercise causes a transient increase in insulin receptors in the cellular membrane; i.e., during exercise the muscle cell becomes more insulin-sensitive so that more glucose enters, even though the insulin level does not change. This is important not only in terms of muscle metabolism but also in understanding the hypoglycemic effect of exercise in the diabetic.

In addition to oxidizing glucose and fatty acids, the exercising muscle also oxidizes amino acids via the citric acid cycle to generate reducing equivalents for ATP production. The amino group can be transferred to pyruvate to form alanine which then goes via blood to the liver. In the liver, alanine is reconverted to pyruvate and the amino group goes into the formation of urea. Pyruvate can be converted to glucose in the liver and return to muscle. This pyruvate-alanine cycle is similar to the Cori cycle except that its function is to carry amino groups to the liver that have been produced by amino acid catabolism in muscle. Amino groups can also be transported to the liver from muscle by attaching them to glutamate to form glutamine.

Thus, all three classes of stored nutrients can con tribute to the generation of ATP in muscle. The relative importance of each depends upon the rate of ATP utilization for muscle contraction and the availability of oxygen for aerobic metabolism.

Substrate for Recovery After Exercise

Oxygen consumption remains elevated after the cessation of vigorous exercise to allow readjustment of the metabolic processes to the pre-exercise state.

After cessation of vigorous exercise, the body must have a readjustment period during which oxygen consumption remains elevated until lactate and fatty acids, built up during the exercise, are cleared by heart, liver, and even skeletal muscle if there is sufficient oxygen. As epinephrine and glucagon return to pre-exercise levels, respiration and heart rate decline to normal. Glycogen stores in muscle and liver return to pre-exercise level provided there is sufficient glucose available from dietary sources.

The additional calories required for vigorous exercise can come from triglyceride stores. This can be important in a weight-reduction program, but only if caloric consumption is also restricted. An exercise program can be helpful in the prevention of cardiovascular diseases, but for some patients vigorous exercise can exacerbate the problem.

Most of your patients will be interested in exercise not for making them more competitive in athletic events but rather as a part of general health maintenance. Exercise, particularly running or jogging, has become popular as a method for weight control, and it obviously will increase caloric expenditure. The popular idea that exercise will diminish appetite because of glucagon-mediated elevation of blood glucose is partially true. That is, appetite may be diminished for a short time after moderate exercise. To be effective in reduction of body fat stores, exercise must be of sufficient intensity and duration (at least 30 minutes) to evoke an adrenergic response which will result in mobilization of triglyceride. In addition, these fat stores would be quickly regenerated unless the exercise is coupled with caloric restriction. Aerobic dancing, popularized by books and television, offers no particular advantage over other forms of aerobic exercise in reducing fat stores except that for some patients it may be less boring than running. It too, like other forms of exercise, should be coupled with caloric restriction if it is to be effective in reducing body fat stores.

It is important to differentiate between body weight and body fat stores. An active football player may be overweight according to the height-weight tables but he may not have excessive fat stores. A patient, particularly a young one who attempts to reduce fat stores by vigorous exercise without restricting caloric intake, may find that body fat stores are reduced but the body weight has not changed because of an increase in muscle mass. It is erroneous to assume that the optimum fat content of either athletes or non-athletes is near zero. All cellular membranes are composed of fat along with proteins, which amounts to a fat content of about 6% of body weight. Fat stores are a normal part of the nutrient storage system for each of us (see Module 18, Metabolic Principles). For athletes, a reasonable amount of stored fat is necessary to be competitive because it provides a source of substrate for aerobic events. For swimmers, fat stores provide necessary buoyancy as well as a source of energy.

Exercise may be of value in prevention of coronary vascular diseases, but patients should be cautioned that it is not absolute insurance. It strengthens muscles involved in the coronary vascular system and increases blood high-density lipoproteins, all of which should be advantageous (see Module 19, Risk Factors and Disease Prevention). In the event of a myocardial infarction, the cells in the segment of the heart deprived of oxygen for more than three to five minutes will die. However, if exercise has strengthened the portion of the heart that has not been deprived of substrate so that it can continue to supply blood to the rest of the body, the patient has a greater chance of survival. On the other hand, if atherosclerosis restricts the blood flow to a section of the heart, exercise may not only NOT protect against a heart attack, it may actually contribute to it because of adrenergic-mediated constriction of blood vessels and increased heart rate. Under such conditions, exercise may be dangerous to health. It is worth noting that the blood enzyme pattern of a marathon runner after a race may not differ significantly from that of a patient who has suffered a myocardial infarction.

Muscle Type and Athletic Performance

Each of us has two types of muscle fibers: fast-twitch and slow-twitch. Fast-twitch muscle fibers generate ATP anaerobically and are designed for short bursts of energy expenditure. Slow-twitch fibers generate ATP aerobically and are designed for slower energy generation and utilization over a longer period of time. The ratio of the two types is determined genetically and is not affected by physical training. The ratio is a major determinant of the type of athletic activity in which a participant is able to excel.

It is important that athletes and their parents recognize some of the factors which determine athletic ability, the most important of which is genetic potential. One such determinant that is not obvious is proportion of muscle type. Each of us has a mixture of two types of muscle fibers, called fast-twitch and slow-twitch muscle.

Fast-twitch muscle is analagous to the white meat on the Thanksgiving turkey. It is designed for short bursts of energy expenditure and generates ATP primarily by anaerobic glycolysis. An athlete with a high proportion of fast-twitch muscle fibers will be capable of excelling in sports such as basketball or sprints.

Slow-twitch muscle is analagous to the red meat on a turkey. It is red because it contains more mitochondria and oxygen-carrying protein, myoglobin. Slow-twitch muscle, as the name implies, is designed for slower energy utilization and generation over a long period of time. ATP is generated primarily by the aerobic pathway. An athlete with a high proportion of slow-twitch muscle fibers will be capable of excelling in sports such as long-distance running. Athletes with an equal mixture of fast-twitch and slow-twitch muscle fibers are capable of excelling at such sports as speed skating or bicycle racing.

The ratio of muscle fibers is determin d genetically. Exercise can strengthen body types of muscle fibers but cannot change the ratio. Thus, if parents are concerned that their child cannot play short stop on the little league team, they should be aware that it is more likely a problem of genetics than motivation to try to play well. The ratio of muscle fiber types can be determined by microscopic and histological examination of muscle taken by biopsy, but it is doubtful that the answer is worth the difficulty of obtaining it. A more reasonable approach is to allow a child interested in participating in sports to try a variety of activities and choose those which are of most interest.

Fluid and Electrolyte Regulation During Exercise

For the athlete, maintaining adequate fluid and electrolyte balance is particularly relevant as the duration of exercise progresses. Without adequate hydration, an athlete cannot compete at optimal performance levels in any activity, especially endurance events such as marathon running, cross-country skiing, or cycling. Most problems encountered by marathon runners are the result of inadequate water replacement. In the 1967, national AAU 26-mile championship race in Holyoke, Massachusetts, 87 out of the 125 well-conditioned runners were unable to finish the race in the 97-degree heat. The main cause of the high drop-out rate was inadequate heat acclimation.

Body water is of critical importance in regulating body temperature. Also hormones, nutrients (amino acids, glucose, free fatty acids), and waste products (urea, creatinine, CO_2) are all transported in a water medium (plasma) and even moderate dehydration diminishes maximal muscle response.[6,7]

Excessive heat produced with exercise is dissipated by sweating, which functions only if sufficient water is delivered to the sweat glands. If the body is completely covered or if environmental heat and humidity are high, body heat loss by sweat evaporation is decreased. Sweat is derived from the interstitial fluid. The volume of interstitial fluid is maintained by the transfer of plasma and cellular fluid. Sweating during heat exposure without exercise depletes mainly the extracellular fluid compartment, and sweating during exercise depletes both extracellular and intracellular fluid compartments. The body protects interstitial fluid volume during exercise by shifting plasma to the interstitial space in proportion to the increase in systolic blood pressure, which is directly proportional to exercise intensity. This fluid shift occurs in the first 10 minutes of exercise; the magnitude increases from about 6% (180 ml) with moderate exercise to about 16% (500 ml) during maximal exercise. Also, water is liberated from the metabolism of glycogen during exercise. Oxidation of 500 gm of muscle glycogen over a period of 4 to 6 hours could produce 1500 ml of water.[7]

Because continued sweating during prolonged exercise can reach a rate of 700 to 1000 ml/hr, additional fluid must be provided by drinking. An average size man running a marathon can lose as much as 5 liters of fluid via sweating. Also soccer, tennis, basketball, and football players have reported losing from 5 to 12 pounds during a game, match, or long practice session on a hot and humid day. Trained athletes, who are able to work at high work loads for prolonged periods, have higher sweat rates than their untrained counterparts. This is a part of the heat acclimation process so important for optimal performance in hot environments. This heat acclimation usually takes up to two weeks of training in a hot environment. The athlete's goal should be to condition the body to sweat better by enlarging the sweat glands and widening the vessels in the skin so more blood can be carried to the surface and heat can be dissipated by evaporation. Heat acclimation can be better accomplished by wearing some clothing (i.e., sweat suit) while training so that sweating can be induced. If an athlete is training in cooler weather for a warm-weather event, sweating can be stimulated by wearing several layers of clothing.[8,9]

Fluid Intake

Continued sweating during prolonged exercise can reach a rate of 1000 ml/hr; therefore, additional fluid must be provided during the event. The thirst mechanism is not an accurate gauge of the body's fluid replacement needs, therefore the individual needs to consciously replace lost fluids. Weighing the individual before and after practice and competition is a good method of evaluating the amount of water needed. For each pound of weight lost as sweat, the athlete should drink 2 cups (16 oz) of water. During endurance events, the individual should try to drink 1 to 1½ cups of water every 15 to 20 minutes.

It was not long ago that some coaches and trainers felt that fluid could be restricted during an athletic or training event without adverse effects. This philosophy resulted in some tragic outcomes when athletes ended up suffering severe heat stroke and even death because of dehydration. There is no known scientific evidence to suggest that the body can adapt to successive periods of dehydration. Withholding needed fluid only hastens deterioration of physical and mental performance (Figure 22-1).[8] In fact, people undergoing intensive exercise training will require progressively greater fluid intake to compensate for the increased sweating that results from acclimation.[8,9]

Dehydration reduces physical performance and can lead to a dangerous rise in the body's core temperature because vascular volume is gradually reduced. This makes it more difficult for the heart to pump sufficient blood to the skin for the transfer of body heat to the environment and to meet the energy demands of active muscle tissue. Thus, the stroke volume of each heart beat decreases, the heart rate increases, the blood flow to the skin begins to fall, and the body's core temperature rises steadily toward the danger level (40.5-41.1° C or 105 to 106° F). In practical terms, performance falls off and the work effort is more labored, even though the subject does not feel hot. In some cases the rise in body temperature can be life-threatening.[9]

The thirst response is not an accurate gauge of the needs for body fluid replacement since it is blunted considerably during and immediately after exercise. Therefore, the exercising individual needs to consciously attempt to replace lost fluid as much as possible. Practically speaking, few athletes have the time or inclination to replace all the fluid lost during an event, which could amount to 8 ounces of water every mile (i.e., 6 to 8 minutes of running). Table 22-3 outlines signs of various types of heat injury and how to treat them appropriately.[10]

Some studies have indicated that pre-hydration or overhydration [drinking a large volume of water (i.e., up to 2 to 3 liters) before or during exercise so that more water is consumed than lost by sweat] has resulted in better maintenance of blood volume and stroke volume, as well as lower heart rates and temperature regulation. But this should be done gradually to avoid abdominal distention or cramping.

The risk of dehydration is greatest in the untrained or non-acclimated individual and in youngsters. A good way to evaluate fluid loss is to monitor body weight before and after exercise. This weight change, added to normal fluid requirements (about 2.5 liters) can be an indicator of the quantity of fluid needed to be consumed before the next training bout.[1] Any young individual exhibiting more than 2% weight loss from day to day

Figure 22-1 Adverse Effects of Dehydration

% PLASMA VOL. LOSS	% BODY WT. LOSS	
0	0	THIRST
2	1	
4	2	STRONGER THIRST, VAGUE DISCOMFORT AND SENSE OF OPPRESSION, LOSS OF APPETITE*
6	3	INCREASING HEMOCONCENTRATION,* REDUCTION IN URINARY OUTPUT, DRY MOUTH
8	4	INCREASED EFFORT FOR PHYSICAL WORK,* FLUSHED SKIN, IMPATIENCE, SLEEPINESS,* APATHY, NAUSEA,* EMOTIONAL INSTABILITY
10	5	DIFFICULTY IN CONCENTRATING
12	6	IMPAIRMENT IN EXERCISE TEMPERATURE REGULATION,* INCREASED PULSE RATE AND RESPIRATORY RATE
14	7	
16	8	DIZZINESS, CYANOSIS AND LABORED BREATHING WITH EXERCISE, INDISTINCT SPEECH, INCREASING WEAKNESS, MENTAL CONFUSION
18	9	
20	10	SPASTIC MUSCLES, INABILITY TO BALANCE WITH EYES CLOSED, GENERAL INCAPACITY, DELIRIUM AND WAKEFULNESS, SWOLLEN TONGUE
22	11	CIRCULATORY INSUFFICIENCY, MARKED HEMOCONCENTRATION AND DECREASED BLOOD VOLUME; FAILING RENAL FUNCTION

* ALSO OBSERVED IN ASTRONAUTS DURING FLIGHT

Reprinted courtesy of Art Heck, Ross Laboratories. Table presented at nutrition workshop, June, 1983.

should be carefully monitored for dehydration. A good rule of thumb is to replace every pound of weight lost with 2 cups (16 oz.) of water.

For endurance events, 600 ml (21 oz or about 2 2/3 cups) of fluid should be drunk two hours prior to competition, 400 to 500 ml (14 to 17 oz or about 2 cups) 10 to 15 minutes before, and small amounts during the event. The competitor should try to drink 200 to 300 ml (1/2 to 3/4 cup) every 15 minutes throughout the duration of the event.[11]

Electrolyte Losses and Replacement

Under most circumstances, the use of salt tablets enhances dehydration by accelerating the loss of water and should not be used. An *ad libitum* diet, especially the high-calorie diet of the typical athlete, more than supplies the amount of sodium, chloride, magnesium, and potassium lost during exercise. Adding extra salt to the post-event meal will adequately replace lost sodium. Commercial sports drinks are not necessary for adequate fluid and electrolyte replacement and may actually hamper performance by delaying gastric emptying due to their high osmolality. If they are utilized, they should be diluted by 50% to make them more isotonic to body fluid.

Table 22-3 Signs To Look Out For

	If your athletes have any of the symptoms below, they may be developing a heat injury.		Watch for these symptoms and be prepared to take appropriate actions to correct them.
	SYMPTOMS	*WEIGHT LOSS*	*TREATMENT*
HEAT CRAMPS	• Thirst • Chills • Clammy skin • Throbbing heart beat • Nausea	A loss of up to 5 percent of body weight as sweat • up to 5 lb for 100-lb athlete • up to 7½ lb for 150-lb athlete • up to 10 lb for 200-lb athlete	Athlete should: • Drink ½ cup of water every 10-15 minutes • During breaks, move to shade and remove as much clothing as possible
HEAT EXHAUSTION	• Reduced sweating • Dizziness • Headache • Shortness of breath • Weak, rapid pulse • Lack of saliva • Extreme fatigue	A loss of 5-10 percent of body weight as sweat • 5-10 lb for 100-lb athlete • 7½-15 lb for 150-lb athlete • 10-20 lb for 200-lb athlete	Athlete should: • Stop exercise and move to a cool environment • Drink 2 cups of water for every pound lost • Take off wet clothing and sit on a chair in a cold shower • Place an ice bag on his or her head
HEAT STROKE	• Lack of sweat • Dry, hot skin • Lack of urine • Hallucinations • Swollen tongue • Deafness • Visual disturbances • Aggression • Unsteady walking • Excessively high body temperature	A loss of over 10 percent of body weight as sweat • over 10 lb for 100-lb athlete • over 15 lb for 150-lb athlete • over 20 lb for 200-lb athlete	You should: • Call for emergency medical treatment • Until help arrives, place ice bags on back and front of athlete's head • Remove clothing and rub alcohol over most of the athlete's body • Put athlete on chair in cold shower

Food Power: A Coach's Guide to Improving Performance, Courtesy National Dairy Council.

The total amount of electrolytes lost during exercise varies greatly. Sodium and chloride are the principal electrolytes lost in sweat. While body sweat can contain 2.3 to 3.4 gm NaCl/l, the concentration of potassium in sweat remains fairly constant at 4-5 mmol/l. Some sports authorities have advocated the use of salt tablets, erroneously thinking that it was sodium that needed to be replaced rather than fluid. Actually, salt tablets compound dehydration by accelerating the loss of water. Therefore, unless an individual is sweating excessively (3 to 4% of body weight during the course of a workout), salt tablets are not necessary and can be dangerous.[1]

An *ad libitum* diet, especially the high-calorie diet of a typical athlete, more than supplies the amount of electrolytes (i.e., sodium, chloride, magnesium, and potassium) lost during exercise.[9] The athlete should be encouraged to eat his normal diet, and extra salt can be added to the post-exercise meal. The average intake of salt has been estimated at 8 to 13 gm for the training athlete, and the typical mixed diet furnishes 50 to 150 mEq of potassium, which more than meets the needs of the athlete or exercising individual.

During some prolonged, intense physical activities, especially for extended periods, an athlete may experience excessive water and electrolyte losses which cannot be replaced by diet alone. In these cases, some electrolyte replacement should be considered. The American College of Sports Medicine (ACSM) recommends a maximum of 10 mEq (230 mg) of sodium, 10 mEq (355 mg) of chloride, and 5 mEq (195 mg) of potassium per liter of solution.[11] Numerous commercial solutions are available for use by athletes. When determining the best solution to use during an event, keep in mind that fluid replacement is the primary concern.

When fluid and electrolyte replacement is planned, gastric emptying time is important to consider. Factors that affect gastric emptying include the volume ingested, the temperature of the drink, and the intensity of the exercise.[12] As mentioned previously, 150 to 200 ml every 15 minutes of activity is about all most individuals can tolerate. Cold drinks (4 to 10° C or 40 to 50° F — refrigerator temperature) empty from the stomach faster than warm drinks. As the rate of exercise increases, gastric emptying does slow, but not until exercise intensity exceeds 65 to 70% of VO_2 max.[12] The primary factor that affects gastric emptying is the osmolality of the beverage, especially its sugar content. Studies indicate that if the concentration of sugar in the beverage exceeds 2.5% of total volume, gastric emptying is delayed (commercial soft drinks contain 10% sucrose). In general, the best evidence to date indicates that beverages taken during exercise should be hypotonic, with an osmolality of 200 milliosmoles/l.[9] The market is flooded with electrolyte solutions which generally have a high osmolality that can result in fluid retention and abdominal distress.[13] Therefore it is recommended that if commercial sports drinks are utilized, they should be diluted by 50%.

Glucose may be beneficial during prolonged exercise (more than 2 hours) since it is readily absorbed, preserves glycogen stores by maintaining blood sugar levels, and decreases free fatty acid release and glycerol production.[8] However, the research is not conclusive on this issue nor on what form of carbohydrate (sucrose, fructose, maltodextrins, etc.) is best utilized during exercise.

In summary, with regard to fluid and electrolyte replacement prior to and during exercise, the concern of the coach, trainer, and exercising individual should be replacement of body fluid. During most events, this is best accomplished by drinking water in 200 to 300 ml doses every 15 minutes when possible. Unless the event exceeds two hours this should sufficiently replace lost fluids, provided that the participant is consuming an *ad libitum* diet of a variety of foods. In strenuous events or training sessions exceeding two hours, cold hypotonic solutions containing sugar, sodium, chloride, and little, if any, potassium, may be beneficial. Advertisements for athletic drinks often promise more than they can deliver. Nothing can take the place of adequate training under acclimatization conditions. Also, there needs to be considerably more research on how to provide the ideal amount of energy, fluids, and electrolytes for optimal athletic performance. The physician should advise the athlete or exercising individual to pay attention to individual body needs and develop a program that provides the best results for individual performance.

Energy Costs of Exercise

High-intensity, short-term events, such as sprinting, are not felt to be immediately limited by nutritional factors as long as the individual follows a well-balanced nutritional program during training and is adequately hydrated. The recommended diet for the individual in training is one from the basic four food groups for the specified age group, with emphasis on carbohydrate energy sources. Additional energy is obtained by consuming additional servings from the four food groups.

Tables 22-4 and 22-5 provide the approximate energy costs of several physical activities. Of course, energy costs vary with each individual and depend on body weight and composition as well as level of training. High-intensity, short-term anaerobic events, such as rowing, wrestling, and sprinting are not generally felt to be immediately limited by nutritional factors, assuming the individual followed a well-balanced nutritional program before the event and is adequately hydrated. In anaerobic exercise with exercise intensity above 75% VO_2 max, glycogen from muscle tissue and liver is the major source of energy; glycogen depletion does not occur in short-term events in trained individuals.[4,7] However, if the individual is involved in day-long competition, with several events scheduled at intervals throughout the day, then glycogen stores could become a limiting factor. One study has indicated that glycogen loading did show a beneficial effect on anaerobic work.[12]

Training can increase phosphocreatine (PC) stores in the muscle, which can assist the athlete during anaerobic work. Also, increased myoglobin concentration of muscle can influence anaerobic work. However, no food supple-

Table 22-4 Caloric Cost of Exercise Per Day

Short Burst Maximal Effort or 1-min Effort (3400 kcal/day)	*1-10 min Sustained Effort (3000-5000 kcal/day)*	*1 min or More of Intense Repeated Effort (4000-5000 kcal/day)*	*Endurance (3000-5000 kcal/day)*
Shotput	Run 880 yd, 2 miles	Football	Run 6 miles
Javelin	Swim 100 yd	Basketball	Soccer
High jump	Wrestling	Ice hockey	Cross-country skiing
Dashes, hurdles	Gymnastics	Lacrosse	
Swim 100 yd			

From Vitousek S: "Is more better?" *Nutrition Today,* 14(6):12, 1979. Reprinted by permission.

ment (other than perhaps iron) can increase PC or myoglobin. Increased myoglobin concentration following training has not been demonstrated in humans.[12] When considering the diet in relationship to the intensity of the exercise, the fundamental objective should be to meet the energy requirement of the sport or activity in which the individual is engaged. This caloric requirement can range from 3000 to 6000 kcal/day, depending on the duration and intensity of the daily exercise.

Prior to high-intensity exercise events, no special dietary adjustments are necessary, provided the individual is well hydrated. This is also true for medium-intensity sports or activities such as football, baseball and soccer. However, as the ambient temperature and the length of time for the activity increases, methods to maintain glucose, fluid, and electrolyte balance should be implemented, as discussed in other sections.

Nutritional Guidelines During Training for High-Intensity Exercise

The recommended diet for the athlete in training is one chosen from the basic food groups for the athlete's specific age level[1,5,13,14] (Table 22-1), with emphasis on carbohydrate energy sources to provide adequate muscle and liver glycogen stores. Such a diet will provide 1200 to 1500 kcal/day, whereas a high school or college athlete may need two to three times this amount of energy or more. The energy deficit can be overcome by eating additional servings from any of the four food groups, with particular emphasis on carbohydrate foods. The form of the carbohydrate (simple sugars or complex sugars) does not appear to be a factor in the glycogen repletion process; however, most nutritionists recommend that the bulk of calories be supplied from complex carbohydrates, such as starchy vegetables, pastas, bread, and cereals — foods that also provide fiber, vitamins, and minerals.[14,15]

Nutritional Concerns When "Making Weight" for Wrestling

Often wrestlers "make weight" before an event by extraordinary means such as fasting, restricting fluids, and taking diuretics and laxatives. These practices can result in dehydration and pose potential health risks. There are safe and healthful ways to lose weight when done gradually at least one month before the event, by utilizing a balanced diet from the four food groups and by avoiding binging and crash dieting.

The high-intensity, limited-weight sport of wrestling presents particular nutritional problems. Athletes in this sport must be well-nourished and hydrated, yet maintain a pre-determined minimal body weight. Often wrestlers practice "making weight" before an event via extraordinary means, such as fasting or restricing fluids; using hot boxes, rubbery apparel, diuretics and laxatives; or inducing vomiting.[16] These practices are strongly discouraged and potentially dangerous. Most of these methods will result in dehydration which will only increase fatigue and reduce performance, especially under tournament conditions when energy reserves are more critical. Wrestlers have been reported to lose as much as 10 to 12 pounds in the few days prior to a meet. In the light-weight classes (approximately 98 to 132 pounds) this can represent up to 10% of body weight."[18]

The physician and coach, confronted with the task of determining ideal weights for prospective wrestlers, must consider the immediate pitfalls of rapid weight loss and the possible long-term effect of calorie restriction on normal growth and development. A strategy for arriving at an approximate competing weight in a rapid, yet practical, manner has been developed. The Task Force on Health and Safety Consideration for Interscholastic Wrestling — 1983 developed a series of guidelines for helping the wrestlers "make weight" safely.[19,20] These guidelines are outlined in Table 22-6.[20]

The daily caloric requirements for wrestlers should be obtained from a balanced diet and determined on the

Table 22-5 Approximate Energy Cost of Various Physical Activities

Sport Activity	*kcal/expended per minute of activity*
Climbing	10.7-13.2
Cycling	45
5.5 mph	7.0
9.4 mph	7.0
13.1 mph	11.1
Dancing	3.3-7.7
Football	8.9
Golf	5.0
Gymnastics	
Balancing	2.5
Abdominal exercises	3.0
Trunk bending	3.5
Arm swinging, hopping	6.5
Rowing	
51 str/min	4.1
87 str/min	7.0
97 str/min	11.2
Running	
Short distance	13.3-16.6
Cross-country	10.6
Tennis	7.1
Skating (fast)	11.5
Skiing	
Moderate speed	10.8-15.9
Uphill, maximum speed	18.5
Squash	10.2
Swimming	
Breaststroke	11.0
Backstroke	11.5
Crawl (55 yd/min)	14.0
Wrestling	14.2

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Table 22-6 Weight Reduction for Wrestlers—A Practical Approach

Attempts to devise formulas for predicting the ideal weight for wrestlers have been unsatisfactory. Percent body fat estimations are not sufficiently accurate even when underwater weighing or skinfold thicknesses are combined with body girth measurements, and they are time-consuming and expensive. Practical considerations suggest the following guidelines:

1. Moderate diet restriction beginning at least one month before the season can result in substantial weight loss without loss of strength and efficiency.
2. Desired weight should be maintained as constant as possible by restricting food and avoiding alternate binges and crash diets.
3. Restriction of water intake for 8 to 12 hours before weigh-in is reasonable if it is necessary to drop about 1 lb or so.
4. Weigh-in should be followed by rehydration with water only. Avoid solutions containing sugar, which may cause a critical fall in blood sugar several hours later during a match.
5. Heavy eating between weigh-in and competition should be avoided because it may produce gastrointestinal distress, and in the extreme degree, pancreatitis. A light meal rich in complex carbohydrates and low in fat and protein may be desirable to relieve hunger and provide energy for later in the day
6. Water should be allowed freely to wrestlers at all times during practice and competition.
7. Working out in rubber or plastic suits and spending long periods in saunas and steam baths may cause serious dehydration and expose the wrestler to heat exhaustion and stroke. These methods will not reduce body tissue weight.

From *The Physician and Sports Medicine*, a McGraw-Hill publication, Vol. 9, No. 9, 1981. Reprinted by permission.

basis of age, body surface area, growth, and physical activity. The daily turnover of kcal can range from 3000 to 5000/day; training can increase requirements as much as 500 to 1500 kcal. Normal calorie requirements often do not apply to more highly trained and efficient athletes, such as wrestlers, who often maintain less than 10% body fat. In order to protect the wrestler's health, the physician or coach can determine his minimal wrestling weight.

Basal body energy requirements for young athletes have been calculated at 24 kcal/kg body weight/day. To this figure is added additional kcal to cover daily activities: 50% of basal for light work, 75% of basal for moderate activity, and 100% of basal for heavy work. The calorie needs for the athletic event are then estimated and added to the total.[19]

For example:

Basal requirement for 105-lb wrestler (male)

105 lb = 47.73 kg	
x 24	kcal/kg body wt
1,145.5	Basal kcal need
x 50	add 50% for light activity
572.0	kcal
+ 1,145.5	
1,717.5	basal kcal + light activity
+ 852.0	estimated energy cost of wrestling = 14.2 kcal/minute = 852 kcal/60 minutes of wrestling
2,569.5 + 100 kcal/day	

Therefore, the approximate energy need of a 105-lb male wrestler who wrestles 1 hr/day would be 2600 kcal/day.

Exercise Training and Body Building

The major nutritional support required for an exercise program is additional calories provided from a variety of foods which will provide any additional vitamins and minerals needed. Body-building exercises deposit very small amouts of protein relative to normal intake, so protein supplementation is not necessary. The primary care physician should advise the young athlete on his stage of maturational development and on what he can reasonably accomplish from a weight-training program.

Athletes in some sports, such as football or basketball, may wish to gain weight, particularly muscle mass, often within an unreasonably short period of time. Interviews with 48 varsity basketball players in Seattle revealed that 65% had tried to gain weight at some time during their high school sports careers through the use of special diets, drugs, supplements, protein powder, etc.[15]

It is important for the athlete and the coach to understand that only through increased muscle mass will increased athletic potential be achieved. Increased body fatness reduces speed and endurance and increases the risk of injury. Only muscle work will increase muscle size, and this is limited by genetic potential. There is no specific nutrient, protein compound, hormone, or drug that will increase muscle mass. It is a popular misconception that increasing muscle mass requires a substantial increase in dietary protein. The fallacy of this is obvious since an increased deposition of 3 to 6 gm of protein per day, which is less than the protein in one egg or one ounce of meat, is all that is needed to produce a 10 to 20 pound increase in muscle mass per year. The calculation:

10 pounds = 4.54 kg weight or
4.54/4 = 1.14 kg protein since each gm of protein is stored with 3 gm of water
1.14 kg protein deposited /year = 3.1 gm/day

Rather than consuming large amounts of protein, the body builder should be concerned about consuming adequate calories to make up for the large expenditure of energy during exercise. A substantial portion of these dietary calories should be from carbohydrate because insulin is required for amino acid entry as well as protein synthesis in muscle cells.

The physician and coach also must consider the level of maturation of the young athlete before initiating a weight-training program. Physicians are encouraged to inform coaches, parents, and young athletes of the normal maturation sequence of young men and women as they acquire adult body size, weight, strength, and endurance. The normal sequence of growth levels is regulated and controlled by the normal hormonal changes that occur during adolescence and is related directly to sexual maturation. Physicians are encouraged to monitor stages of adolescent development by grading the development of external genitalia and distribution of body hair. Boys will not have a significant potential for developing increased muscle size and strength until approximately 12 to 18 months after they have experienced peak gains in height. At this stage testicular growth will have reached near adult size and genital hair will have begun to appear in the inner aspects of the upper thigh. Prior to this maturational hallmark, young men must understand that weight training, though it will yield modest increases in strength, will not result in significant major gains in muscle mass and body weight.

The best advice to the young man who is accepting the challenge of "making the team" but is a late developer and unhappy with his body size, muscle strength, and endurance is to work on skills necessary to participate in sports that do not depend on strength and size. Then at the appropriate maturational stage he can become conscientious in pursuit of a well-planned weight-training program. Many tall, late-maturing young men with real athletic ability have missed the opportunity for a positive and rewarding athletic experience by being pushed beyond their capabilities by parents and coaches whose performance expectations have been in relation to the size instead of the stage of maturity.[1]

The athlete who is developmentally ready and wishes to increase muscle mass, strength, and endurance must schedule a well-supervised program of weight training. The program should be implemented many months prior to the athletic season. A well-planned diet must be increased by approximately 500 to 1000 kcal/day. This can be accomplished by adding a fourth meal to the conventional three-meal plan. Food choices should come from an attractive selection of preferred foods from the basic food groups[5] (see Table 22-1). The increased food energy intake is the critical dietary contribution that will support the increase in muscle weight stimulated by the weight-training program. The athlete should weigh weekly and aim for a weight gain of approximately one pound per week. Estimates of body fat, such as triceps skinfold measurement, can be useful to assure that the weight increase is primarily a result of increased muscle mass and not solely body fat.[1,10] Coaches and physicians should regularly counsel the athlete to avoid binge eating and crash dieting programs, which can set a pattern of eating that can carry over into adulthood, long after the participation in the athletic program has ceased. Also, the dangerous and ineffectiveness of drugs, such as androgenic hormones or steroids, must be emphasized. In healthy young athletes these agents are ineffective in increasing muscle strength of muscle mass and can be associated with serious toxic side effects.

Low Intensity Exercise

Dietary adjustment can affect performance during longer-endurance events of lower intensity (VO_2 max of approximately 65%) such as marathon running, cross-country cycling, and skiing. This is especially true for the trained as compared to the untrained individual. Training can improve physical performance in several ways. The number and size of skeletal muscle mitochondria are increased, and mitochondrial enzymes are favorably modified. There is also increased capillary density per unit of muscle tissue, which reduces the distance nutrients must travel between capillaries and muscle cells. With continuous and regular training, other benefits include increased tendon, muscle, and bone strength; better coordination; and perhaps a delay in the onset of fatigue.[13] Since carbohydrate depletion in the form of depleted glycogen stores appears to be a contributing factor to overall fatigue and reduced performance, considerable attention has been given to the issue of fuel metabolism during exercise and possible dietary manipulations to optimize fuel supplies.

Carbohydrate, specifically glucose, is the preferred fuel source of the body. As described earlier, body carbohydrate is stored in muscle tissue and the liver. The untrained human skeletal muscle generally stores 80 to 100 mmol glucose units/kg of tissue, even if the individual's diet is high in carbohydrate. The leg muscle of a trained distance runner can contain from 150 to 250 mmol/kg after two days of rest and a diet of 350 to 400 grams of carbohydrate/day. This is due to a biological adaptation to training rather than the effect of an acute bout of exercise.[21,22]

The resting muscle in the fasting state uses principally fat for energy, but if muscle work increases to 70 to 80% VO_2 max, such as during a sprint, carbohydrate becomes the primary energy source of muscle until it is depleted. At lower-intensity levels, fatty acids are a more important substrate for exercising muscle, and the fat utilized primarily is that which is stored in the muscle itself. The trained athlete appears to be more efficient than the untrained individual in burning fat as a fuel source and conserving glycogen in an endurance event.[23,24]

If the training has been optimal, can nutrition influence performance? If you are advising an athlete or exercising individual who asks you this question, how do you respond?

First of all, you need to be assured that the individual is consuming a nutritionally balanced diet, with the recommended proportion of energy from the various major nutrients, as described earlier, and at a sufficient caloric level to prevent unwanted weight loss.

Glycogen Loading

A higher than normal concentration of glycogen can be achieved in muscle by manipulation of exercise and diet. The process, called glycogen loading, purportedly improves athletic performance for long-term events, such as distance running. Glycogen loading occurs after muscle glycogen is depleted by vigorous exercise and by eating a low-carbohydrate diet over a two- or three-day period, followed by limited exercise and a high-carbohydrate diet for at least two days.

With regard to carbohydrate loading, there is some evidence to suggest that muscle can be supersaturated with glycogen, and therefore, can improve performance.[21,22] Whenever glycogen is depleted in muscle, or for that matter in the liver, repletion results in an overshoot of glycogen synthesis. That is, more glycogen is deposited during repletion than the amount normally present when the stores are full. The mechanism of this overshoot, which also occurs in triglyceride synthesis after a fast, has not been established, but some athletes have been trying to take advantage of its occurrence.

The process of glycogen loading first requires that muscle glycogen be reduced to very low levels through vigorous exercise and the consumption of a low-carbohydrate diet over a two- or three-day period. Glycogen is not totally depleted in muscle or any other cell because resynthesis requires that glucose units be added to pre-existing glycogen. The low-carbohydrate diet is necessary during the depletion phase because it reduces blood insulin levels, insulin is necessary for glucose entry into muscle and to activate glycogen synthase.

After glycogen is depleted, limited exercise and a high-carbohydrate diet will result in overshoot of glycogen synthesis in muscle. The elevated glycogen content lasts one to two days. The timing of the depletion phase can be arranged so that muscle will be overloaded with glycogen during the competitive event. Since glycogen availability is not the limiting factor in short-term events, if glycogen loading has an advantage it is in long-duration events such as a marathon.

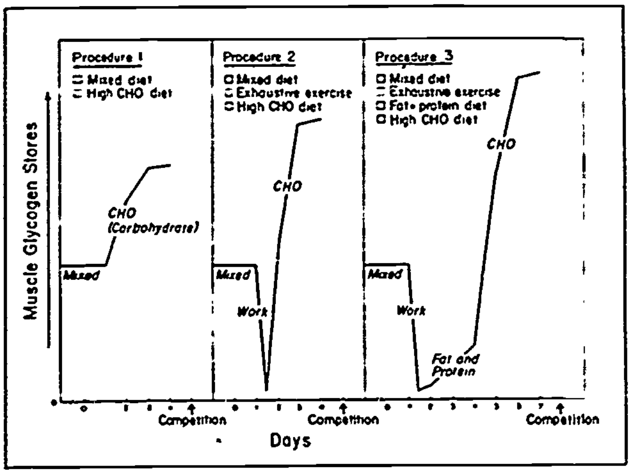
Definitive evidence has not been obtained to indicate that glycogen loading does, in fact, improve athletic performance because it is impossible to conduct a double-blind study. Without such a study, a scientific determination cannot be made. Some marathon runners who have competed after glycogen loading argue that it helped them to perform better, although psychological effects are obviously an important part of athletic competition. On the negative side, each gram of glycogen is stored with three grams of water; thus an athlete who has loaded muscle with extra glycogen is starting the race with extra weight.

There are some problems with carbohydrate loading as usually practiced, and it will not benefit every individual in an endurance event. A more moderate regimen has been proposed (Figure 22-2) which omits the high-fat and high-protein, low-carbohydrate portion of the program, and substitutes three days of exhaustive exercise while eating a normal balanced diet. This is then followed by a high-carbohydrate diet (250 to 525 gm/day) during the two to three days before the event.[1] This results in muscle glycogen levels of 65% to 75% of those achieved by complete glycogen loading but limits some of the stressful side effects of complete loading.[1,14,25] Such diets are not recommended for children or adolescents.

Carbohydrate loading is beneficial only during endurance events. No data are available on the possible long-term effects of this program, therefore, the full sequence should probably not be used more than two or three times a year. Glycogen loading should be used with care in individuals with diabetes or hypertriglyceridemia. The biggest drain on glycogen stores occurs at the beginning of a marathon when approximately 20% of the available glycogen can be utilized in the first five minutes of the race.[24]

There may be some value in elevating triglycerides prior to an endurance event to minimize initial glycogen loss[1,21]; however, this manipulation of the diet needs to be investigated more thoroughly. This may be accomplished by eating a higher-fat meal several hours before the event or by drinking caffeine-containing beverages. Caffeine, a phosphodiesterase inhibitor, prevents conversion of cyclic-AMP to its inactive compound (see Module 18, Metabolic Principles). Epinephrine, which is elevated in competitive situations, stimulates lipolysis via c-AMP and hence increases free fatty acid levels. Caffeine can facilitate this response. Caffeine ingested at 4 to 5 mg/kg of body weight when administered 60 minutes before exercise stimulates an increase in fat metabolism and a decline in muscle glycogen usage and also produces a lessening of the subjective rating of effort by subjects.[26] Therefore, part of the benefit of caffeine could be psychological in nature. Despite the endurance advantage provided by the ingesrion of dietary irems such as coffee and tea, the erhical use of these drinks must be considered in light of their stimulating effecr on the heart and central nervous system.

Figure 22-2 Glycogen Loading Procedures



From Fox, E. L.: *Sports Physiology*. Philadelphia: W. B. Saunders Co., 1979. Reprinted by permission.

In-Training Nutritional Maintenance

Energy Requirement

During the emotional and physical stress of training the athlete may have a difficult time meeting energy needs, which can be as great as 3000 to 5000 kcal/day. Periodic three-day food records as diaries can be used to monitor food and energy intake. Adjustment can be made on food intake based on body weight and body composition.

Several factors influence the energy cost of exercise. These include the individual's age, sex, size (body weight and height), metabolic rate, the type of intensity, frequency and duration of the activity, and the level of training of the athlete.[26,27]

For example, a heavier person expends more energy than a lighter-weight person for a given activity, and the energy cost of short-distance racing is less than marathon racing.[27-29] Energy turnover among athletes varies from 3000 to 5000 kcal/day, increasing an additional 500 to 1500 kcal during training.[29] Normally, appetite and satiety are sensitive regulators of food inrake, automatically adjusting energy intake to meet the increased energy requirement.[27,29,30] However, under the emotional stress of training and competition the athlete may fail to consume sufficient food for energy or, conversely, eat excessively. Therefore, it is recommended that athletes make a conscious effort to monitor their daily food intake by keeping periodic three-day food intake records to estimate energy intake and to make adjustments based on body weight and body composition. Excess body fat decreases mechanical work efficiency; that is, more energy and oxygen are required to produce a given amount of physical work.[30]

It is not possible to accurately recommend the "ideal" percent of total body fat for men and women engaged in various types of exercise. It is estimated that the average untrained adult male has 16 to 20% body fat and the female has 24 to 28%. Optimal body fat percentages have been esrimared at 10 to 12% body fat for men and 18 to 20% for women. These levels vary with the age of the individual and the athletic event in which the individual most commonly participates. Minimum body fat levels have been estimated to be 7% for men and 12%

for women, for both growing and mature adults. Athletes with body fat below these levels may not only impair physical performance but also endanger normal body function. For example, menstruation may stop in females who drop below their minimum body fat level.

Body fat can be estimated by utilizing underwater weighing techniques which require special equipment or by anthropometric measures, such as skinfold measurements and body circumferences which require calipers and a tape measure.[10]

Protein/Fat

A high-carbohydrate (50% or more total energy), moderate-protein (10 to 15% of total calories, or 0.8 to 1.5 gm/kg of body weight), and moderate-fat (30 to 35% of total energy) diet seems to provide the best balance of nutrients for physically active individuals. A high-carbohydrate diet is especially beneficial during training for endurance events to promote glycogen storage. Sufficient rest between exercises is necessary to replenish muscle glycogen stores.

The most difficult myth to dispell regarding the athlete's diet is that a substantial amount of protein is needed to meet extra energy demands, to improve athletic performance, and to increase muscle mass. However, an individual athlete consuming 4000 kcal/day, 15% of which are provided by protein, ingests 150 gm of protein, or 2.14 gm/kg of body weight for a 70 kg man, which exceeds the RDA by 270%. The Recommended Dietary Allowance (RDA) for protein is 0.8 gm/kg of body weight. Even growing youngsters undergoing a vigorous training program do not require more than 1.5 gm of protein/kg/day. Some athletes believe that since protein is the building block for muscle, the more protein eaten the more muscle may be developed. Actually, muscle is only 22% protein. Additional protein taken in excess of requirements is either burned for energy to support activity or converted to fat. It is possible to meet the protein needs of the athlete on a vegetarian diet; the lacto-ovo-vegetarian diet poses no problems in meeting protein and nutrient needs. A vegetarian diet devoid of animal and dairy products may be deficient in vitamin B_{12}, this nutrient should be supplemented.

Contrary to popular opinion, protein, while essential to build and repair tissue, is the least important nutrient as an energy source.[28,29] Because fat has almost unlimited storage in the body, there is no rationale for drastically increasing the fat content of the athlete's diet. A fat content of 30 to 35% of the total calories will provide sufficient energy supplies and possibly avert some of the potential long-term consequences of a high-fat diet.[31,32]

Carbohydrate

In contrast to the high-fat or high-protein diet, a high-carbohydrate diet (50% or more of total calories) has been shown to enhance physical performance.[32] This is especially true in prolonged, submaximal-intensity endurance activities such as cross-country skiing, cycling, marathon running, or distance swimming. Research by Costill and Miller[32] has indicated that the chronic fatigue often expressed by athletes during repetitive strenuous training conditions may be due to a gradual decline in muscle glycogen. Since chronic fatigue can limit an athlete's ability to participate in a heavy training program, appropriate dietary management can minimize the effect. Because all athletes performing heavy exercise (aerobic or anaerobic) require large quantities of carbohydrate, a high-carbohydrate diet may facilitate its use during exercise. A high-carbohydrate diet during training promotes significant 24-hour glycogen storage rebound, returning muscle glycogen stores to near-normal levels on each succeeding day of high-intensity training (see section on glycogen loading).

During training, carbohydrate intake can reach approximately 500 gm/day for the adult male athlete (60 to 70% of total calories on a 3000 to 4000 kcal diet). It is important that the athlete consume sufficient calories to meet the energy needs of training since a negative calorie balance compromises the ability to synthesize glycogen. In addition, under hypocalorie circumstances, other nutrients may be consumed in insufficient quantities, thus further limiting performance.[1] Also, sufficient rest between exercise bouts will help muscles to replenish the glycogen stores.

The athlete in training will best meet nutritional needs by consuming a diet high in carbohydrates and consumed in three regular meals, supplemented with between meal snacks similar to the ones outlined in Appendix A-1. It appears from current research that the form of the carbohydrate (simple sugars such as sucrose, fructose, and lactose vs. complex carbohydrates such as breads, cereals, potatoes, and crackers,) does not appear to be a factor in the glycogen repletion process.[33] However, excessive consumption of simple sugars, besides being cariogenic, may increase liver synthesis of triglycerides, and many high-sucrose foods are not particularly good sources of other important nutrients. Appendix B identifies the number of servings from the basic food groups which will meet an athlete's needs during the training season and during endurance events.[10]

Fluid Needs During Training

During training it is essential for all athletes to be mindful of maintaining appropriate fluid and electrolyte balance, as described in the previous section. Dehydration is an enemy of optimal performance and, if allowed to become severe, can be life-threatening. To prevent dehydration, coaches and trainers, as well as physicians involved in supervising sports activities, should encourage a liberal fluid intake before, during, and after vigorous exercise. A young athlete exhibiting more than a 2% weight loss from day to day of training should be carefully monitored for symptoms of dehydration.

Vitamins and Minerals

A balanced diet which includes a variety of foods will provide adequate amounts of vitamins and minerals. Supplementation with vitamins and minerals has not been shown to enhance physical performance, with the possible exception of iron for young women. If serum iron, hematocrit and hemoglobin, or serum ferritin levels consistently fall below normal, iron supplementation with ferrous sulfate should be prescribed and monitored by the physician.

Although sweat loss can be substantial, the loss of electrolytes and minerals in sweat is relatively small. Renal conservation of electrolytes (principally sodium), consumption of regular meals, and adequate fluid intake in all but the most exceptional circumstances adequately maintain electrolyte homeostasis. There have been some claims that individuals who train exhaustively on repeated days deplete potassium stores with resultant muscle weakness. However, Costill and Miller[32] and Costill[26] were not able to demonstrate this even when dietary potassium intake was very low.

A balanced diet which includes a variety of food is a safe and adequate source of minerals. Supplementation with minerals has not been shown to enhance physical performance, particularly since exercise does not appear to require a significant increase in mineral requirements. The possible exception to this is iron. A transient condition of borderline, low-hemoglobin levels is observed in some athletes during the early stages of strenuous physical training.[28,29,34] It is theoretically possible for muscular endurance of an individual participating in aerobic activities to be affected by low hemoglobin levels, but the cause and significance of this phenomenon are not known.[28] The etiology of sports anemia could be a physiological adaptation to training, an increased susceptibility of red blood cells to lysis during exercise, and/or a loss of iron in sweat.[29] Whether the condition affects working capacity is not known.

Inadequate dietary iron intake is of most concern to women of child-bearing age, to teenage boys, and to strict vegetarians whose dietary intake may be low. Iron deficiency anemia in these cases will adversely affect performance because the oxygen-carrying capacity of the blood is reduced. The Recommended Dietary Allowance for iron is 10 mg for men and 18 mg for women.[35] The average American diet provides 6 mg iron/1000 kcal ingested. In most cases, iron needs can be met by diet. Table 22-7 outlines some suggestions for increasing dietary intake of iron; Table 22-8 lists iron-rich food sources.[16] In high-risk groups, hemoglobin and hematocrit levels or serum ferritin levels (for a more sensitive picture of iron status) should be monitored regularly. If levels fall below normal, iron supplementation with ferrous sulfate should be prescribed. Excess iron is toxic, and iron should not be supplemented in large doses unless a measurable deficiency exists. Daily intake of a multivitamin and mineral tablet containing the RDA (10 to 18 mg) for iron is probably not harmful.

The single nutrient group most abused by athletes and the fitness conscious are the vitamins. Supplemental vitamins are easily obtained (although expensive), easily swallowed, and often believed by athletes and coaches to contain near-magical properties. In any gym or locker room you can hear athletes proclaim the merits of

Table 22-7 Methods to Increase Iron Stores[36]

1. Vitamin C helps in the body's absorption of iron. Eat fruits and vegetables rich in vitamin C, such as orange juice, tomatoes, broccoli, and potatoes, along with iron-rich foods. For example, orange juice increases the absorption of the iron in enriched cereals by 250 percent.
2. Tea and coffee interfere with iron absorption. Drink other beverages with your meals.
3. Meat enhances the absorption of iron in vegetables. Eat them together for greater nutritional value.
4. Iron utensils, such as cast-iron skillets, are an excellent source of iron, especially when used for cooking acidic foods. The iron content of spaghetti sauce increases from 3 to 88 mg per ½ cup of sauce when simmered in an iron pot for three hours.
5. Buy breads and cereals which have "enriched" or "fortified" written on the label. These grain products have iron added to them.
6. Select iron-rich foods each day. The iron content of some foods is listed in Table 22-8. Men should try to ingest 10 mg iron and women 18 mg iron per day to meet the Recommended Dietary Allowances.

From "Methods to Increase Iron Stores," in Cantu, R.D., and Gillespie, W.J. *Sports Medicine, Sports Science: Bridging the Gap.* New York: Macmillan Publishing Co., 1982. Reprinted by permission.

Table 22-8 Iron Content of Selected Foods

Food	Iron Content (mg)
Liver, 3 oz	7
Turkey, 3 oz	5
Pork, 3 oz	5
Beef, 3 oz	4
Shrimp, 3 oz	3
Chicken, 3 oz	1
Fish, 3 oz	1
Egg, 1 large	1
Dried apricots, 12	6
Prune juice, ½ cup	5
Dried dates, 9	5
Raisins, ½ cup	2
Spinach, ½ cup	2
Peas, ½ cup	1
Baked beans, ½ cup	3
Kidney beans, ½ cup	3
Bean curd (tofu), 4 oz	2
Cereal, 100% fortified (Most, Total), ¾ cup	18*
Cream of wheat, ½ cup	9*
Raisin bran, ¾ cup	5*
Bread, 1 slice	1*
Spaghetti, ½ cup	1*
Molasses, 1 Tbsp blackstrap	3
Molasses, 1 Tbsp regular	1
Brewer's yeast, 1 Tbsp	2
Wheat germ, 1 Tbsp	1

*Commercially enriched with iron

From Bowes, A.D.: *Bowes' Food Value of Portions Commonly Used* (13th ed.). New York: Harper and Row, 1980. Reprinted by permission.

megadoses of one vitamin over another. In spite of these claims, even basic vitamin supplements which supply the RDA for vitamins and minerals are not necessary in most circumstances. A few at-risk groups for vitamin or mineral deficiencies are

1. anorexic athletes who under-restrict food intake;
2. weight-conscious individuals who dramatically reduce their calorie intake; and
3. individuals who get an excessive amount of food energy from soda pop, sugar, and fat-dense foods.

Otherwise, there are no scientific data that demonstrate that supplemental vitamins at any dosage improve athletic performance; the exception to this rule is the possible placebo effect which can have a dramatic impact on performance because the athlete expects to perform better.[37]

The physician should not take the issue of vitamin and mineral megadoses lightly since they are not harmless substances, if a little is good a lot is not necessarily better. Vitamins A, C, D, E, and niacin have all been shown to be toxic in large doses.[3,38] Table 22-9 lists some vitamin toxicity effects.

Primary care physicians are encouraged to take a diet history or refer the patient to a dietitian to evaluate the overall adequacy of the individual's diet; if potential

Table 22-9 Vitamin Toxicity Effects*

VITAMIN A	
	Skin lesions
	Blurred vision
	Itching
	Hair loss
	Headache
VITAMIN C	
	RBC hemolysis
	Rebound scurvy
	Oxalate kidney stones
	Decreased copper absorption
	Adverse effects on growing bone
VITAMIN D	
	Weakness
	Anorexia
	Constipation
	Weight loss
	Hypercalcemia
	Bone loss
VITAMIN E	
	Interferes with vitamin K metabolism, causing bleeding diathesis
	Interferes with vitamin A metabolism, causing poor vision
NIACIN (3 gm)	
	Skin changes
	Hypermetabolism
	Hypertension
	Sweating

*There is no evidence that vitamin supplementation enhances athletic performance, and vitamins A, C, D, E, and niacin have been shown to have toxic effects.

problems exist, the physician should suggest increasing the intake of foods to supply the needed nutrients.

If your patient insists on a supplement, one containing no more than 100% of the RDA for the essential vitamins and minerals should be recommended. Megadoses should be strongly discouraged.

There is a lack of well-designed studies of the impact of moderate vitamin and mineral deficiencies on physical performance. Major or serious deficiencies will result in reduced performance before clinical manifestations of the deficiency appear.[39]

A distinction needs to be made between modest supplementation of vitamins and minerals (25% of the RDA), which might be beneficial for some individuals, and the indiscriminate use of megadoses of these nutrients and other substances advocated by fitness gurus and some athletes. Many athletes take massive doses of vitamin C (10,000 mg/day) to help relieve soreness and speed healing. However, excessive amounts of ascorbic acid can cause gastrointestinal discomfort, and a dependence on high levels over many months can promote symptoms of scurvy when the vitamin is discontinued. In some people ascorbic acid at doses of 1500 mg/day has the potential for producing hemolysis of red blood cells.

Vitamin E is another popular vitamin among athletes, yet numerous scientific studies have failed to shown any improvement in performance from taking vitamin E.[40] It does not increase stamina, improve circulation, deliver extra oxygen to muscles, or lower cholesterol. Furthermore, vitamin E is widely available in the diet, especially in vegetable oils, and dietary deficiencies are not normally a problem.

"Vitamin" B_{15} (pangamic acid) is another popular ergogenic aid among sports enthusiasts, especially in other countries. Samples of B_{15} that have been analyzed by the FDA contain a variety of substances unrelated to the expected content; pangamin does not meet the specifications for classification as a vitamin, and it has not been proven to be of value as an ergogenic aid.

Pre-Event Nutrition: The Pre-Game Meal

The goal of the pre-game meal is to maintain blood glucose levels, support fluid and electrolyte balance, and prevent undesirable gastrointestinal complaints. It should be composed of foods the athlete enjoys and feels will benefit performance. Basically it should be high in carbohydrate foods; low in fat, bulk, and salt; and moderate in protein content. Liquid pregame meals may prove advantageous to some athletes because of their convenience and composition.

The pre-event meal period is usually considered to be the four hours prior to competition or the athletic event.

The composition and exact timing of this meal have been the source of considerable controversy among athletes, trainers, and coaches. Since digestion requires 4 to 5 hours and muscle glycogen synthesis requires even longer, the pre-competition meal contributes little to energy stores of the athlete. These energy stores depend more on nutrition in the training period prior to the event. Therefore, the goal of the pre-game or pre-event meal is to maintain blood glucose, support fluid and electrolyte balance, and prevent undesirable gastrointestinal complaints.

Psychological factors are very important and, within reason, foods that the athlete believes enhance performance should be consumed. Timing can also vary, based on the athlete's preference. A heavier meal can be consumed 3 to 4 hours prior to competition or a light, high-carbohydrate meal or liquid meal can be ingested 2 to 3 hours in advance.[1] Table 22-10 provides some sample pre-competition meals, and Table 22-11 lists a few high-carbohydrate foods to include in the pre-competition meal.[10]

The athlete should be advised not to initiate any new dietary regimen prior to a big game or event. Such programs should be tested prior to the event to avoid any psychological or physiological disadvantages. In general, the following guidelines are recommended for the pre-event meal:

1. Ensure adequate carbohydrate intake; i.e., 60 to 70% of total calories to support blood glucose levels.
2. Keep fat and protein content at reasonable levels since fat slows gastric emptying time and a high-protein meal can aggravate dehydration.
3. Avoid high-salt foods and added table salt. A high-salt meal can cause greater sodium losses.
4. Avoid high-bulk foods to cut down on gastrointestinal residue and avoid "gassy" foods that can cause stomach cramps, such as beans and carbonated beverages.
5. Drink adequate amounts of fluid. One to two 8-ounce glasses of water or juice are recommended for adequate hydration. Drink another 8 to 12 ounces just prior to an endurance event.
6. Avoid caffeine and alcohol-containing beverages. Caffeine is a diuretic and can increase urinary output. It can also aggravate jitteriness and/or hyperactivity. Alcohol is also a diuretic and a CNS depressant, which can affect coordination.

Table 22-10 Some Sample Pre-Competition Meals

Four sample pre-competition meals are listed below. Notice that each contains plenty of high-carbohydrate foods, low-fat milk products, and a beverage or other source of fluid.

SAMPLE MEAL #1:
Orange juice, cornflakes with a sliced banana, whole wheat toast with jelly, and skim milk

SAMPLE MEAL #2:
Vegetable soup, chicken sandwich on wheat bread, applesauce, and low-fat strawberry yogurt

SAMPLE MEAL #3:
Julienne salad (lettuce and other fresh vegetables with thin strips of cheese and turkey), a hard roll, pudding, and grape juice

SAMPLE MEAL #4:
Pork and beans, crackers, carrot sticks, fruit cup, and skim milk

From *Food Power: A Coach's Guide to Improving Performance*, 1983. Courtesy National Dairy Council.

7. Enjoy the meal. This is very important since psychological factors and preferences have more to do with performance than the composition or size of the meal.
8. A liquid pre-game meal may prove beneficial for some athletes.

There is no research to date to demonstrate that liquid meals are better tolerated or improve athletic performance over solid meals. However, they do provide some advantages since they are high in carbohydrate, low in residue, minimize gastrointestinal discomfort, contribute to pre-game hydration, are nutritionally equivalent to solid meals, and may be helpful in avoiding pre-game nausea sometimes associated with solid food.[1,41]

Commercial liquid meals usually contain 250 to 450 kcal/eight ounces. Some examples are Sustacal, Ensure-Plus, Ensure, and Nutriment. These formulas can be useful for day-long competitive events, such as swimming or track, and for tournaments when the athlete has little time for or interest in food.

Table 22-11 High-Carbohydrate Foods

	Grams of carbohydrate
Milk Group	
Milkshake, chocolate, 10.6 oz	63
Yogurt, strawberry, 1 cup	42
Pudding, chocolate, ½ cup	30
Milk, chocolate, 1 cup	26
Cocoa, ¾ cup	19
Ice cream, vanilla, ½ cup	16
Milk, low-fat and skim, 1 cup	12
Milk, whole, 1 cup	11
Meat Group	
Refried beans, ½ cup	26
Blackeye peas, mature, ½ cup	17
Fruit-Vegetable Group	
Raisins, 4 Tbsp	33
Potatoes, french-fried, 20 pieces	31
Potato, baked, large	30
Applesauce, sweetened, ½ cup	30
Banana, medium	26
Peaches, canned in syrup, ½ cup	26
Pear, medium	25
Fruit salad, ½ cup	25
Pineapple, large slice	24
Grape juice, ½ cup	21
Apple, medium	20
Potatoes, boiled, 2 small	18
Potato, sweet, ½ medium	18
Beans, lima, ½ cup	17
Corn, ½ cup	16
Orange, medium	16
Squash, winter, ½ cup	14
Potatoes, mashed, ½ cup	13
Grapefruit, pink ½ medium	13
Orange juice, ½ cup	13
Watermelon, 1 cup	13
Grain Group	
Cornbread, 2½" x 3"	30
Roll, hard	30
Bagel	28
Rice, ½ cup	25
Roll, hamburger or frankfurter	21
Noodles, egg, ½ cup	19
Waffles, 2	17
Cornflakes, ¾ cup	16
Hominy grits, ½ cup	14
Tortilla, corn, 6" diameter	14
Biscuit, baking powder	13
Bread, white, 1 slice	12
Oatmeal, ½ cup	12
Bread, whole wheat, 1 slice	11

From *Food Power: A Coach's Guide to Improving Performance*, 1983. Courtesy National Dairy Council.

Nutritional Support During Competition

The type of activity or exercise determines the nutritional support, if any, required during competition or exercise. High-intensity, short-term activities, such as sprinting, are not limited by nutritional factors, assuming the athlete is well-hydrated and has normal nutritional status. Long-term distance events, such as distance running, cycling, and cross-country skiing, can be influenced by the individual's fluid and carbohydrate intake during the event. Appropriate fluid and electrolyte balance was discussed earlier. If a calorie-containing beverage is consumed during the event (not prior to it), it is recommended that it be consumed

1. when cold (40 to 50°F),
2. in relatively small quantities (100 to 300 ml),
3. at frequent intervals (every 15 to 20 minutes) and be isotonic to body fluids (200 milliosmoles/l), and
4. have a pleasant flavor to enhance ingestion.[1]

Post-Exercise Nutrition

In general, the post-game meal should be enjoyable and relaxing. Some researchers recommend that it resemble the general compo-

sition of the pre-game meal. The use of beer as a fluid replacement following exercise is strongly discouraged because of its high osmolality, diuretic properties, and effect on liver metabolism.

Once competition has been completed for the day, nutritional management is not any different than during training. Most athletes prefer liquids rather than solid foods immediately following a strenuous event. Within a few hours after the event appetites are usually increased and large portions are generally consumed. Some researchers recommend that the post-competition meal also should be high in carbohydrate and resemble the general composition of the pre-event meal.[1] However, all agree that it should be a well-balanced meal composed of foods the athlete enjoys.

The use of beer as a fluid replacement after exercise has been proposed. This practice should be discouraged since beer leaves the stomach slowly because of its high osmolality. Alcohol in beer acts as a diuretic and can aggravate dehydration, and excess beer drinking can have negative effects on liver metabolism.

Nutrition Recommendations for the Fitness-Conscious Adult

The best nutrition program for the fitness-conscious adult is a balanced diet selected from a variety of foods and consumed at the appropriate energy level to support the activity. If weight control is also a goal of exercise, the individual needs to restrict calories, along with an aerobic exercise program, for best results. For the older individual who is out of shape, a cardiac stress test should be performed before starting on an exercise program.

For individuals who participate in regular exercise for health and overall physical appearance benefits, no special nutrition program other than eating a balanced diet from a variety of foods is necessary. Many individuals institute an exercise program to improve cardiovascular health and help in weight control. As discussed earlier, the physician must counsel patients that regular exercise will alter body composition by decreasing body fat and increasing lean body mass, but it must be accompanied by some calorie restricrions to result in significant weight loss. Muscle tissue weighs more than fat tissue, therefore the scales may not indicate immediately the rewards of exercise. This can be very discouraging to the dieter unless it is explained thoroughly. Measurement of body composition through skinfold measurement or underwater weighing (refer to Module 2, Appraisal of Nutritional Status, or Ref. 10) can be very useful in monitoring changes in body composition.

If such techniques are not readily available, the patient can be encouraged to take simple body measurements with a tape measure (i.e., chest or bust, waist, hips, thigh, upper arm) before initiating an exercise program and repeat every several months to evaluate changes in shape.

The physician must caution the weight-conscious, particularly females, on the hazards of undereating (less than 1000 kcal/day), especially in combination with strenuous exercise. Glycogen stores will certainly be depleted and overall nutrient intake is inadequate on such programs. Rather, a high-carbohydrate (50 to 60% total calories), 1200- to 1400-kcal plan would provide sufficient energy and satiety yet result in an average two-pound-per-week weight loss if normal caloric needs were 2500 kcal. For the exercising male who works out 3 to 4 times/week in an aerobic activity, weight losses of two or more pounds per week can be achieved on 1600 kcal/day if normal calorie needs are approximately 2600 kcal/day.

All activity requires energy, and therefore increased activity is beneficial for weight-control purposes. Aerobic activities of at least 30 minutes duration promote mobilization of fat from fat stores, which is the primary goal in weight reduction. Therefore, the weight-conscious patient should be encouraged to initiate an aerobic program when possible. This can be as simple and inexpensive as a brisk walking program. An excellent book, *Fit or Fat,* by Covert Bailey,[42] describes how to initiate an exercise program that should meet most adult individuals' fitness needs. To maintain cardiovascular fitness, 30 to 40 minutes of exercise at 60 to 85% of maximum predicted heart rate is generally recommended. However for the individual over age 35 and who is in poor physical shape, a stress test is strongly recommended before starting such a program. For weight control, daily aerobic activity will obviously result in more energy expanded and a more rapid overall loss of body fat.

Child Athletes: Nutritional Needs

Children require energy and nutrients for growth and development, in addition to requirements for maintenance and exercise. In general, the child athlete needs 60 kcal/kg of ideal body weight for adequate growth and development of lean body mass. Inadequate nutrition will result in decreased stature as an adult.[43] For children and adolescent athletes who desire to lose weight, a specific dietary program should be followed and carefully monitored. In general, caloric restriction should cause minimal weight loss and should permit the youth to "grow up to his or her weight," unless the child is more than 20% above ideal body weight.[44] The physician should make periodic measurements of height to be certain that linear growth occurs normally; fasting and unbalanced diets should never be used because they result in loss of lean body mass and can retard normal growth.

Evaluation

Persons who are physically active or who are making the effort to increase their physical activity often come to their physician not only for a physical examination but also for advice on nutrition. While each individual requires personally tailored nutritional advice, it is possible to address categories of physical activity with regard to nutritional considerations. For each of the categories of physical activity listed below, prepare a list of general advice addressing:

a. General food intake
    1. Calories
    2. Types of foods
b. Fluid intake
c. Vitamin and mineral requirements

Physical Activity Category:

1. Exercise for health maintenance
2. Exercise for weight loss
3. Participation in low-intensity activities (bicycling, cross-country, football, tennis, running)
4. Participation in high-intensity activities (short-distance running, short-distance swimming races, wrestling, downhill skiing)

Competitive sports require additional care be given to proper nutrition. Select any sport of interest to you (or a sport in which one of your patients is involved) and address the nutritional needs for an athlete in terms of

1. in-training nutritional maintenance,
2. pre-event nutrition,
3. competitive nutritional support,
4. post-event nutrition, and
5. off-season nutrition.

To obtain the full benefit of the exercises above, discuss the notes you have prepared with the residents, faculty physicians, and nutrition specialists with whom you work. It may be worthwhile to pursue the development of patient handouts based on the above exercises and your discussions with your colleagues.

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Appendix A-1

Sample Menu for a High-Calorie Diet (5000 kcal)

Meal	Snack
Breakfast 8 oz orange juice ½ cup oatmeal 1 cup milk 1 fried egg 2 slices whole wheat bread 2 tsp margarine 2 tbsp jelly Tea with honey or sugar	*Snack* Cream cheese and jelly sandwich Large glass of fruit juice
Lunch Hamburger on roll Large serving of french fries Lettuce, tomato and cucumber salad with dressing 3 large cookies 1 cup milk	*Snack* 1 cup dried fruits and nuts
Dinner Cream of mushroom soup Fried fish Large portion of spaghetti with sauce Spinach with margarine Tossed salad with dressing Roll with margarine Large piece of cake Tea with honey or sugar	*Snack* Peanut butter and jelly sandwich 1 cup malted milk Large banana

Appendix A-2

Sample 3000-Calorie Diet

Food	*Composition of 1 serving*	*Daily servings*	*Serving size*
Meat or substitute	7 gm protein; 5 gm fat; 73 kcal	8	1 oz fish, poultry, veal, beef, lamb or pork 1 egg 2 oz cottage cheese 2 tbsp peanut butter 1 oz hard cheese ½ cup cooked dried peas or beans
Milk (whole)	8 gm protein; 12 gm carbohydrate; 10 gm fat; 170 kcal	2	1 cup
Milk (skim)	8 gm protein; 12 gm carbohydrate; 80 kcal		
Bread or substitute	2 gm protein; 15 gm carbohydrate; 68 kcal	15	1 slice bread ½ cup cooked cereal or grits ¾ cup dry cereal ½ cup cooked rice or pasta 3 cups popcorn ¼ cup wheat germ 1 small corn-on-the-cob
Fat	5 gm fat; 45 kcal	6	1 tsp butter, margarine, oil, or mayonnaise 1 strip bacon 1 tbsp cream cheese 2 tsp salad dressing 6 small nuts
Fruit	15 gm carbohydrate; [illegible] kcal	6	1 medium size fruit ½ large fruit (e.g., banana, grapefruit) 4 oz fruit juice ½ cup canned fruit
Vegetable	2 gm protein; 5 gm carbohydrate	3-4	½ cup
Dessert	Approximately 200 kcal	1	1 small Danish 1 small brownie 1 small piece of plain cake 4 chocolate chip cookies ¾ cup ice cream ½ cup pudding
Sugar	5 gm carbohydrate; 20 kcal	6	1 tsp sugar, honey, or jelly 1 hard candy

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Appendix A-3

Sample menu for a 3000-calorie daily diet, including a menu for an ovolactovegetarian.

Breakfast

½ cup orange juice
1 cup oatmeal
1 cup milk
1 egg
2 slices whole wheat bread
2 tsp margarine
1 tsp jelly
Beverage

Snack

1 banana
2 slices bread with 2 tbsp peanut butter
Beverage

Lunch

3 oz tuna fish with 1 tsp mayonnaise
2 slices whole wheat bread
Lettuce and tomato
½ cantaloupe
1 cup milk

Snack

2 slices bread
1 tbsp cream cheese
½ cup fruit juice

Dinner

3 oz baked fish
2 cups cooked spaghetti with tomato sauce
Steamed broccoli
Tossed salad with 2 tsp French dressing
1 slice bread with 1 tsp margarine
1 apple
Beverage

Snack

Piece of cake
Beverage

Menu for an Ovolactovegetarian

Breakfast

½ cup orange juice
1 cup oatmeal
1 cup milk
1 egg
2 slices whole wheat bread
2 tsp margarine
Beverage

Snack

8 oz plain yogurt
¼ cup wheat germ
½ banana
6 nuts

Lunch

3 oz cheddar cheese
2 slices whole wheat bread
Lettuce and tomato with 1 tsp mayonnaise
½ cantaloupe
Beverage

Snack

2 tbsp peanut butter
2 slices bread
1 cup fruit juice

Dinner

1 cup kidney bean stew
1½ cups steamed brown rice
Steamed string beans
1 slice whole wheat bread
2 tsp margarine
Piece of cake
Beverage

Snack

2 oz cottage cheese
12 whole wheat crackers
½ cantaloupe
Beverage

Appendix B

Recommended Daily Servings of Food Groups for Training Diet and Endurance Diet		
	Training Diet	Endurance Diet
	To be used by: ■ Athletes throughout the training season	To be used by: ■ Endurance athletes 3 days before competition
Four Food Groups	Recommended Daily Servings	
Milk Milk cheese, yogurt, cottage cheese, ice cream	teenagers: 4 or more adults:2 or more	teenagers: 4-5 adults: 2-3
Meat Meat, fish, poultry, eggs, dry beans and peas, nuts	2 or more	2-3
Fruit-Vegetable Fresh, frozen, canned, dried, and juiced fruits and vegetables	8 or more	8 or more
Grain Cereals, breads, rolls, pasta, muffins, pancackes, grits	8 or more	12 or more
"Others" category Cakes, cookies, pies, candy, soft drinks, chips, fats, alcohol	No recommendation. Select foods from the "Others" category if you can afford the calories after eating the recommended servings from the four food groups.	No recommendation. Select foods from the "Others" category if you can afford the calories after eating the recommended servings from the four food groups.

Check with your doctor before going on any of these diets.

Adapted from National Dairy Council, Rosemont, IL, 1983.

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a page number followed by a "t" indicates a table; an "f" refers to a figure.

Some Abbreviations Used in the Nutrition in Primary Care Series

ATP	adenosine triphosphate
c	cup
cc	cubic centimeter
CNS	central nervous system
FDA	Food and Drug Administration
gm	gram
IBW	ideal body weight
IU	International Units
kcal	kilocalorie
kg	kilogram
lb	pound
lg	large
MCV	mean corpuscular volume
MDR	minimum daily requirement
med	medium
μg	microgram
mEq	milliequivalent
mg	milligram
MJ	megajoule
ml	milliliter
oz	ounce
RDA	Recommended Dietary Allowances
RE	retinol equivalents
sl	slice
sm	small
Tbsp	Tablespoon
TPN	total parenteral nutrition
tsp	teaspoon
USDA	United States Department of Agriculture