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Nutrition for Sport & Exercise

Fifth Edition

Nutrition

for Sport and Exercise

FIFTH EDITION

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Preface

Sports nutrition is a natural marriage of two fields: nutrition and exercise physiology. These complementary academic disciplines enable us to understand the energy expenditure that is required by exercise and sport and the energy intake that is vital to support these activities. Exercise challenges the human body to respond and adapt, and proper nutrition supports the physiological processes that make it possible to do so. Although all people can benefit from proper nutrition and exercise, athletes must pay careful attention to both. Training and nutrition are key elements of excellent athletic performance.

Nutrition for Sport and Exercise is designed primarily as a college-level text for upper-division courses in sports nutrition. It carefully illustrates the links among exercise, nutrition, and the ultimate goals, which are recovery, optimal performance, and good health. In addition to explaining the rationale behind the recommendations made to athletes, the text helps instructors and students translate these recommendations to specific plans for the appropriate amount and type of foods, beverages, and/or supplements to support training, recovery, and performance. First and foremost, this book is scientifically sound and evidence based, but it is also filled with practical nutrition information and designed so faculty can easily teach from the text.

To understand sports nutrition, students must understand both nutrition and exercise physiology. For example, carbohydrates are found in food and are used by the body to fuel exercise. The type and amount of carbohydrates in foods are "nutrition" issues. The influences of exercise intensity and duration on carbohydrate usage are "exercise physiology" issues. Sports nutrition requires an understanding and integration of these issues because the timing of carbohydrate intake or the amount needed to delay the onset of fatigue involves both nutrition and exercise physiology. The goal of this book is to integrate the principles of nutrition and exercise physiology in a well-organized, scientifically sound, and practical sports nutrition text.

The Plan of the Text

Chapter 1, *Introduction to Sports Nutrition*, sets the stage. Broad terms such as *athlete* and *exercise* are defined, and basic training and sports nutrition principles are outlined. The intensity and duration of exercise training and the unique demands of competition affect nutrition requirements and food intake. Many recreational athletes require only a good basic diet. Nearly all athletes have questions about supplements, and the first chapter discusses basic introductory information about dietary supplements.

The first chapter also emphasizes the science behind sports nutrition recommendations. From the beginning, students should recognize that the recommendations made throughout the text are evidence based. As part of the critical thinking process, future chapters will reinforce the basic concepts introduced in the initial chapter, such as the strength of the scientific evidence, research design, and consensus opinion. Each chapter includes a *Focus on Research feature*, which examines a specific research study in detail. The feature provides a more in-depth look at a topic relevant to the content of the chapter and uses different types of research studies to explain scientific methods used by the researchers, what was discovered, and the significance of the research.

A unique feature of this chapter is the information on the scope of practice of dietitians, exercise physiologists, athletic trainers, strength and conditioning coaches, and other sports-related professionals. As with any integrated discipline, no one profession "owns" sports nutrition. However, the extent of professional training and licensure can help students understand practice boundaries and when to refer to someone with the appropriate expertise, professional training, and/or credentials.

Chapters 2 and 3 cover energy concepts. Extensive teaching experience has convinced us that students more easily understand the difficult area of energy when presented in a two-part approach. The first part (*Defining and Measuring Energy*) introduces general energy concepts—what energy is and how it is measured by direct and indirect calorimetry. This leads to a discussion of energy balance and an explanation of factors that affect it, such as resting metabolic rate, physical activity, and food intake.

After that foundation is established, students can more easily understand the specific energy systems needed to fuel exercise of varying intensities as presented in Chapter 3, *Energy Systems and Exercise*. The

focus of this chapter is an explanation of the three major energy systems used to replenish ATP: creatine phosphate, anaerobic glycolysis, and oxidative phosphorylation. Oxygen consumption, fuel utilization, and the respiratory exchange ratio are described, and the safety and effectiveness of creatine supplements are reviewed.

Chapters 4, 5, and 6 cover three energy-containing nutrients—*Carbohydrates*, *Proteins*, and *Fats*. These topics are at the heart of sports nutrition. Each chapter includes a description of digestion, absorption, and metabolism of these nutrients and explains each as a source of energy based on the intensity and duration of exercise. Current recommendations for athletes are outlined, and the effects of inadequate intake on training, recovery, and performance are discussed. Type, amount, and timing are important nutrition concepts, and these chapters end with a focus on the translation of current recommendations to appropriate food and beverage choices.

Similar to Chapters 4 through 6, Chapters 7 through 9 are nutrient focused. *Water and Electrolytes* are covered first, followed by *Vitamins* and *Minerals*. These chapters feature a global approach so that students can relate to body systems that are influenced by many different factors. For example, Chapter 7 begins with an overview of water and electrolytes but emphasizes the effect that exercise has on fluid and electrolyte balance by examining water and electrolyte loss and intake during training and competition. The recommendations for replenishment of water and electrolytes are a logical extension of understanding fluid homeostasis.

To avoid the encyclopedic approach that can overwhelm students with detailed information about vitamins and minerals, Chapters 8 and 9 are organized according to function. In the case of vitamins, their major roles in energy metabolism, antioxidant protection, red blood cell function, and growth and development are explained. The minerals chapter is organized according to bone, blood, and immune system function and emphasizes calcium, iron, and zinc, respectively. Each chapter also discusses adequate intake and the potential for clinical and subclinical deficiencies and toxicities. Vitamin- and mineral-rich foods, fortified foods, and supplement sources are covered, with special attention paid to the perceived need for supplementation by athletes.

After a solid foundation in principles of sports nutrition has been laid, the text moves into comprehensive diet planning. Chapter 10 is titled *Diet Planning: Food First, Supplements Second* and helps students take the science-based nutrient recommendations made in the previous chapters and translate them into daily food choices, including food and fluid intake prior to, during, and after exercise. The chapter emphasizes developing a plan for matching dietary intake to the demands imposed by training, with consideration for the athlete's specific sport. This chapter also contains information about caffeine, alcohol, and dietary supplements. Supplements are a complicated issue requiring an understanding of legality, ethics, purity, safety, and effectiveness. Although many dietary supplements have not been shown to be effective, practitioners will have little credibility with athletes if they simply dismiss their use. Exploring the issues surrounding dietary supplements helps students become better critical thinkers.

No sports nutrition book would be complete without a chapter on body composition. Chapter 11, *Weight and Body Composition*, is realistic—it considers measurement techniques, error of measurement, interpretation of body composition results, and the relationship of body composition and weight to performance. The chapter begins with a review of methods for determining body composition and the advantages and disadvantages of each. The role of training and nutrition in increasing muscle mass and decreasing body fat is explained. Minimum and target body weights, based on a body composition that promotes health, are discussed for sports in which making weight or achieving a certain appearance is important. Muscle-building and weight loss supplements are also covered.

Chapter 12 covers disordered eating and exercise patterns in athletes. The philosophy expressed throughout the book is that normal eating is flexible and that food is eaten both for fuel and for fun. However, disordered eating and life-threatening eating disorders can touch the lives of anyone who works with athletes, and these problems cannot be ignored. This chapter follows the progression of eating and activity patterns from "normal" to disordered to severely dysfunctional. Low energy availability is explained and the interrelated elements of the Female Athlete Triad and the Reduced Energy Deficiency in Sport (RED-S) are discussed.

Whereas the focus in most of the chapters is on the trained athlete, the final chapter gives ample coverage to diet and exercise for lifelong fitness and health and their roles in preventing or delaying chronic disease. Many students dream of working with elite athletes, but, in reality, most will work with many people who are recreational athletes or are untrained, have relatively low fitness levels, eat poorly, and want to lose weight. This chapter addresses the issue of declining physical activity associated with aging and uses scenarios of former athletes to highlight chronic diseases such as obesity, type 2 diabetes, heart disease, metabolic syndrome, osteoporosis, and lifestyle-related cancers. The chapter has been organized to reflect the primary role that overweight and obesity play in the

development and progression of many chronic diseases. It also explains the many mechanisms, some of which are not precise, that the body uses to regulate body weight.

Nutrition for Sport and Exercise is a blend of nutrition and exercise physiology and both scientific and practical information. It fully integrates both fields of study. It is not an exercise physiology book with nutrition as an afterthought or a nutrition book with superficial explanations of core exercise physiology principles. The authors, a registered dietitian and an exercise physiologist, have more than 50 years of classroom experience in sports nutrition. They have used that experience to create a text that meets the needs of both nutrition and exercise science majors and faculty.

Features of the Text

Each chapter is designed to guide students through the learning process, beginning with ***Learning Objectives*** for students to master as they study the material. A ***Pre-test*** helps to assess students' current knowledge of the topic to be discussed. At the end of each chapter, a ***Post-test*** is given to test what students have learned. The answers to the *Post-test* found in Appendix O are used to illuminate misconceptions about the topic as well as to pinpoint material that warrants further study.

Glossary terms are highlighted throughout the chapters, giving students immediate access to their definitions as well as helping them identify important terms to study as they prepare for exams. The definitions have also been gathered into an alphabetical glossary at the back of the book.

Numerous sidebars appear throughout the text, exposing students to high-interest information on diverse topics. The sidebars highlight applications of concepts, present the latest findings, and point out controversial ideas without interrupting the flow of the text. Selected ***Spotlight features*** highlight important online resources that students can trust to find information on each topic.

Every chapter has a *Focus on research* feature. This feature walks the reader through a published research study, discussing the specific purpose of the study, what the researchers did, what they found, and the significance and context of their findings. Readers are introduced to different types of research studies; exposed to both current research and classical, historical studies in the topic area of each chapter; and given examples of how to clearly and concisely summarize and apply research in the field.

Each chapter ends with a ***Summary*** that restates the major ideas, and a ***Self-Test*** is provided, which includes multiple-choice, short-answer, and critical thinking questions, so students can test their knowledge of the content and concepts presented. The answers to the multiple-choice questions can be found in Appendix O. ***References*** for the major articles discussed throughout each chapter as well as suggested readings are available in a new appendix in the text. All of these features are designed with students in mind, to help them identify and grasp the important concepts presented in each chapter.

New to the Fifth Edition

The fifth edition of *Nutrition for Sport and Exercise* includes a thorough review of the most recent published literature so that the material included in the textbook represents the most current, cutting-edge scientific information, up-to-date guidelines, and evidence-based recommendations.

Learning objectives have been closely matched with major headings and multiple-choice questions to help students recognize and learn the major concepts of each chapter. Current guidelines and position papers appear throughout, including the 2020–2025 Dietary Guidelines and the 2016 Nutrition and Athletic Performance position paper. The analysis of a 24-hour diet of a male collegiate cross-country runner, which is used as an example throughout the text, has been updated to make it easier to compare goals with intake. Other new or updated content includes the following:

Chapter 1: Introduction to Sports Nutrition

- Inclusion of the 2020–2025 Dietary Guidelines
- Inclusion of My Plate, My Wins, which helps consumers implement the 2020–2021 Dietary Guidelines
- Inclusion of the 2018 Physical Activity Guidelines for Americans
- New Spotlight on a Real Athlete feature with critical thinking questions
- Updated information on purity, effectiveness, certification programs, and use of dietary supplements among athletes
- Up-to-date requirements for exercise and nutrition credentials and certifications

Chapter 2: Defining and Measuring Energy

- New Spotlight on wearable fitness/activity tracking devices
- New Spotlight on a Real Athlete feature with critical thinking questions
- New Focus on Research feature with analysis of a current research article
- Updated and revised section about self-reported dietary and energy intake
- Updated references and revised section on resting metabolic rate

Chapter 3: Energy Systems and Exercise

- New Spotlight on a Real Athlete feature with critical thinking questions
- Updated references and revised Spotlight on creatine loading and supplementation
- Updated images, tables, and references
- New, updated section on factors that influence oxygen consumption and $\dot{V}O_2max$

Chapter 4: Carbohydrates

- Updated references on glycemic index and exercise
- Updated Focus on Research feature
- Updated information about training with low carbohydrate, high-fat diets
- Updated information on commercially available carbohydrate products throughout the chapter
- Updated section on the use of the carbohydrate mouth-rinsing strategy during exercise
- Updated information and references in Spotlight on sports drinks, bars, and gels
- New section on carbohydrate hydrogels
- Updated Spotlight on a Real Athlete feature with addition of critical thinking questions
- Updated section on lactose intolerance

Chapter 5: Proteins

- Revision of protein quality section to include discussion of digestible indispensable amino acid score (DIAAS) method
- Revision of protein quality score table to include DIAAS scores
- Updated Spotlight on a Real Athlete feature with addition of critical thinking questions
- Updated product information of selected protein supplements
- Revision of the branch chain amino acid supplements section to reflect new research evidence
- Revision of section on dietary nitrates and nitric oxide to reflect recent research findings

Chapter 6: Fats

- Updated section on fat oxidation during exercise to include most recent research on high intensity interval training and weight/fat loss
- Revised and updated section on training with high-fat, low-carbohydrate diets to reflect the most current research
- Revised to reflect Dietary Guidelines for Americans 2020–2025
- Addition of a new section on the consumption of ketone esters to manipulate fat oxidation
- Revised section on caffeine
- Updated Spotlight on a Real Athlete feature to include critical thinking questions

Chapter 7: Water and Electrolytes

- New Spotlight on a Real Athlete feature with critical thinking questions
- Updated table on commercially available sodium-containing products
- Updated table on composition of various commercially available pre-exercise beverages
- Updated table on composition of various commercially available beverages consumed during exercise
- Updated table on composition of various commercially available beverages consumed after exercise
- Revised and updated section on sodium intake recommendations during exercise
- Revised and updated section on monitoring hydration
- Updated section on fluid replacement after exercise and intravenous rehydration
- Updated product information on commercially available energy drinks
- Revised and updated section on glycerol hyperhydration

Chapter 8: Vitamins

- New Spotlight on a Real Athlete feature with critical thinking questions
- Updated section on riboflavin
- Updated and revised section on vitamin C
- Revised and updated table on antioxidant vitamins and health
- Revised and updated summary table on vitamin D

Chapter 9: Minerals

- Updated RDA or AI and UL table
- New Spotlight on a Real Athlete feature with critical thinking questions
- Revised and updated section subclinical and clinical deficiencies
- Revised sections on bone density and bone loss
- Updated section on iron deficiency and iron deficiency anemia

Chapter 10: Diet Planning: Food First, Supplements Second

- Inclusion of the 2020–2025 Dietary Guidelines and the Healthy U.S.-Style Dietary Patterns
- Revised figure summarizing Healthy Dietary Pattern for Adults
- Updated section on low carbohydrate, high fat diets
- Updated section and table on safety and effectiveness of dietary supplements commonly used by athletes
- Updated Spotlight on a Real Athlete feature with addition of critical thinking questions

Chapter 11: Weight and Body Composition

- Revised section reliability of body composition assessment methods
- Updated section and references on plethysmography
- Revised comparison table on techniques used for assessment of body composition
- Updated Spotlight on a Real Athlete features with addition of critical thinking questions
- Revision of section on anthropometric techniques, including ISAK standards
- Updated section and references on DEXA
- Revised table on safety and effectiveness of weight loss and muscle building supplements
- Updated references and revised section on weight cycling
- Updated references and images for Spotlight on Athletes and Appearance
- Updated and revised section on ephedrine containing compounds

Chapter 12: Disordered Eating and Exercise Patterns in Athletes

- New Spotlight on a Real Athlete feature with critical thinking questions
- New Focus on Research feature with analysis of a current research article
- Revised section and updated references on consensus statements outlining risk assessment for participation and return-to-play guidelines for athletes following treatment for eating disorders or disordered eating
- Revisions to the section on amenorrhea
- Revised section and updated references on low bone mineral density
- Revised and updated section on Reduced Energy Deficiency in Sport (RED-S)

Chapter 13: Diet and Exercise for Lifelong Fitness and Health

- New Spotlight on a Real Athlete feature with critical thinking questions
- Addition of critical thinking questions to existing Spotlight on a Real Athlete features
- New Focus on Research feature with analysis of a current research article
- Updated to include the Dietary Guidelines for Americans 2020–2025, Physical Activity Guidelines for Americans 2018, and the most current guidelines from American Heart Association and the American Cancer Society
- Revised the leading and actual causes of death figures to reflect more current national statistics
- Updated table comparing various organizations' nutrition guidelines
- Updated table of comparison of weight-loss plans with current program information
- Updated new prevalence information for Spotlight features on Type 2 diabetes, heart disease, metabolic syndrome, and osteoporosis

Appendices

- Updated Appendix B titled Healthy U.S.-Style Pattern: Recommended Intake Amounts
- Updated Appendix C titled Healthy Vegetarian Pattern: Recommended Intake Amounts
- New Appendix P: References

Instructor and Student Resources

Instructor Companion Site

Everything you need for your course is in one place! This collection of book-specific lecture and class tools is available online at www.cengage.com. Access and download PowerPoint presentations, images, instructor's manual, and more.

Nutrition MindTap

The Nutrition for Sport and Exercise MindTap brings course concepts to life with interactive learning, study, and exam preparation tools that support the printed textbook. The MindTap includes an interactive eReader and interactive teaching and learning tools, including quizzes, flashcards, and more. It also contains built-in metrics tools that monitor student engagement in the course.

Test Bank

Powered by Cognero, the Test Bank is a flexible, online system that allows instructors to author, edit, and manage test bank content from multiple Cengage Learning solutions; create multiple test versions in an instant; and deliver tests from your Learning Management System (LMS), your classroom, or anywhere you want.

Diet & Wellness Plus

Take control. Reach your goals. Experience Diet Analysis Plus. Diet Analysis Plus allows students to track their diet and physical activity, and analyze the nutritional value of the food they eat so they can adjust their diets to reach personal health goals—all while gaining a better understanding of how nutrition relates to and impacts their lives. Diet Analysis Plus includes a 55,000+ food database; customizable reports; new assignable labs; custom food and recipe features; the latest Dietary Reference Intakes; and goals and actual percentages of essential nutrients, vitamins, and minerals. New features include enhanced search functionality with filter option, easy-to-use instructor page, and resources tab with helpful information.

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© Dr. Marie Dunford

Marie Dunford, Ph.D., has been involved in sports nutrition since the mid-1980s. In 1985, while a faculty member at California State University, Fresno, she created the curriculum for an upper division course titled Nutrition and the Athlete. She taught the course for a total of 16 years during which she interacted with thousands of student-athletes. This direct exposure to nutrition and exercise science majors and NCAA Division I athletes helped her to develop an understanding of how students learn and the sports nutrition topics that are most difficult for students to master. In addition to this textbook, Dr. Dunford has written three other books—*Fundamentals of Sport and Exercise Nutrition*, *The Athlete's Guide to Making Weight: Optimal Weight for Optimal Performance*, and *Nutrition Logic: Food First, Supplements Second*—and numerous online sports nutrition courses for nutrition and exercise professionals. She is also an avid recreational tennis player.

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To my husband, Greg. *C'est le ton qui fait la chanson*. It's the melody that makes the song.
MD

Dedicated to Paul Linck. You are truly an inspiration, as a friend and an athlete.
JAD

Introduction to Sports Nutrition

CHAPTER 01

Learning Objectives

LO 1.1 Explain the need for an integrated training and nutrition plan.

LO 1.2 Explain basic nutrition principles and how they might be modified to meet the needs of athletes.

LO 1.3 List sports nutrition goals.

LO 1.4 Outline the basic issues related to dietary supplements and ergogenic aids, such as legality, ethics, purity, safety, and effectiveness.

LO 1.5 Distinguish between types of research studies, strengths and weaknesses of research designs, and correlation and causation.

LO 1.6 Compare and contrast the academic training and experience necessary to obtain various exercise and nutrition certifications.

Proper nutrition supports training, performance, and recovery.

PRE-TEST

Assessing Current Knowledge of Sports Nutrition

Read the following statements, and decide if each is true or false.

1. An athlete's diet is a modification of the general nutrition guidelines made for healthy adults.
2. After a healthy diet plan is developed, an athlete can use it every day with little need for modification.
3. In the United States, dietary supplements are regulated in the same way as over-the-counter medications.
4. The scientific aspect of sports nutrition is developing very quickly, and quantum leaps are being made in knowledge of sports nutrition.
5. To legally use the title of sports nutritionist in the United States, a person must have a bachelor's degree in nutrition.

Welcome to the exciting world of sports nutrition. This relatively new field is a blend of nutrition and exercise physiology. These fields are complementary academic disciplines that help us understand the energy expenditure that is required by exercise and sport, as well as the energy and nutrient intake that is vital to support excellent **training, recovery**, and performance. Exercise and sport challenge the human body to respond and adapt, and proper nutrition supports these processes. Training and nutrition are keys to athletic performance at any level. The Olympic motto is *Citius, Altius, Fortius*, which is Latin for "swifter, higher, stronger." To achieve the highest level of success, athletes must be genetically endowed, and they must train optimally to meet their genetic potential. Proper nutrition supports the demands of training, and the field of sports nutrition emerged to help athletes train, perform, and recover to the best of their abilities. To run faster, jump higher, and be stronger, athletes must use genetics, training, and nutrition to their advantage.

1.1 Training, Nutrition, and the Athlete

LO 1.1 Explain the need for an integrated training and nutrition plan.

Sports nutrition is a blend of exercise physiology and nutrition

Exercise physiology is the science of the response and adaptation of bodily systems to the challenges imposed by movement—physical activity, exercise, and sport. Nutrition is the science of the ingestion, digestion, absorption, metabolism, and biochemical functions of nutrients. **Sports nutrition** is the integration and application of scientifically based nutrition and exercise physiology principles that support and enhance training, performance, and recovery. These principles also help athletes attain and maintain good health.

First and foremost, these disciplines are based on sound scientific evidence. But there is also an art to applying scientific principles to humans. For example, scientists identify nutrients found in food that are needed by the body, but food is sometimes eaten just because it tastes delicious or smells good. Exercise physiologists know from well-controlled research studies that the size and strength of athletes' muscles can be increased with overload training, but choosing the appropriate exercises, the number of sets and repetitions, the amount of resistance, the rest intervals, and the exercise frequency for optimal response by each individual athlete is as much an art as it is a science. Because sports nutrition is a relatively young field, the knowledge base is continually expanding, and our understanding of the field is constantly evolving. There is more research to be done and much more to be learned, presenting an exciting opportunity for exercise science– and nutrition-oriented students.

The term *athlete* is very broad and inclusive

The word *athlete* describes a person who participates in a sport. Using that definition, professional, collegiate, and weekend basketball players are all athletes (Figure 1.1). Clearly there are differences among them. One difference is skill, and another is training. Elite athletes are exceptionally skilled and dedicated to their training regimens. Their lives are planned around their training and competition schedules because athletic competition is their profession.

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FIGURE 1.1 Anyone who participates in a sport can be called an athlete. As a means of distinction, the terms *elite athlete, well-trained athlete,* and *recreational athlete* are often used.

Collegiate athletes are also trained athletes, although the level of their training is probably less than that of their professional counterparts. Dedication to training is important because proper training is necessary to improve or maintain performance. Many people are recreational athletes. Some of them are former competitive athletes who continue to train, albeit at a lower level, to remain competitive within their age group or in masters events. They are sometimes referred to as performance-focused recreational athletes. However, many recreational athletes train little, if at all, and their primary focus is not improving performance. They participate in sports to be physically active, to maintain a healthy lifestyle, and for enjoyment.

Physical activity, exercise, and sport differ from each other

Physical activity is bodily movement that results in an increase in **energy** expenditure above resting levels. Examples can include activities of daily living such as bathing, walking the dog, raking leaves, or carrying bags of groceries. Exercise and sport are very specific types of physical activity. Exercise has been defined as "physical activity that is planned, structured, repetitive, and purposive in the sense that improvement or maintenance of one or more components of physical fitness is the key" (Caspersen, Powell, and Christensen, 1985). For example, running is a specific type of physical activity that is often done regularly by people who hope to improve their **cardiovascular fitness**. Sports can be thought of as competitive physical activities. Track, cross country, or road running (for example, marathon) are examples of running as a sport.

Exercise may be described as **aerobic** or **anaerobic.** Aerobic means "with oxygen" and is used in reference to exercise or activity that primarily uses the oxygen-dependent energy system—oxidative phosphorylation (Chapter 3). These types of activities can be sustained for a prolonged period of time and are referred to as endurance activities. Those who engage in them are referred to as endurance athletes. Some endurance athletes are better described as ultraendurance athletes because they engage in sports that require hours and hours of continuous activity, such as triathlons. Endurance and ultraendurance athletes are concerned about the same issues, such as adequate carbohydrate and fluid intake, but there are enough differences between them that their concerns are often addressed separately.

Training: A planned program of exercise with the goal of improving or maintaining athletic performance.

Sports nutrition: The application of nutrition and exercise physiology principles to support and enhance training, performance, and recovery.

Recovery: An undefined period of time after exercise for rest, replenishment, and adaptation.

Energy: The capacity to do work. In the context of dietary intake, energy is defined as the caloric content of a food or beverage.

Cardiovascular fitness: Ability to perform endurance-type activities, determined by the heart's ability to provide a sufficient amount of oxygen-laden blood to exercising muscles and the ability of those muscles to take up and use the oxygen.

Aerobic: "With oxygen." Refers to exercise that primarily uses the oxygen-dependent energy system, oxidative phosphorylation.

Anaerobic: "Without oxygen." Refers to exercise that primarily uses one or both of the energy systems that are not dependent on oxygen, creatine phosphate or anaerobic glycolysis.

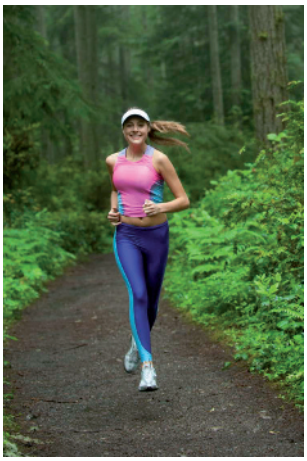

FIGURE 1.2 Although each participates in the same sport, the training and nutritional needs of recreational and elite athletes are very different.

Anaerobic means "without oxygen" and refers to exercise that primarily uses one or both of the energy systems that are not dependent on oxygen—creatine phosphate or anaerobic glycolysis (Chapter 3). These types of activities are short in duration and high in exercise **intensity**. Athletes in high-intensity, short-duration sports are often called strength athletes or strength/power athletes. Although few sports are solely anaerobic, and weight lifting to strengthen muscles is usually a part of an endurance athlete's training, *strength athlete* and *endurance athlete* are terms that are commonly used.

Training and nutrition go hand in hand

The longtime columnist, book author, and running philosopher George Sheehan (1980) once wrote that "everyone is an athlete; only some of us are not in training." Athletes improve their sports performance through skill development and training. Skill development is enhanced through practice and instruction or coaching. Success in many sports is directly related to fitness levels achieved by sport-specific training. For example, to be successful, competitive distance runners must have a high level of cardiovascular fitness, which is developed through following a rigorous running training program.

As advances in exercise and sports science have become more widely recognized and adopted, athletes from a wide variety of sports have begun to use improved physical conditioning as a way to further improve their performance. Even athletes in sports such as golf and auto racing incorporate physical training as a strategy to improve personal sport performance. Physical training to improve specific components of fitness must be taken into account when considering nutritional needs, such as total energy and carbohydrate intakes. Nutrition supports training and good health—two factors that are essential to excellent performance.

Although nutrition by itself is important, it may have the greatest performance impact by allowing athletes to train consistently. Proper nutrition during the recovery period is essential for replenishing nutrient stores depleted during training, for example, muscle **glycogen**. Inadequate replenishment of energy, fluid, carbohydrates, proteins, and/or vitamins and minerals limits the potential for full recovery after training. Limited recovery can result in **fatigue** during the next training session, and consistent lack of nutritional replenishment can lead to **chronic** fatigue (Thomas, Erdman, and Burke, 2016). Although the basic nutrition principles are the same for well-trained and recreational athletes, the specific nutrient needs will depend on the intensity and duration of training (Figure 1.2).

Athletes perceive that nutrition is important, but they sometimes fail to realize or acknowledge that it is a factor that needs daily attention. This often leads to **crash diets** and other quick fixes, which may interfere with training and undermine performance and recovery. Nutrition and training are similar in that each is a process that needs a well-developed plan (Dunford and Macedonio, 2017).

Athletes can also get so focused on one small aspect of their diet that they neglect their comprehensive daily nutrition requirements. For example, athletes may concentrate on the best precompetition meal, but if they fail to address their day-to-day nutrition needs, then their training will suffer. Inadequate training that is a result of inadequate nutrient replenishment is much more detrimental to performance than the precompetition meal is beneficial to performance (Thomas, Erdman, and Burke, 2016).

Nutrition supports training, recovery, and performance

The main goal for any competitive athlete is to improve performance. Improvements in sport performance can

come as a result of many factors: skill enhancement, psychological changes, specialized equipment and clothing, or physiological improvements due to training. All aspects of training should support this primary goal of improving performance. However, in the quest for excellent performance, the importance of good health should not be disregarded or overlooked. General training goals are as follows:

- Improving performance
- Improving specific components of fitness
- Avoiding injury and overtraining
- Achieving top performance for selected events (that is, peaking)

To support training and improve performance, athletes need to establish both long-and short-term nutrition goals. Some of these goals are listed here (Thomas, Erdman, and Burke, 2016).

Long-term sports nutrition goals:

- Adequate energy intake to meet the energy demands of training and performance
- Adequate replenishment of muscle and liver glycogen with dietary carbohydrates
- Adequate protein intake for growth and repair of tissue, particularly skeletal muscle
- Adequate hydration, along with electrolyte balance
- Adequate overall diet, including all necessary vitamins and minerals, to maintain good health and support a healthy immune system
- Appropriate weight and body composition

Short-term sports nutrition goals:

- Consumption of food and beverages to delay fatigue during training and competition
- Minimization of dehydration and **hypohydration** during exercise
- Utilization of dietary strategies known to be beneficial for performance, such as precompetition meal, appropriately timed caffeine intake, or carbohydrate loading
- Intake of nutrients that support recovery from exercise and injuries
- Appropriate timing of nutrient intake

It is important to understand basic training principles

As the athlete trains, the body responds to the individual exercise sessions and gradually adapts over time. The nature and degree of the adaptations depend on the type of training the athlete does. The basic principles explained next are derived from the results of many research studies.

The principle of progressive overload. Adaptation occurs as a result of a stimulus that stresses the body. The stimulus must be of sufficient magnitude to cause enough stress to warrant longer-term changes by the body. Stimulus of this magnitude is called **overload** (Figure 1.3). If exposed to an overload stimulus repeatedly, the body will adapt over time to that level of stimulus. For further adaptation to occur, the overload stimulus must be progressively increased.

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FIGURE 1.3 An overload stimulus, such as an arm curl with weights, is required for the biceps muscles to get stronger.

For example, in order for the biceps muscles to get stronger, an athlete must perform a weight-lifting exercise such as an arm curl. The muscles will not get stronger curling the weight of a pencil; rather, the weight must be heavy enough to achieve overload. After the muscles have adapted to that weight, they will not get any stronger until the overload stimulus is progressively increased (that is, the weight is increased further).

The principle of individuality. Although general training principles apply to all people, individuals may respond and adapt slightly differently, even when exposed to the same training stimulus. Two similar athletes who follow the same strength-training program will both improve their strength, but it is likely that the amount

Intensity: The absolute or relative difficulty of physical activity or exercise.

Glycogen: Storage form of glucose in the liver and muscle.

Fatigue: Decreased capacity to do mental or physical work.

Chronic: Lasts for a long period of time. Opposite of acute.

Crash diet: Severe restriction of food intake in an attempt to lose large amounts of body fat rapidly.

Hypohydration: An insufficient amount of water; below the normal state of hydration.

Overload: An exercise stimulus that is of sufficient magnitude to cause enough stress to warrant long-term changes by the body.

and rate of change in strength will be slightly different. People do not respond in precisely the same way or time frame, so individual differences must be taken into account when considering an athlete's training program.

The principle of specificity. The type of physiological responses and eventual adaptations will be specific to the type of stimulus and stress imposed on the body. In the most general sense, aerobic exercise will result primarily in cardiovascular adaptations, and resistance training will result in neuromuscular adaptations. Adaptations can be more subtle and specific, for example, the effect intensity and duration of aerobic exercise may have on changes in energy system pathways such as carbohydrate and fat metabolism (Chapters 4 and 6).

The principle of hard/easy. The stimulus part of training receives the most attention, but often neglected are the rest and recovery that are required for the adaptation to occur. Training programs are usually designed so that hard physical efforts are followed by training sessions with less physical stress to allow for the rest necessary for optimal adaptation.

The principle of periodization. Adhering to the principle of **specificity**, training programs are also often arranged in time periods according to the specific adaptation that is sought. For example, competitive long distance runners may spend a portion of their yearly training time concentrating on running longer distances to improve their maximal aerobic capacity and endurance and another portion of their training time on running shorter distances at higher intensity to improve their speed. Within this principle of **periodization**, training programs are generally arranged according to different time periods:

Macrocycle: A macrocycle is an overall time period that begins at the onset of training and includes the time leading up to a specific athletic goal, such as an important competition. For an athlete seeking to peak at the annual national championship, the macrocycle may be a calendar year. A macrocycle may be longer (for example, 4 years for an athlete concentrating on the Olympics) or shorter (for example, 6 months for a distance runner training for a springtime marathon), depending on the specific competitive goals of the athlete.

Mesocycle: A macrocycle is subdivided into time frames called mesocycles, each having a specific training purpose. As with the macrocycle, the mesocycles may be of varying lengths of time, depending on the athlete's goals, but typically they are weeks or months in duration. The competitive distance runner may have a mesocycle focused on improving aerobic capacity and endurance and another mesocycle focused on improving speed.

Microcycle: Each mesocycle is made up of repeated time intervals called microcycles. Microcycles are often designed to coincide with the weekly calendar, but they can vary from the standard 7-day week, depending on the athlete's specific needs. Weekly training mileage for the competitive distance runner is an example of a microcycle.

The principle of disuse. Just as the body adapts positively in response to training stress, it can adapt negatively, or **atrophy**, if stress is insufficient or absent. Gradual erosion of physiological capacity over time is often observed in individuals as a result of sedentary lifestyles. Athletes who have improved function through training can experience the loss of function, either intentionally for short periods (for example, resting during the "off-season") or unintentionally due to forced inactivity from injury. This is the physiological equivalent of the aphorism, "Use it, or lose it."

In addition to a training plan, an athlete needs a nutrition plan

Training periodization involves changing the intensity, **volume**, and specificity of training for each individual athlete to achieve specific goals. It is imperative that a parallel nutrition plan be developed to support the various training cycles (Figure 1.4). The periodized nutrition plan should match the training plan and fully consider each athlete's individual dietary needs. If the training macrocycle is 1 year, then the athlete should also have an annual nutrition plan. Each mesocycle will have specific nutrition goals as well. For example, weight loss by an endurance athlete is usually planned to take place during a recovery period ("off-season") and early in the preparation period so a restricted-calorie diet can be avoided during high-volume training periods or during the competitive season. During each microcycle, refinements are made to dietary intake.

FIGURE 1.4 A registered dietitian can help an athlete develop a diet plan that is well matched to the demands of training.

	Prior to season					Pre-season			Racing season		Off-season	
	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Training goals:	Training volume increasing; emphasis on aerobic base training with some speed/anaerobic training		Training volume high; maintain aerobic base training and increase high-intensity/speed/anaerobic training			Training volume decreased to emphasize speed/anaerobic training			Training volume decreased to emphasize speed training and tapering for competitive races		No formal training; physical activity and exercise for recreation	
Body composition goals:	Reduce 5 lb body fat		Increase skeletal muscle mass by 3 to 5 lb			Maintain the increased skeletal muscle mass			Maintain body composition		3 to 5 lb loss of skeletal muscle mass and 5 lb increase in body fat are acceptable to this athlete	
Energy (caloric) intake:	Decrease energy intake from food and increase energy expenditure from training for a slow loss of body fat over 2 months		Increase caloric intake to support muscle growth and an increase in training volume			Caloric intake should equal caloric expenditure so body composition can be maintained					If caloric intake is not reduced, body fat will increase	
Nutrient intake:	Adequate carbohydrate and fluid to support a return to training. Compared to the off-season diet, current diet has fewer high-fat, high-sugar foods and more water, fruits, vegetables, and whole grains.		Compared to the past 2 months, diet has a slight increase in carbohydrate and protein intakes			For sufficient glycogen stores, a high-carbohydrate diet is recommended. Diet is generally high carbohydrate, moderate protein, and moderate/low fat. In the pre-season, diet plan is fine-tuned to make sure it is realistic (especially on travel days/away meets) and well tolerated.					A nutritious diet that meets the Dietary Guidelines is recommended.	

FIGURE 1.5 A training and nutrition periodization plan for a male 800 m runner.

Figure 1.5 illustrates the concept of having a nutrition plan that matches the demands imposed by various training periods. In this example of a male collegiate 800 meter (m) runner, the plan covers a year (that is, the macrocycle), starting in September, when school begins, through the following August. The training and nutrition goals of each mesocycle vary. During the early months of the preparation period (September through October), the primary focus is on aerobic training. This athlete also wants to decrease 5 pounds of body fat that has been gained during the summer. Energy (calorie) and carbohydrate intakes must be sufficient to support training and recovery, but energy intake must be reduced from baseline so that some of the energy needed is provided from stored fat. The second part of the preparation period (November through January) focuses on maintaining aerobic fitness, increasing strength and power, and technique. This athlete also wants to increase muscle mass by 3 to 5 pounds. The volume of training is increased and is equally divided between aerobic (for example, running) and anaerobic (for example, high-repetition lifting and **plyometric** exercise) activities. Proper energy, carbohydrate, protein, and fat intakes are needed to support his training, recovery, and body composition goals.

During the precompetition period (February through April), most of the training takes place on the track. Training is approximately 40 percent anaerobic and 60 percent aerobic. Weight lifting is decreased because the goal is maintenance of gained muscle rather than a continued increase in muscle mass. There is an

Specificity: A training principle that stresses muscles in a manner similar to which they are to perform.

Periodization: Dividing a block of time into distinct periods. When applied to athletics, the creation of time periods with distinct training goals and a nutrition plan to support the training necessary to meet those goals.

Atrophy: A wasting or decrease in organ or tissue size.

Volume: An amount; when applied to exercise training, a term referring to the amount of exercise usually determined by the frequency and duration of activity.

Plyometric: A specialized type of athletic training that involves powerful, explosive movements. These movements are preceded by rapid stretching of the muscles or muscle groups that are used in the subsequent movement.

emphasis on plyometric training and an alternating schedule—Monday and Wednesday feature hard workouts whereas Tuesday and Thursday involve easy recovery runs as the athlete prepares for competition on Saturday. During the competitive season (May through mid-June), more emphasis is placed on anaerobic training (~75 percent) and less on aerobic training (~25 percent). Almost all of the training is on the track, and the athlete does no weight lifting. Friday is a rest and travel day in preparation for racing on Saturday. A new period begins after the competitive season ends and the school year is complete. For about 3 weeks (mid-June to early July), the athlete does no training in an effort to recuperate mentally and physically from the rigorous months of training and competition. Through most of July and August, the focus is on moderate-duration, low-intensity running. Energy expenditure over the summer is the lowest of the entire year, and this runner will need to reduce food intake to match reduced expenditure to prevent excessive weight gain as body fat. If he does not, he will likely gain unwanted weight and body fat.

Some athletes create elaborate nutrition plans. The plan can be as simple or detailed as the athlete feels is necessary, but the fundamental issues are the same: For optimal training, performance, and recovery, proper nutrition intake is important, changes in weight or body composition need to be appropriately timed, and good health should not be overlooked.

KEY POINTS

- Sports nutrition requires an understanding of the physiological challenges of training and competition and the scientific and applied principles of nutrition.
- The physical demands of activity, exercise, and sport can vary dramatically between athletes and for individual athletes over a given time period.
- Training and nutrition go hand in hand.
- An organized training plan that takes into account specific goals and incorporates basic principles of training is critical for excellent performance.
- Athletes need a nutrition plan that complements the physical demands of training and performance and supports good health.

What would be some specific training goals of a collegiate-level soccer player?

Fiber: A component of food that resists digestion (for example, pectin, cellulose).

Electrolyte: A substance in solution that conducts an electrical current (for example, sodium, potassium).

Dietary Reference Intakes: Standard for essential nutrients and other components of food needed by a healthy individual.

1.2 Basic Nutrition Standards and Guidelines

LO 1.2 Explain basic nutrition principles and how they might be modified to meet the needs of athletes.

Sports nutrition principles are based on sound general nutrition principles that have been modified to reflect the demands of training, recovery, and competition. General guidelines help all people, including athletes, to achieve optimal nutritional health over a lifetime. While the following guidelines are a starting point for athletes, consultation with a sports dietitian is also recommended as these professionals are trained in thorough nutrition assessments to determine if an athlete's diet is adequate. An optimal diet is one in which there are neither deficiencies nor excesses.

The early focus of nutrition research was on the amount and type of nutrients needed to prevent deficiencies. After nutrient deficiency diseases were well understood, the research focus changed to the amount and type of nutrients that help prevent chronic diseases. A chronic disease is one that progresses slowly, such as heart disease or osteoporosis (that is, loss of bone mineral density). These diseases are a reflection of long-term, not short-term, nutrient intake. Keeping in mind the need to prevent nutrient deficiencies as well as nutrient excesses, guidelines have been established for energy (calories), carbohydrates, proteins, and fats, **fiber**, vitamins, minerals, **electrolytes** (for example, sodium or potassium), and water. These guidelines are known as the **Dietary Reference Intakes (DRI)** (Institute of Medicine, 1997, 1998, 2000, 2001, 2003, 2005a, 2005b, 2011; National Academies of Sciences, 2019).

The Dietary Reference Intakes (DRI) is a standard used to assess nutrient intake

The DRI is a standard used to assess and plan diets for healthy individuals and groups (Institute of Medicine, 2006). The DRI is a general term that includes four types of reference values—Recommended Dietary Allowances (RDA), Adequate Intake (AI), Estimated Average Requirement (EAR), and Tolerable Upper Intake Level (UL). These terms are defined in Figure 1.6.

The DRI values are based on the RDA whenever possible. When an RDA cannot be determined, the AI becomes the reference value for the DRI. The AI is not as scientifically strong because it is based on estimates or approximations derived from scientific research. The DRI and the reference value used for each vitamin and mineral are found on the inside gatefold of this textbook. Values for other nutrients are found in Appendix A.

Dietary Reference Intakes (DRI) Definitions

The Dietary Reference Intakes (DRI) is a standard used to assess and plan diets. This standard is made up of the four reference values shown below.

Recommended Dietary Allowance (RDA): the average daily dietary intake that is sufficient to meet the nutrient requirement of nearly all (97 to 98%) healthy individuals in a particular group according to stage of life and gender.

Adequate Intake (AI): a recommended intake value based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of healthy people, that are assumed to be adequate; AI is used when an RDA cannot be determined.

Estimated Average Requirement (EAR): a daily nutrient intake value that is estimated to meet the requirements of half of the healthy individuals in a group according to life stage and gender—used to assess dietary adequacy and as the basis for the RDA.

Tolerable Upper Intake Level (UL): the highest daily nutrient intake that is likely to pose no risk of adverse health effects for almost all individuals in the general population. As the intake increases above the UL, the potential risk of adverse effects increases.

Regarding vitamin and mineral intake, the EAR is used only when planning diets for groups. For individual diet planning, the RDA or the AI is used to guard against inadequate vitamin and mineral intakes and the UL is used to guard against excess intakes.

Source: Reprinted with permission from Institute of Medicine. (2003). *Dietary Reference Intakes: Applications in Dietary Planning* (Food and Nutrition Board). Washington, DC: National Academies Press.

FIGURE 1.6 The DRI reference values defined

SPOTLIGHT ON...

The Physical Activity Guidelines for Americans

In 2008, the U.S. Department of Health and Human Services published the first-ever Physical Activity Guidelines for Americans, a series of recommendations for individual physical activity that complements the Dietary Guidelines for Americans. Being physically active and consuming a healthy diet promote good health and reduce the risk of various chronic diseases, such as cardiovascular disease and certain types of cancer (Piercy et al., 2018). These two documents provide science-based nutrition and physical activity guidance that can help people obtain long-term health benefits.

The Physical Activity Guidelines for Americans were updated in 2018 and include the following key guidelines (https://health.gov/paguidelines):

Key Guidelines for Children and Adolescents

- Children and adolescents ages 6 through 17 years should do 60 minutes (1 hour) or more of moderate-to-vigorous physical activity daily.
- Aerobic: Most of the 60 minutes or more per day should be either moderate- or vigorous-intensity aerobic physical activity, and should include vigorous-intensity physical activity on at least 3 days a week.
- Muscle-strengthening: As part of their 60 minutes or more of daily physical activity, children and adolescents should include muscle-strengthening physical activity on at least 3 days a week.
- Bone-strengthening: As part of their 60 minutes or more of daily physical activity, children and adolescents should include bone-strengthening physical activity on at least 3 days a week.
- It is important to provide young people opportunities and encouragement to participate in physical activities that are appropriate for their age, that are enjoyable, and that offer variety.

Key Guidelines for Adults

- Adults should move more and sit less throughout the day. Some physical activity is better than none. Adults who sit less and do any amount of moderate-to-vigorous physical activity gain some health benefits.
- For substantial health benefits, adults should do at least 150 minutes (2 hours and 30 minutes) to 300 minutes (5 hours) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) to 150 minutes (2 hours and 30 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Preferably, aerobic activity should be spread throughout the week.
- Additional health benefits are gained by engaging in physical activity beyond the equivalent of 300 minutes (5 hours) of moderate-intensity physical activity a week.
- Adults should also do muscle-strengthening activities of moderate or greater intensity and that involve all major muscle groups on 2 or more days a week, as these activities provide additional health benefits.

Additional guidelines are provided for preschool-aged children, older adults, women during pregnancy or postpartum, and adults with chronic health conditions or disabilities. See https://health.gov/paguidelines/.

Source: Piercy, K. L., Troiano, R. P., Ballard, R. M., Carlson, S. A., Fulton, J. E., Galuska, D. A., George, S. M., and Olson, R. D. (2018). The Physical Activity Guidelines for Americans. *JAMA.* 320 (19), 2020–2028. doi:10.1001/jama.2018.14854