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Nutrition for Sport & Exercise

Fifth Edition

Nutrition

for Sport and Exercise

FIFTH EDITION

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***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 $\dot{V}O_2$max

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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JAD: I would like to thank Marie Dunford for inviting me along on this wonderful, crazy journey. I particularly appreciate her friendship and her patience, persistence, discipline, and good humor throughout the writing process. My wife, Colleen, my sons, Patrick and Jackson, and my sister, Liz Doyle, have always been supportive of my education and my career, and I would like to thank them for their love and support. They have been very patient and supportive when this project has demanded a lot of my time and attention. Thank you to Colleen also for reviewing Chapter 13 from the perspective of her outstanding public health career in nutrition and physical activity. Many thanks are due also to the students who have been an integral part of my courses and research over the years. Their curiosity, questions, and comments have inspired me to continue to grow and develop as a teacher. Finally, I would like to thank the faculty and staff of the Department of Kinesiology and Health at Georgia State University for their support.

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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.

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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.

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.

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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

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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.

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.

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.

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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

Athletes in training may wonder how the DRI values apply to them because they were developed for the general population. Because the goal of the DRI is to guard against both nutrient inadequacies and excesses, athletes use the DRI to assess the adequacy of their current diets and to plan nutritious diets. For example, the DRI is used to evaluate an athlete's vitamin intake even though there is some evidence that moderate to strenuous exercise may increase the need for some vitamins (Chapter 8). The reason is that the DRI has a built-in margin of safety that likely exceeds the increased need associated with exercise.

On the other hand, some of the DRI, such as the estimated energy requirement or the need for water and sodium intake, may not be appropriate to use with athletes in training because athletes' energy, fluid, and electrolyte needs may be far greater than those of the general population. In such cases, other standards and guidelines more appropriate for athletes are used.

The Dietary Guidelines for Americans provide basic dietary and exercise advice

The Dietary Guidelines for Americans are published every 5 years by the U.S. Department of Health and Human Services and the U.S. Department of Agriculture (2020). The purpose of the Dietary Guidelines is to provide dietary and exercise advice to Americans over the age of 2 that will promote health and reduce the risk for chronic diseases. The Dietary Guidelines help Americans choose a healthy eating pattern and enjoyable diet. The key recommendations are listed in Figure 1.7, and dietary patterns that reflect these recommendations are found in Appendixes B and C.

Even though they were developed for the general population, most of the recommendations in the Dietary Guidelines apply to athletes, such as consuming foods that are **nutrient dense**; eating fiber-rich fruits, vegetables, and whole grains to meet carbohydrate

The Dietary Guidelines Recommendations Encompass Four Overarching Goals:

- Follow a healthy dietary pattern at every life stage.
- Customize and enjoy nutrient-dense food and beverage choices to reflect personal preferences, cultural traditions, and budgetary considerations.
- Focus on meeting food group needs with nutrient-dense foods and beverages, and stay within calorie limits.
- Limit foods and beverages higher in added sugars, saturated fat, and sodium, and limit alcoholic beverages.

Key Dietary Principles (See full document at: DietaryGuidelines.gov)

- Meet nutritional needs primarily from foods and beverages
- Choose a variety of options from each food group
- Pay attention to portion size

The core elements that make up a healthy dietary pattern include:

- Vegetables of all types—dark green; red and orange; beans, peas, and lentils; starchy; and other vegetables
- Fruits, especially whole fruit
- Grains, at least half of which are whole grain
- Dairy, including fat-free or low-fat milk, yogurt, and cheese, and/or lactose-free versions and fortified soy beverages and yogurt as alternatives
- Protein foods, including lean meats, poultry, and eggs; seafood; beans, peas, and lentils; and nuts, seeds, and soy products
- Oils, including vegetable oils and oils in food, such as seafood and nuts

A healthy eating pattern limits:

- Added sugars—Less than 10 percent of calories per day starting at age 2. Avoid foods and beverages with added sugars for those younger than age 2.
- Saturated fat—Less than 10 percent of calories per day starting at age 2.
- Sodium—Less than 2,300 milligrams per day—and even less for children younger than age 14.
- Alcoholic beverages—Adults of legal drinking age can choose not to drink, or to drink in moderation by limiting intake to 2 drinks or less in a day for men and 1 drink or less in a day for women, when alcohol is consumed. Drinking less is better for health than drinking more. There are some adults who should not drink alcohol, such as women who are pregnant.

FIGURE 1.7 2020–2025 Dietary Guidelines for Americans

Source: U.S. Department of Agriculture and U.S. Department of Health and Human Services. (2020). *Dietary Guidelines for Americans*, 2020–2025. 9th ed. Available at: DietaryGuidelines.gov

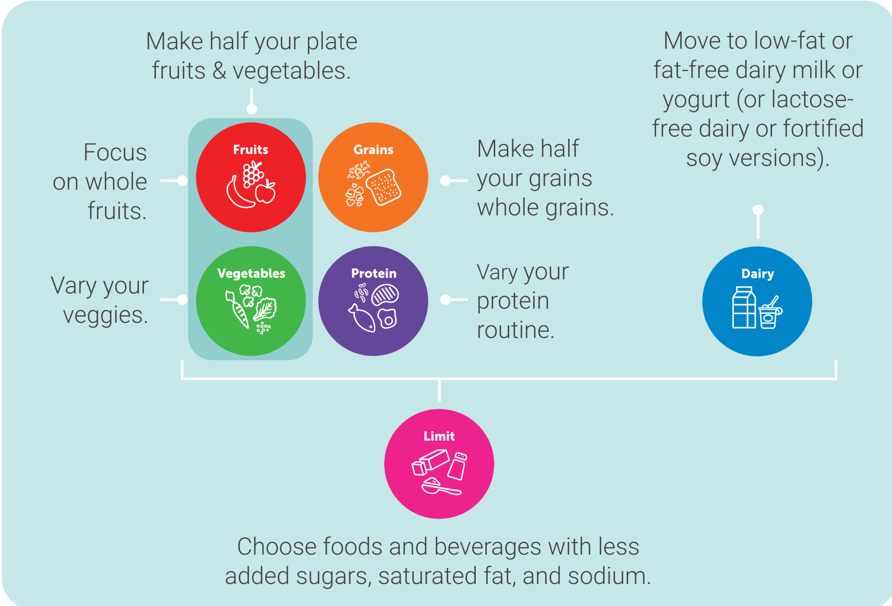
Try the MyPlate Plan

A healthy eating routine is important at every stage of life and can have positive effects that add up over time. It's important to eat a variety of fruits, vegetables, grains, dairy or fortified soy alternatives, and protein foods. When deciding what to eat or drink, choose options that are full of nutrients. Make every bite count.

Think about how the following recommendations can come together over the course of your day or week to help you create a healthy eating routine:

To learn what the right amounts are for you, try the personalized **MyPlate Plan**.[2]

Based on decades of solid science, MyPlate advice can help you day to day and over time.



The benefits of healthy eating add up over time, bite by bite. Small changes matter. **Start Simple with MyPlate**.

DGA Dietary Guidelines for Americans   Start simple with MyPlate

[2] Available at: **MyPlate.gov/myplate-plan**

FIGURE 1.8 MyPlate is a tool that can be used to create a healthy diet.

Source: U.S. Department of Agriculture and U.S. Department of Health and Human Services. *Dietary Guidelines for Americans,* 2020–2025. 9th Edition. December 2020

needs; and focusing on a pattern of eating healthy foods and beverages. But some of the recommendations may not apply. For example, for those athletes who lose large amounts of sodium in sweat, limiting sodium intake to 2,300 milligrams (mg) daily may be detrimental. Athletes engaged in regular training will usually easily meet and exceed the physical activity recommendations contained in the Dietary Guidelines. However, some athletes concentrating on sports involving very specific components of fitness (for example, muscular strength for weight lifting or bodybuilding) may need to be conscious of including other components of fitness (for example, cardiovascular exercise) necessary for long-term health. The Dietary Guidelines are a good starting point for people who want to improve their health and fitness. The general nutrition principles can then be modified to fit the demands of training.

MyPlate is a tool that can be used to help consumers implement the Dietary Guidelines

The Dietary Guidelines are developed and written for a professional audience. MyPlate is a tool that helps consumers implement the recommendations found in the 2015–2020 Dietary Guidelines (Figure 1.8). The MyPlate.gov website provides comprehensive nutrition information to help you translate the Dietary Guidelines into healthy meals. Consumers are encouraged to start with small changes.

Nutrient dense: A food containing a relatively high amount of nutrients compared to its caloric content.

The simple MyPlate graphic is intended to communicate the basics of a healthy diet. The plate is divided into four parts—fruits, vegetables, grains, and proteins. A smaller circle in the upper-right corner represents dairy foods. These groups form the basis of a healthy diet. The website provides extensive information about each food group and suggests how many servings from each group are needed based on the caloric content of the diet.

In addition to the basic foods groups shown in MyPlate, information is included that reflects the 2020–2025 Dietary Guidelines. Important points include the following:

- Make half your plate fruits and vegetables.
- Focus on whole fruits.
- Make half your grains whole grains.
- Move to low-fat or fat-free dairy milk or yogurt (or lactose-free dairy or fortified soy versions).
- Vary your veggies.
- Vary your protein routine.
- Choose foods and beverages with less added sugars, saturated fat, and sodium.

A food pyramid has been developed for athletes

The Swiss Forum for Sport Nutrition has developed a Food Pyramid for Athletes (Figure 1.9). The purpose of the pyramid is to help athletes translate scientific recommendations, which are frequently made in grams per kilogram (g/kg) of body weight, into the amounts and kinds of foods that meet those recommendations. This pyramid has been scientifically validated for athletes 20–35 years old, weighing 50–85 kg (110–187 pounds [lb]), who train 5–28 hours per week.

The guidelines for the Basic Food Pyramid are listed on the left-hand side of the graphic. These foods make up a lifelong healthy diet. Additional servings are recommended for those in training based on the number of hours of moderate-intensity exercise per day. Each column under the Sports heading represents 1 hour. In general, each hour of exercise requires additional fluids, whole grains and legumes, and oils and nuts. When added to an already healthy diet, these foods provide the additional energy and nutrients that an athlete in training needs. Serving sizes are given as a range, with the smaller portions being appropriate for lower weight athletes (Mettler, Mannhart, and Colombani, 2009).

Macronutrient: Nutrient needed in relatively large amounts. The term includes energy, carbohydrates, proteins, fats, cholesterol, and fiber but frequently refers to carbohydrates, proteins, and fats.

Micronutrient: Nutrient needed in relatively small amounts. The term is frequently applied to all vitamins and minerals.

Several other meal-planning tools are also available

Another diet-planning tool is the Food Lists system, formerly referred to as the exchange lists. This system categorizes foods based on their carbohydrate, protein, and fat contents (American Diabetes Association and Academy of Nutrition and Dietetics, 2019). There are three main groups—carbohydrate, protein, and fat—with the carbohydrate and protein groups containing several subgroups and the fat group containing two subgroups. The foods on each list can be chosen or "exchanged" in place of another food on the same list because each has approximately the same **macronutrient** content for the portion size listed. For example, one small banana (~4 ounces [oz]) has approximately 15 g of carbohydrates and 60 kilocalories (kcal), about the same as one small orange.

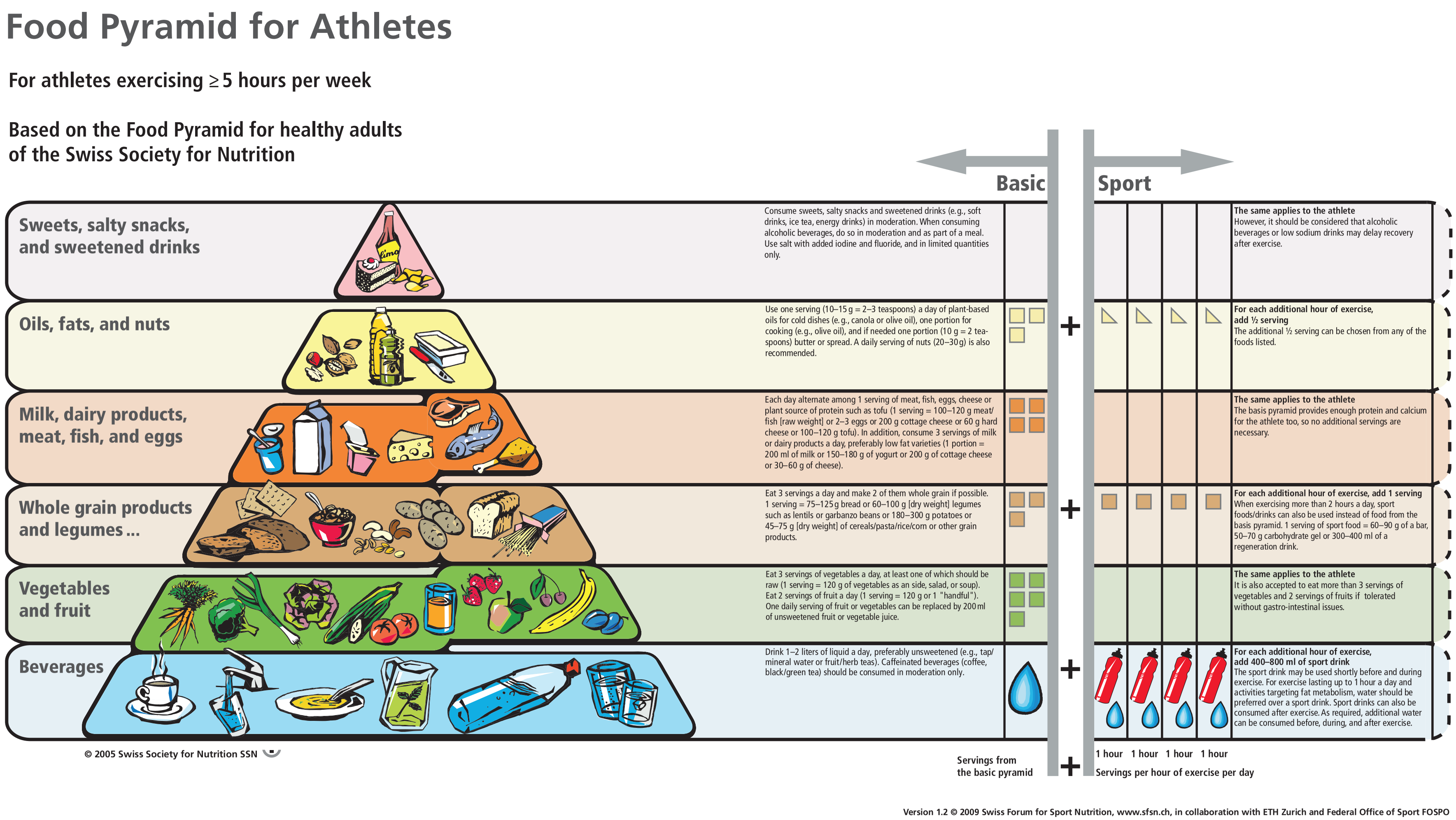
However, foods are broadly categorized according to macronutrient content and there can be substantial **micronutrient** (that is, vitamin and mineral) differences between foods on the same list. For example, an orange is an excellent source of vitamin C (~70 mg), whereas a banana has little (~10 mg). Similarly, whole wheat and white bread contain equivalent amounts of carbohydrates, proteins, and fats. However, whole wheat bread is a nutritionally superior food to white bread because of the fiber and trace mineral contents. Additionally, each food listed does not have the same portion size. On the fat list, the portion size for avocado is 2 tablespoons whereas the portion size for oil is considerably smaller at 1 teaspoon. More information can be found on the National Heart, Lung, and Blood Institute website (www.nhlbi.nih.gov).

Another method that some athletes use is carbohydrate counting. The amount of carbohydrates needed daily is determined and then distributed throughout the day in meals and snacks. Although carbohydrate intake is emphasized to ensure adequate muscle glycogen for training, it is part of a larger plan that considers daily energy (calorie), protein, fat, and alcohol intakes.

A meal-planning system is useful, especially when athletes are learning about the nutrient content of foods and beginning to plan a diet that supports training. Over time, athletes typically want more precise information about the nutrient content of food, and this leads to use of nutrient analysis software, such as the dietary analysis program that accompanies this textbook.

The Nutrition Facts label provides specific nutrition information

One of the best nutrition education tools available to consumers is the Nutrition Facts label, which was revised in May 2016. This label is required for most



The Food Pyramid for Athletes is based on the Food Pyramid designed and developed by the Swiss Society for Nutrition (Schweizerische Gesellschaft für Ernährung) for healthy adults, which will be referred to as the Basic Food Pyramid. This Basic Food Pyramid has been expanded to cover the energy and nutrient needs for daily exercise typically performed by athletes and active individuals.

The Food Pyramid for Athletes is aimed at healthy adults exercising on most days of the week for at least 1 hour or more per day at moderate intensity, totaling at least 5 hours of exercise per week.

Moderate intensity represents continuous activities such as swimming (2.5 km/h), running (8 km/h) or cycling (2 watts per kg body mass) or the "stop and go" of most intermittent and team sports such as an ice hockey match, a soccer game or tennis match. The Basic Food Pyramid reflects balance in food choice, and the same applies to the recommendations for athletes. Both pyramids ensure sufficient energy and nutrient supply for their target population. All foods are allowed, but it is important that a variety of foods are chosen from each section, that produce is chosen seasonally, and all foods are prepared and processed with care. The regular intake of vitamin and/or mineral-fortified foods and beverages or the use of dietary supplements may exceed the upper tolerable intake level for micronutrients.

Adherence to the Food Pyramid for Athletes offers a solid foundation for longterm, successful performance capability. In contrast to the Basic Food Pyramid, where the recommendations do not have to be followed strictly on a daily basis, it is suggested that athletes meet the guidelines consistently to ensure optimal regeneration and performance capability. The additional requirement to cover exercise training includes a volume of 1–4 hours of moderate intensity exercise per day. For high-intensity exercise and/or greater volumes, the energy and nutrient requirements will be higher. An experienced sports dietitian may help with adjusting food selection and serving size to individual needs.

Serving size selection: From the serving size range given in the pyramid, small athletes of about 50 kg body mass should choose the smallest serving size, whereas the largest serving size applies to athletes weighing about 85 kg. Intermediate serving sizes apply to athletes of corresponding intermediate body mass (for example medium serving size for 67.5 kg).

FIGURE 1.9 Food pyramid for athletes

© 2005 Swiss Society for Nutrition SSN

Nutrition Facts

8 servings per container

Serving size 2/3 cup (55g)

Amount per serving	
Calories	**230**
	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**13%**
Dietary Fiber 4g	**14%**
Total Sugars 12g	
Includes 10g Added Sugars	**20%**
Protein 3g	
Vitamin D 2mcg	10%
Calcium 260mg	20%
Iron 8mg	45%
Potassium 235mg	6%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

FIGURE 1.10 Nutrition facts label

Source: US Food and Drug Administration FDA

packaged foods. Figure 1.10 illustrates and explains the new label.

- Serving Size and servings per container. Serving size is based on the amount that people actually eat (not on what they should be eating). Some labels will have a second column indicating the calories and nutrients in the entire package.
- Calories per serving. The font size is large to highlight the amount of Calories.
- Nutrients. Nutrients that must be shown include total fat, saturated fat, *trans* fat, cholesterol, sodium, total carbohydrate, dietary fiber, total sugars, added sugars, protein, vitamin D, calcium, iron, and potassium.
- % Daily Value*. The % **Daily Value** (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. A diet of 2,000 Calories a day is used for general nutrition advice.

Application**EXERCISE**

SCENARIO: *Five years after graduation, a former collegiate tennis player decided to return to competitive play in a local league. Based on his skills, he is ranked 5.0, the highest recreational ranking. To his great disappointment, he has not been very competitive in this league. Although his tennis skills are well matched to his opponents', he realizes that his fitness has declined and that he consistently fades in the third set due to fatigue. One of his opponents commented that the same thing used to happen to him until he "bit the bullet and started to eat better."*

1. Analyze this athlete's 1-day dietary intake using the Food Pyramid for Athletes. Assume 2 hours of exercise and a 24-hour food intake as follows:
   Breakfast: 16 oz strong black coffee
   Lunch: Double cheeseburger, large fries, large soft drink (typical fast-food meal)
   Prematch snack: two bananas, 16 oz water
   Postmatch meal: four slices of a large pepperoni pizza, two 12 oz bottles of beer
2. What conclusions can be drawn about the nutritional adequacy of this diet?
3. If you were a registered dietitian, in what ways might you use the Food Pyramid for Athletes or other dietary analysis tool to help this athlete "bite the bullet" and start eating better?

KEY POINTS

- The Dietary Guidelines; MyPlate; Food Pyramid for Athletes; and the Nutrition Facts label are tools that can be used to develop a nutritionally sound diet plan for athletes.
- The Dietary Reference Intakes (DRI) is a standard used to assess and plan diets.

Are the various meal-planning tools substantially different from each other?

1.3 Basic Sports Nutrition Guidelines

LO 1.3 List sports nutrition goals.

Sports nutrition recommendations build on and refine basic nutrition guidelines. Athletes need to understand and apply general nutrition principles before making modifications to reflect their training and sport-specific nutrient demands. Ultimately, sports nutrition recommendations are fine-tuned and are as precise as possible to closely meet the unique demands of training, recovery, and competition in the athlete's sport and reflect the needs of the individual athlete. Here is a brief overview of some key sports nutrition recommendations (Thomas, Erdman, and Burke, 2016).

Energy: An adequate amount of energy is needed to support training, recovery, and performance and to maintain good health. Appropriate amounts of food should be consumed daily to avoid long-term energy deficits or excesses. Adjustments to energy intake for the purpose of weight or fat loss should be made slowly and started early enough in the training mesocycle (for example, off-season or well prior to the competitive season) so as not to interfere with training or performance.

Carbohydrates (CHO): An intake of 3 to 10 g of carbohydrates per kilogram of body weight per day (g/kg/d) is recommended. Up to 12 g/kg/d may be needed for ultraendurance activities. The daily amount needed depends on the sport, type of training, and need for carbohydrate loading. Timing is also important, and recommendations for carbohydrate intake before, during, and after exercise are made.

Proteins: An intake of 1.2 to 2.0 g of protein per kg of body weight per day is generally recommended. This recommendation assumes that energy intake is adequate. The daily amount of proteins needed depends on the sport, type of training, and the desire to increase or maintain skeletal muscle mass. Timing of protein intake is also important, and a recent recommendation is 0.3 g/kg/d after exercise and throughout the day. Postexercise protein ingestion aids in muscle protein resynthesis.

Fats: After determining carbohydrate and protein needs, the remainder of the energy intake is typically from fats, although adult athletes may include a small amount of alcohol. Fat intake should range from 20 to 35 percent of total calories. Diets containing less than 20 percent of total calories from fat do not benefit performance and can be detrimental to health.

Vitamins and minerals: Athletes should meet the DRI for all vitamins and minerals. The DRI can be met if energy intake is adequate and foods consumed are nutrient dense (that is, abundant nutrients in relation to caloric content). Any recommendation for vitamin or mineral supplementation should be based on an analysis of the athlete's usual diet.

Fluid: Athletes should balance fluid intake with fluid loss. A number of factors must be considered, including the sweat rate of the athlete and environmental conditions such as temperature, humidity, and altitude. A body water loss in excess of 2–3 percent of body mass can decrease performance and negatively affect health. Similarly, an intake of water that is far in excess of fluid lost (primarily through sweat) puts the athlete at risk for a potentially fatal condition, known as **hyponatremia**, due to low blood sodium.

Food and fluid intake prior to exercise: Many athletes consume a beverage, snack, or meal 1 to 4 hours prior to exercise to relieve hunger and to help with hydration. The volume of food and fluid depends to a large extent on the amount of time before exercise and the athlete's gastrointestinal tolerance. In general, a meal or snack should be relatively high in carbohydrate, moderate in protein, and low in fat and fiber.

Food and fluid intake during exercise: Food or beverage intake during exercise can be beneficial for athletes engaged in prolonged exercise because it can help to replace fluid lost in sweat and provide carbohydrate for energy.

In events longer than 60 minutes, 30 to 60 g/CHO/hour contribute to muscle fuel needs and blood glucose regulation. Up to 90 g/CHO/hour may be needed by athletes in events lasting 2.5 hours or longer. An individualized fluid plan must be developed to replace as much fluid lost in sweat as is practical.

Food and fluid intake after exercise: After exercise, the goal is to consume foods and beverages that will help replenish the nutrients lost during exercise and to speed recovery. Athletes focus on carbohydrate to replenish muscle glycogen (~1.0 to 1.2 g/kg/h during the early recovery phase), fluid to restore hydration status (~1.25 to 1.5 liters for every 1 kg body weight lost), electrolytes such as sodium if large amounts of sodium have been lost in sweat, and protein to build and repair skeletal muscle tissue (~15 to 25 g of protein).

In addition to the preceding recommendations, there are a number of other critical areas that involve diet:

- Attaining or maintaining appropriate body composition
- Achieving weight loss in a healthy manner
- Fostering a positive relationship with food in order to avoid **disordered eating** (that is, abnormal eating patterns) and **eating disorders**, such as anorexia or bulimia
- Evaluating dietary supplements and ergogenic aids
- Modifying dietary intake because of existing medical conditions, such as diabetes or high blood pressure

Daily Value (DV): A term used on food labels; estimates the amount of certain nutrients needed each day based on a 2,000 Calorie diet. Not as specific as Dietary Reference Intakes (DRI).
Hyponatremia: Low blood sodium level.

All of these issues are covered in depth in the chapters of this text.

With so many details to consider, some athletes find that they begin to adhere to a rigid daily diet. The key is to meet nutrient needs and support training, recovery, and performance while maintaining dietary flexibility. Athletes need to keep their diet in perspective: food is needed to fuel the body and the soul (see Keeping It in Perspective).

Adhering to a very rigid eating plan can lead to social isolation and can be a sign of compulsive behavior, both of which can create problems for athletes. Some find themselves eating the same foods every day, and the joy of eating is diminished. The key is to have a flexible eating plan that is nutritious and includes a variety of foods. Flexibility usually results in short-term over-and undereating but long-term weight stability, proper nutrition, and enjoyment of eating.

Flexible eating is not the same as unplanned eating. Sports nutrition is complicated, and the failure to plan a nutritious diet often results in poor nutrient intake, which may hamper performance and undermine long-term health. But eating according to a rigid schedule is a problem, too. Food is for fuel and fun, and athletes must find the right balance.

The demands of an athlete's sport must be carefully considered

The basic sports nutrition guidelines are a good starting point for both strength and endurance athletes, but they must be modified according to the athlete's sport. The sport of running provides an excellent example. Sprinters, such as 100 m and 200 m runners, spend hours in training but only seconds in competition and have no need for food or fluid during their competitive event. They need a moderate amount of carbohydrate daily to support training, recovery, and performance. In contrast, long distance runners, such as marathon runners, spend hours in training and competition and must determine the right combination of food and fluids during exercise to provide them the fuel and water they need. The amount of carbohydrate used and the volume of fluid lost during a training session can be substantial, and they need to replenish both before the next training session. Monitoring daily carbohydrate consumption is important to ensure adequate intake, and in the days prior to competition, carbohydrate intake may be further manipulated to make sure that muscle glycogen stores are maximized. The precompetition meal is very important but must be tested during training because gastrointestinal distress could interfere with the race. Cycling and swimming are other sports in which the distance covered influences food and fluid requirements.

In track and field, the nutrition-related issues of "throwers" and "jumpers" are different, in part because one group is throwing an object and the other is hurling the body. Shot putters and discus, hammer, and javelin throwers benefit from being large-bodied and strong. Body fat adds to total body weight, which can be a performance advantage because it adds mass. However, some of these athletes readily gain abdominal fat, which may not affect performance but may be detrimental to health. In contrast, jumpers generally do not want excess body fat because it negatively affects their ability to perform sports such as high jump, long jump, triple jump, or pole vault. Both throwers and jumpers are strength/power athletes, but they focus on different nutrition-related issues.

Many sports are team sports, and it is important to consider the demands of each position. For example, weight and body composition vary in baseball outfielders, in part, because of their offensive skills. Some hit for power, whereas others hit to get on base, steal bases, and score on base hits. Power hitters benefit from greater body weight, whereas fast base runners are likely to have a lower body weight when compared to players who hit for power. Sports in which position plays a major role include baseball, basketball, football, ice and field hockey, lacrosse, rugby, soccer, and softball (Dunford and Macedonio, 2017).

In addition to the intrinsic physical demands of competing in a specific activity, consideration must be given to various extrinsic factors related to participation in that sport that may affect an athlete's physical stress and dietary practices. Travel and game schedules may disrupt sleep, eating, and recovery patterns and may limit access to appropriate dietary choices. Financial resources may influence how effectively an athlete may be able to implement specific dietary recommendations. Athletes may be competing in the same sport but may have different demands or challenges at different competitive levels. For example, baseball players at the major league (MLB) and minor league (MiLB) levels all face demanding competitive and travel schedules; however, the MiLB players may have additional demands imposed by having significantly lower team and personal financial resources. To properly address each individual athlete's needs, these extrinsic challenges must be considered, as well as the specific demands of the sport and position within the sport.

KEY POINTS

- Sports nutrition recommendations include guidelines for energy, nutrient and fluid intake, and nutrient timing.
- The athlete's sport and position must be considered when making nutrition recommendations.

Why might a lineman, linebacker, and wide receiver on the same football team have very different nutrition needs?

1.4 Dietary Supplements and Ergogenic Aids

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

Athletes typically have as many, or more, questions about dietary supplements and ergogenic aids as they have about their basic diet. **Ergogenic aid** is a broad term used to describe any external influence that may enhance training, recovery, or performance, including mechanical, nutritional, pharmaceutical, and psychological aids. This section will provide an introduction to dietary supplements, which are sometimes referred to as nutritional ergogenic aids. Specific supplements will be discussed in later chapters.

Dietary Supplement Health and Education Act

The Dietary Supplement Health and Education Act (DSHEA), passed in 1994, provides a legal definition for the term *dietary supplement* in the United States. A dietary supplement is defined as a "vitamin, mineral, herb, botanical, amino acid, metabolite, constituent, extract, or a combination of any of these ingredients" (Food and Drug Administration, 1994). This broad definition results in supplements that have very different functions and safety profiles being grouped together. This legislation also provides labeling guidelines, such as the requirements for the Supplement Facts label (Chapter 10).

It is important to know what the law does *not* cover. DSHEA does not ensure safety or effectiveness. The Food and Drug Administration (FDA) does not have the authority to require that a dietary supplement be approved for safety before it is marketed. In other words, any dietary supplement that appears on the market is presumed to be safe. The FDA must prove that a supplement is unsafe or **adulterated** before it can be removed from the market. The law also does not require that a dietary supplement be proven to be effective.

In 2007, quality standards for supplements were mandated by the FDA. These standards were developed to ensure that dietary supplements contain the intended ingredients, are free from contamination, and are accurately labeled. **Good Manufacturing Practices (GMP)** are intended to bring dietary supplement manufacturing standards more in line with pharmaceutical standards. Some dietary supplements have been reported as tainted and have caused athletes to test positive for banned substances. In some cases, these supplements contained tainted ingredients due to poor manufacturing practices, which the quality standards were developed to alleviate. However, there is also evidence that ingredients that could lead to inadvertent doping are intentionally added to some dietary supplements. It is estimated that between 10 and 15 percent of supplements may contain prohibited substances (Outram and Stewart, 2015). In response to this, the FDA newly committed to increasing oversight of the dietary supplement industry (US Food and Drug Administration, 2019).

Many products fall under the umbrella known as dietary supplements

Because the legal definition for a dietary supplement is so broad, it may be helpful to further divide this vast category into three subcategories: (1) vitamins, minerals, and amino acids; (2) botanicals; and (3) herbals. These categories are different in several ways. Vitamins, minerals, and amino acids are all nutrients that are found in food. Most of these compounds have an established standard for how much is needed by humans, such as a DRI. Some also have a UL established, the highest level taken daily that is not likely to cause a health problem. Therefore, it is not difficult to determine whether one's diet is lacking in these nutrients and whether the amount in a supplement exceeds the amount needed or is safe. In surveys of athletes, vitamins are among the most frequently used supplements.

Botanicals are typically compounds that have been extracted from foods and then concentrated into liquid or solid supplements. These supplements have a link to both food (the original source) and medications (a concentrated dose). Botanicals may or may not provide the same benefit as the food from which they were extracted even though the dose is more concentrated. Botanical supplements are difficult to study, and study results are often conflicting. Popular botanical supplements include garlic and soy supplements. Usage of botanicals among athletes is not well-known, as most surveys of athletes do not distinguish between botanical and herbal supplements.

The majority of the most widely used herbal supplements in the United States (for example, ginkgo biloba, St. John's wort, echinacea, saw palmetto) do not contain nutrients that are found in food. In fact, these herbal products are typically being used as alternative medications. Although the DSHEA prohibits manufacturers

Disordered eating: A deviation from normal eating but not as severe as an eating disorder.

Eating disorders: A substantial deviation from normal eating, which meets established diagnostic criteria (for example, anorexia nervosa, bulimia nervosa, anorexia athletica).

Ergogenic aid: Any external influence that may enhance training, recovery, or performance.

Adulterate: To taint or make impure.

Good Manufacturing Practices (GMP): Quality control procedures for the manufacture of products ingested by humans to ensure quality and purity.

SPOTLIGHT ON A REAL ATHLETE

NFL Player's Suspension Due to a Contaminated Supplement?

In order to perform at the highest levels of their sport, athletes seek out the best coaching and instruction, equipment, training techniques, injury prevention and recovery practices, and the most effective nutrition and dietary strategies. Their pursuit of excellence often results in athletes using dietary supplements to enhance their nutrition program in order to further improve their performance. Athletes who are subject to drug testing and doping control must be very careful about what supplements andsubstances they consume to avoid violating performance enhancing drug policies.

In 2019, Taylor Lewan, an offensive tackle for the Tennessee Titans of the National Football League was suspended for the first 4 games of the season for violating the NFL policy on performance-enhancing substances. An off-season drug screening test showed the presence of Ostarine (also known as Enobosarm), a substance on the World Anti-Doping Agency (WADA) banned list that is often used as a body building supplement. Lewan made public statements denying that he knowingly used Ostarine, published the results of a lie detector test indicating his truthfulness, suggested that he must have consumed the performance enhancing drug (PED) in a supplement, and appealed his suspension. The NFL denied his appeal and it is estimated that Lewan forfeited between $3 and $4 million in salary due to his 4 game suspension.

Do dietary supplements contain Ostarine?

Ostarine is designated as an investigational drug in a class known as selective androgen receptor modulators (SARM), developed for clinical applications such as muscle and bone loss in older adults, but also thought to have anabolic effects for athletes similar to steroids. It is not FDA approved for human consumption, and it is therefore not permissible to be included in a dietary supplement in the US. Ostarine can be purchased through various sources (e.g. online sites), although sellers are usually careful to include statements such as "This material is sold for laboratory research use only" and "Not for human consumption, nor medical, veterinary, or household uses." In order for a dietary supplement to have contained Ostarine, the supplement would have to have been either mislabeled or contaminated in the manufacturing process (see Purity of dietary supplements in this chapter).

How can an athlete like Taylor Lewan ensure that they do not inadvertently consume a banned substance through their use of supplements?

The first step is to have a thorough understanding of the policies on performing enhancing substances of the organization(s) that govern the athlete's sport and the consequences for violating those policies. In this case, both the NFL and the NFL Player's Association very clearly point out that each individual athlete is responsible for making sure that they do not ingest or use a prohibited substance, even if the use is inadvertent. The governing bodies do not test or approve supplements for use but do provide resources for athletes, therefore the second step for the athlete is to make extensive use of these resources. In Lewan's case,

from making claims that herbal products can treat, prevent, diagnose, or cure a specific disease, such claims are made frequently, especially when these supplements are marketed via multi-level marketing (MLM), print and online advertising, and often without proper ingredient lists and DSHEA warnings (Cardenas and Fuchs-Tarlovsky, 2018; Ethan et al., 2016).

In most surveys of athletes, 10 percent or less used herbal supplements. Ginseng and echinacea are the most widely used herbal supplements by athletes (Knapik et al., 2016).

Dietary supplement use among athletes is high

Dietary supplements are used by over one-half of the U.S. population. Surveys suggest that up to 80 percent of elite athletes use one or more dietary supplements, while 25 to 70 percent of nonelite athletes are dietary supplement users.

For most dietary supplements, use is similar for male and female athletes. However, a larger proportion of women consume iron supplements (this is expected since iron-deficiency anemia is more prevalent in women). More men than women consume vitamin E, protein, and creatine. Men also use supplements more often than women to increase strength and lean body mass (Knapik et al., 2016).

Athletes consume supplements for many reasons

Limited research suggests that athletes consume dietary supplements for many reasons. Frequently mentioned are the consumption of a poor diet, the physical demands of training and competition, the fact that teammates and competitors are taking supplements, and the recommendation of a physician, coach, trainer, parent, or friend. Dietary supplements are also seen as a way to stay healthy, boost the immune system, increase energy, and aid in recovery (Garthe and Maughan, 2018; Parnell, Wiens, and Erdman, 2015).

Unfortunately, there appears to be a large disconnect between the supplements being consumed and the NFLPA Check Your Supplements website is an important resource which directs players to the NSF Certified for Sport program (Figure 1.12) which certifies specific dietary supplements as being free from contaminants, prohibited substances, and masking agents. The NFLPA also references AegisShield, a website and mobile app that allow players to search specific products or ingredients in products to determine if they contain prohibited substances. The final step for each athlete is to make an informed decision about using a specific supplement based upon a thorough review of the potential performance enhancing benefits compared to possible adverse consequences resulting from its use.

Critical Thinking Questions:

1. Read the reference below (and any other published reports of Taylor Lewan's failed drug test and suspension) and answer the following questions:
   a. What specific steps did Lewan take to determine the source of the Ostarine found in his system? Was a source of contamination found?
   b. What steps could Lewan have taken before his failed drug test to minimize his chances of consuming a prohibited performance enhancing drug?
2. You are a RD/RDN with CSSD certification working as a Sports Nutritionist for an NCAA intercollegiate athletic program. While walking through the sports medicine facility, you overhear an athletic trainer recommending the use of a specific dietary supplement to several student athletes. What are the specific steps that you would take to address this situation?
3. A former student athlete from your institution is now playing football professionally in the NFL. He has been offered an endorsement deal to use and advertise a dietary supplement and has contacted you for your professional expertise and advice. What specific advice would you give this NFL player for evaluating the use (and the subsequent endorsement of) a dietary supplement?

References:

NFL News: Titans OL Taylor Lewan officially suspended 4 games https://www.nfl.com/news/titans-ol-taylor-lewan-officially-suspended-4-games-0ap3000001043763

NFLPA Drug Policies and Resources: https://nflpa.com/active-players/drug-policies

NSF International Certified for Sport: https://www.nsfsport.com/index.php

AegisShield: https://www.aegisshield.com/

the reasons that athletes give for consuming them. Many athletes consume supplements to meet broad goals, such as increasing strength or improving endurance, without knowing whether the supplements they take are effective in reaching such goals. Athletes lack knowledge about the mechanisms of action and the effectiveness of many supplements and often take supplements based on a personal recommendation, advertising, or information found on the internet. In many cases, an athlete's approach to choosing a supplement is poorly thought out (Maughan, Shirreffs, and Vernec, 2018; Maughan et al., 2018). For this reason, the International Olympic Committee provided decision trees to help guide athletes toward informed decision making regarding supplement use in a recent consensus statement on dietary supplements and high-performance athletes (Maughan et al., 2018).

Knowledge of a supplement's legality, safety, purity, and effectiveness is crucial

Determining if, and how much of, a dietary supplement should be consumed requires athletes to gather unbiased information (Figure 1.11). This information then needs to be carefully considered before a judgment is made. Particularly important to consider are the legality, safety, purity, and effectiveness of the dietary supplement.

Joshua Rainey/Dreamstime LLC

FIGURE 1.11 How to choose? Dietary supplements line the shelves in grocery and drug stores in the United States, but athletes need a lot of information to make wise choices.

Legality of dietary supplements. Many athletes are governed by the rules of the WADA, the International Olympic Committee (IOC), the National Collegiate Athletic Association (NCAA), or other national governing bodies (NGB). Other sports governing bodies may adopt these rules or rules of their own, so each athlete is responsible for knowing the current rules as they pertain to dietary supplements. Banned substances may be intentionally or unintentionally added to some dietary supplements. It is considered unethical to circumvent the testing of banned substances with the use of masking agents or other methods that prohibit detection of banned substances.

Safety of dietary supplements. Before consuming any dietary supplement, the athlete should ask, Is it safe? Safety refers not only to the ingredients in the dietary supplement but also to the dose. For example, vitamin supplements are considered safe at recommended doses but may be unsafe at high doses.

At recommended doses, many dietary supplements are safe for healthy adults, including vitamins, minerals, protein powders, and amino acid supplements. Creatine and caffeine at recommended doses have good safety profiles, although the athlete may experience some adverse effects with their use. Androstenedione, dehydroepiandrosterone (DHEA), and ephedrine are banned substances in many sports, in part due to safety concerns. The FDA does not review or approve any dietary supplement before it is available for sale, so it is imperative that the athlete be aware of any potential safety issues (see Chapter 10).

There is concern about the safety of herbal supplements, particularly the risk for liver toxicity. These concerns include lack of standardization of the active ingredients, the risk for contamination, the presence of anabolic androgenic steroids, and potential interactions with medications. Prior to 1994, herbal preparations were considered neither a food nor a drug, but DSHEA reclassified them as dietary supplements. This is in contrast to most European countries, which regulate herbals and botanicals as medications (García-Cortés et al., 2016).

Athletes need to be cautious of both the recommended dosage and the ingredients found in herbal weight-loss supplements. Some may contain ephedrine (for example, Ma Huang), a nervous system stimulant, which has a narrow safe dose range. Others may contain herbal sources of caffeine. Caffeine is also a nervous system stimulant and is typically safe at moderate doses. However, the use of caffeine-containing weight-loss supplements along with energy drinks containing a concentrated amount of caffeine could put an individual at risk for caffeine intoxication. Some herbal weight-loss supplements, such as Citrus aurantium (bitter orange), contain the drug synephrine, which may be a banned substance (Cappelletti et al., 2015).

Purity of dietary supplements. Purity is related to a lack of contamination and accurate labeling. Consumers assume that the ingredients and the amounts listed on the Supplement Facts label are accurate. They should be, but it is not true in all cases.

Many studies have found evidence of dietary substances that are mislabeled or impure, particularly weight-loss and muscle-building supplements. Examples include dietary supplements containing the following:

- 0 to more than 100 percent of the amount stated on the label
- Known allergens
- Prescription drugs
- Melamine (a source of nonprotein nitrogen that falsely elevates the protein content of the product)
- Banned substances, including anabolic androgenic steroids

It is estimated that 50 percent of sports supplements contain melamine and that 10 to 15 percent contain banned substances (Outram and Stewart, 2015; Deldicque and Francaux, 2016). The U.S. Anti-Doping Agency has a supplement awareness feature on its website (www.usada.org/substances/supplement-411).

The presence of banned substances in dietary supplements has led to supplement certification programs. Under these programs, dietary supplements can be certified by an independent testing organization, and athletes can be confident that the labels are accurate and the dietary supplements do not contain any banned substances. For athletes who choose to use supplements, one of the best tools available is to check that the supplement manufacturer is a participant in one of the dietary supplement certification programs (Figure 1.12) listed here:

- NSF (Certified for Sport®)
- United States Pharmacopeia
- Informed-Choice

One of the problems, particularly with herbal dietary supplements, is the lack of standardization. Standardization means that the amount found in the supplement is the same as the amount found in the laboratory standard. For example, if a supplement is supposed to contain 1 percent active ingredient, then every supplement produced in every batch should contain 1 percent active ingredient. Diligent manufacturers use good manufacturing processes to ensure standardization. However, not all manufacturers do so. Standardization is particularly important when using herbs. The amount of the active ingredient depends on the plant's species, the part of the plant used (the leaf has a different amount than the stem), the age at harvest, the way the plant is prepared (cutting gives different results than mashing), the processing (dried or not dried), and the methods used for extraction. It is easy to see why the amount of active ingredient could vary tremendously.

Used with permission of The United States Pharmacopeial Convention

FIGURE 1.12 When these certifications appear on dietary supplements, it means that they are produced using good manufacturing practices.

There is evidence that some dietary supplements can be contaminated with toxic heavy metals (such as lead, mercury, cadmium, and arsenic), pesticides, microbes, and other contaminants. Dietary supplement certification programs provide consumers important information about the quality and safety of dietary supplements (Akabas et al., 2016; Maughan et al., 2018).

Effectiveness of dietary supplements. Most dietary supplements sold are not effective for improving performance, increasing muscle mass, or decreasing body fat. Scientific research suggests that the following supplements are safe and effective at recommended doses (Close et al., 2016):

- **Beta-alanine.** Effective for buffering of muscle pH and for maintaining muscle carnosine concentrations with beneficial performance effects during high-intensity exercise (Chapter 5).
- **Caffeine.** Effective in stimulating the central nervous system; reducing the perception of effort, fatigue, and pain associated with exercise; and improving endurance for intermittent and high-intensity activities (Chapter 10).
- **Creatine.** Effective in conjunction with vigorous training for increasing lean body mass in athletes performing repeated high-intensity, short-duration (<30 seconds) exercise bouts. Effective for increasing performance in weight lifters (Chapter 3).
- **Nitrate.** Effective to temporarily increase plasma nitrite concentrations and improve endurance exercise capacity. Dietary sources include leafy green and root vegetables, particularly beetroot (Chapter 3).
- **Vitamins and minerals.** Effective as a way to increase nutrient intake and to reverse nutrient deficiencies, if present (Chapters 8 and 9).
- **Protein.** Effective as a source of protein (neither superior nor inferior to food proteins). Whey protein may be more effective than casein for stimulating skeletal muscle protein synthesis (Chapter 5).
- **Sodium bicarbonate**. Effective to temporarily raise blood pH and bicarbonate concentrations, as well as improve performance in short-duration, high-intensity exercise bouts or repeated high-intensity intervals (Chapter 3).

The following supplements are promoted and utilized to varying degrees; however, the body of scientific research is not as robust as it is for the previously mentioned supplements:

- Beta-hydroxy beta-methylbutyrate (HMB) for increasing muscle mass and strength and reducing muscle damage
- Branched chain amino acids (BCAA) for immune system support and reduction of postexercise fatigue
- Leucine to stimulate muscle protein synthesis
- Glutamine for improving immune function
- Growth hormone releasers, such as arginine, for stimulating growth hormone release
- Omega-3 fatty acids for reducing inflammation and for reducing respiratory symptoms in some athletes with exercise-induced asthma
- Probiotics to reduce gastrointestinal distress and inflammation
- Quercetin and sour cherry juice for anti-inflammatory effects
- Zinc to reduce colds and upper respiratory symptoms

For the vast majority of dietary supplements, there is little or no scientific evidence of effectiveness. Many of the supplements related to performance and body composition are discussed in the chapters of this textbook.

Quackery. Quackery is the practice of making false claims about health-related products, and some dietary supplements fall under this category. It is very difficult to combat quackery. Many dietary supplements are highly advertised or are sold using MLM, and unscrupulous companies or distributors may exaggerate their value because they will be financially rewarded if sales increase. Consumers can reduce their risk for being a victim of quackery by critically evaluating products before purchasing them. One method for evaluating dietary supplements is shown in the Spotlight on . . . Evaluating Dietary Supplements, later in this chapter.

KEEPING IT IN PERSPECTIVE

Food Is for Fuel and Fun

Many athletes follow rigorous training programs. To support such training, diet planning becomes very important because food provides the fuel and nutrients that are needed to train hard. Endurance and ultraendurance athletes must carefully plan their food and beverage intake before, during, and after training and competition, or they risk running out of fuel and becoming hypohydrated. This need for constant, nutritious food and drink sometimes means that athletes get very rigid about their dietary intake. Rigid meal planning might meet the scientific requirements of nutrition, but it falls short when it comes to the art of eating, which also involves pleasure and enjoyment. In other words, sometimes athletes need to eat food just for fun.

KEY POINTS

- In the United States, dietary supplements are not required to be proven safe or effective before being sold.
- The majority of athletes at all levels use at least one dietary supplement.
- In many cases, athletes use a random approach to choosing dietary supplements.
- Many dietary supplements are safe, but some are not.
- Some supplements may contain banned substances or be contaminated, particularly weight-loss and muscle-building supplements.
- Only a handful of supplements have been shown to be effective with a substantial amount of scientific evidence.

What specific things should an athlete consider before choosing to take a dietary supplement?

1.5 Understanding and Evaluating Scientific Evidence

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

Although sports nutrition is a fairly new academic discipline, there have always been recommendations made to athletes about foods that could enhance athletic performance. Ancient Roman athletes were encouraged to eat meat before competing. One ancient Greek athlete is reported to have eaten dried figs to enhance training. There are reports that marathon runners in the 1908 Olympics drank cognac (brandy) to improve performance (Grandjean, 1997). The teenage running phenomenon, Mary Decker (Slaney), surprised the sports world in the 1970s when she reported that she ate a plate of spaghetti noodles the night before a race. Such practices may be suggested to athletes because of their real or perceived benefits by individuals who excelled in their sports. Obviously, some of these practices, such as drinking alcohol during a marathon, are no longer recommended, but others, such as a high-carbohydrate meal the night before a competition, have stood the test of time.

Today, sports nutrition uses **evidence-based recommendations**. Evidence-based practice is the review and use of scientific research to determine the most effective outcome. The scientific evidence plays a central role, although clinical judgment and the athlete's personal preferences and values must also be considered. Because research findings are fundamental in forming recommendations, the quality of the research is very important (Amonette, English, and Kraemer, 2016; Papoutsakis et al., 2017; Thomas, Erdman, and Burke, 2016).

There are three basic types of research studies

Most research studies fall into one of three categories: case studies, epidemiological studies, or experimental studies. **Case studies** are observational records. They provide information about an individual in a particular situation. Gathering information is an important first step because it helps researchers form hypotheses, but case studies are the weakest of all scientific findings.

Epidemiological studies help to determine the distribution of health-related events in specific populations. Such studies highlight nutrition and exercise patterns and help to show associations and **correlations**. These studies are stronger than case studies because large groups of people are studied, and data are statistically analyzed. However, because these are observational studies, they lack control of many variables.

The strongest studies are **experimental studies**. These studies follow strict protocols and control most variables except the ones being studied. This is how cause-and-effect relationships are established. One example of each type of study is reviewed here.

Morton and colleagues (2010) published a case study of the training and nutritional intake of a 25-year-old professional boxer who was trying to make weight for the superfeatherweight division. They reported the nutritional and conditioning interventions and outcomes

SPOTLIGHT ON...

Evaluating Dietary Supplements

Everyone agrees that a proper diet is necessary for good health. However, opinions vary among professionals in sport-related fields and athletes themselves about dietary supplement use. Professionals emphasize safety because they honor the principle of first, do no harm. Ethics are also a consideration because a dangerous supplement directly affects the athlete, not the person recommending it. Athletes are concerned about safety too, but the decision to use supplements will affect them directly—the athlete will reap the benefits and/or suffer the consequences.

Some athletes are risk takers. When safety data are not available, which is the case for many dietary supplements, they feel comfortable adopting a "probably will not be harmful" approach. Such an approach does not pose an ethical issue for the athlete because of a willingness to accept the consequences. However, it is beyond the comfort and ethical limits of many sports-related professionals because of the potential for harm to the athlete.

Evaluating dietary supplements requires a systematic, multistep process of gathering, weighing, and judging information that leads to decision making. In other words, it requires critical thinking. Here are some questions to ask about any dietary supplement:

- Is it legal?
- Is it ethical?
- Is it safe (both the ingredients and the recommended dosage)?
- Is it effective?
- Is it pure?
- What is not known?
- Could it be quackery?

An athlete and a sports-related professional may examine the same information but come to different conclusions, in part because of each person's perspective. In the end, nearly everyone agrees on the general approach—consume a healthy diet—but philosophies about whether, and which, supplements should be taken vary widely among individuals. "Should I recommend this supplement to an athlete/client?" is a different question from "Would I use this supplement myself?"

over a 12-week period, including changes in energy intake, energy expenditure, total body weight, lean mass, and body fat. The boxer studied followed a low-calorie, high-protein diet over the three-month period and reduced body weight by 9.4 kg (~21 lb) and body fat from 12.1 percent to 7.0 percent. The subject was able to meet his goals with a gradual weight loss that did not include large or rapid losses in body water. These are important observations, but they do not provide a scientific basis for making recommendations to other boxers or to athletes in other sports who want to make weight.

The relationship between physical activity or physical fitness levels and improved health is well known as a result of a number of epidemiological studies. A notable example is the large, well-designed study of Blair et al. (1989) from the Institute for Aerobic Research. In a study that included more than 13,000 subjects, the authors showed that there was a strong relationship between aerobic fitness and decreased all-cause **mortality**, primarily from decreased premature mortality from cardiovascular disease and cancer.

An experimental study that has become a "classic" in sports nutrition was conducted by Coyle et al. (1983) to determine if drinking a carbohydrate beverage helped endurance cycling performance. Well-trained cyclists rode to exhaustion on two occasions, once while drinking a beverage containing carbohydrates and once while drinking a **placebo**. Although muscle glycogen utilization was no different when consuming the carbohydrate drink, blood glucose was maintained, a high rate of carbohydrate oxidation was also maintained, and the cyclists were able to ride at the prescribed intensity for an additional hour before becoming exhausted. This study showed that there was a cause-and-effect relationship between consuming a carbohydrate-containing beverage and the ability to cycle for a longer period of time.

The basis of good research is strong research design and methodology

The hallmark of good scientific research is the use of strong research design and methodology. Well-designed studies reduce bias and help to ensure accurate results. The strongest research protocol is a randomized, double-blind, placebo-controlled, crossover study performed on humans. It may include a familiarization trial. The number of subjects in the study should be as large as possible, and their characteristics (for example,

Evidence-based recommendations: Recommendations based on scientific studies that document effectiveness.

Case study: An analysis of a person or a particular situation.

Epidemiological study: The study of health-related events in a population.

Correlation: A relationship between variables. Does not imply that one causes the other.

Experimental study: A research experiment that tests a specific question or hypothesis.

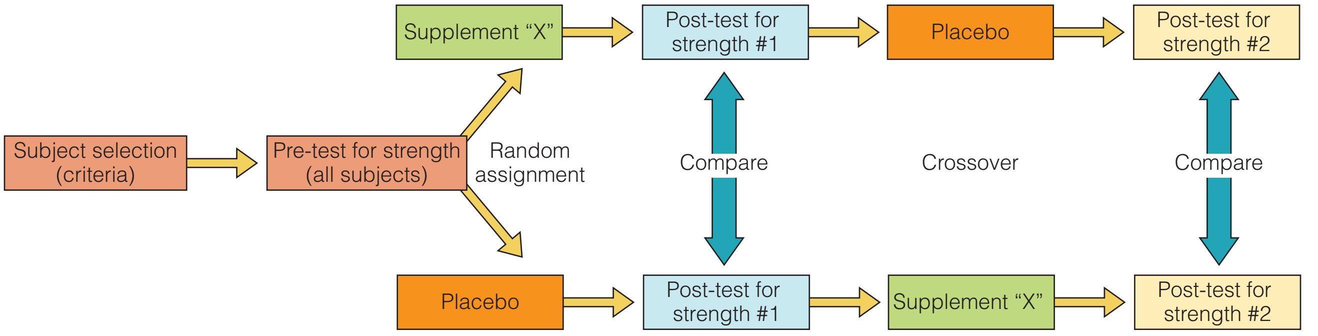


FIGURE 1.13 Research design

age, fitness, training, health status) should be similar in order to reduce variability in results between subjects.

Randomization is part of the subject selection process. It is usually difficult to study 100 percent of the population of interest, so a sample is chosen. Randomization tries to ensure that all people in the study population will have the same chance of being selected for the sample. The study subjects are also randomly assigned to either the treatment or the placebo group. The placebo group receives an inactive substance that resembles the treatment in every way possible. A double-blind study is one in which neither the researchers nor the study participants know which group they are in or which treatment they are receiving. In a crossover study, subjects will be in both the treatment and placebo groups. For example, if two trials were scheduled, subjects would receive the treatment in one of the trials. For the other trial they would "cross over" and be in the placebo group.

Randomized, double-blind, placebo-controlled study designs help to reduce bias, which can lead to inaccurate results and erroneous conclusions. If subjects aren't randomized, then selection bias will be present. Think about what might happen if researchers knew that the subjects were in the treatment group. They might consciously or unconsciously influence the participants to ensure that the treatment works. If the subjects knew that they were receiving a treatment, they may try to perform better.

Before data are gathered, subjects should complete a familiarization trial. This is critical in studies where the subjects' performance is being measured. Consider a study held in an exercise physiology lab on a stationary bicycle. If subjects are not familiar with the bike or other laboratory equipment, their performance might not be as fast during the first trial. A familiarization trial gives the subjects a chance to practice on equipment and also understand what is expected of them (for example, length of time in the lab, intensity of exercise).

Mortality: Death; the number of deaths in a population.
Placebo: An inactive substance.

When data collection begins, unfamiliarity with equipment or the study protocol should not be a factor.

The strongest results come from studies in which data are obtained from both an experimental (treatment) and a control (nontreatment/placebo) group. Most of the time, the treatment and control groups comprise different people. In a crossover design, subjects are in both groups so they serve as their own controls. For example, a study may be designed to have subjects perform two trials. In the first trial, the subject may be in the experimental group and receive a treatment (for example, a carbohydrate-containing beverage). In the second trial, the subject would then be in the control group and receive a placebo (for example, an artificially sweetened beverage that contains no carbohydrates). The results for each person can be directly compared because each subject received both the treatment and the placebo. Crossover studies are advantageous, but researchers must be careful to account for any carryover effects. For example, the effect of creatine loading may last for a month or more, whereas bicarbonate loading may show effects for only a day or two. When designing a crossover study, ample time must be allowed before the next phase of testing begins. An example of a research design for an experimental study is shown in Figure 1.13.

Strong research design and methodology is fundamental to unbiased and accurate scientific information. The recommendations made to athletes are only as strong as the research studies on which those recommendations are based. But how does a person who does not conduct research know if a research study is well designed and accurate? One safeguard is the peer review process.

Peer review is an important safeguard in the publication of scientific research

Every scientific study should be peer reviewed, which means that it is scrutinized by a group of similarly trained professionals (peers) before publication. The peer review process begins when the editor of the publication receives a written manuscript from the researchers. The researchers' names are usually removed, and the manuscript is sent to two or more reviewers who have significant experience in the specific topic of the submitted research. They carefully read the study protocol, review the data, and evaluate the authors' conclusions. If the study design and methodology are not scientifically sound, the peer reviewers will recommend that it not be published. If the method is sound, they may make suggestions to ensure clarity and accuracy in reporting the data and drawing conclusions, which the authors will incorporate into a revised manuscript. The revised manuscript is reviewed by the editor and then scheduled for publication. Like the scientific studies, the peer review process should be blind—researchers should not know who reviewed the article, and reviewers should not know who conducted the research and wrote the article.

Readers can have confidence in the quality of an article in a peer-reviewed journal. The peer review process should be a rigorous one. Journals that have the strongest peer review processes have the best reputations. Examples of peer-reviewed journals that publish articles related to sports nutrition are listed in Figure 1.14.

Examples of Peer-Reviewed Journals Related to Sports Nutrition

American Journal of Clinical Nutrition
European Journal of Applied Physiology
International Journal of Sport Nutrition and Exercise Metabolism
International Journal of Sports Medicine
International Journal of Sports Physiology and Performance
Journal of Applied Physiology
Journal of Athletic Training
Journal of the Academy of Nutrition and Dietetics
Journal of the American Medical Association
Medicine and Science in Sports and Exercise
Sports Medicine (reviews)

FIGURE 1.14 These journals require rigorous peer review before a research article is published.

Levels of evidence and grades of recommendations put the scientific body of literature in perspective

The most conclusive evidence comes from studies that are randomized, double-blind, placebo-controlled, and published in peer-reviewed journals. The results of such studies should be given greater weight than results from other study designs or those published in non-peer-reviewed journals. But even the results of the best-designed study cannot stand alone. Reproducible results are an important part of the scientific process. Recommendations must be based on the cumulative body of scientific literature and not on the results of one study. Just as the strength of each study must be established, the quality of the body of literature must also be determined. This process involves levels of evidence and grades of recommendations.

Level of evidence refers to the relative strength or weakness of the current collective body of scientific research. The strongest evidence comes from a review of all the randomized, controlled trials. Such reviews compare the results of high-quality research studies. Many of these reviews involve meta-analysis, a statistical method of comparison. Articles reviewing the collective body of scientific research give rise to the strongest recommendations.

As noted previously, sports nutrition is a relatively young scientific field, so abundant, high-quality research is lacking in many areas. Practitioners must make recommendations based on the current body of literature, knowing full well the limitations of the current scientific knowledge. Grading the scientific evidence is important because it indicates the relative strength and quality of the body of scientific research. Four grades, designated either by Roman numerals or by letters, are generally accepted as described below. Most professional organizations, such as the Academy of Nutrition and Dietetics and the American College of Sports Medicine, use evidence-based guidelines.

Grade I (Level A; Good): The conclusions are supported by good evidence, known as a rich body of data. The evidence is based on consistent results of well-designed, large randomized research studies. Confidence in the accuracy of these studies is high.

Grade II (Level B; Fair): The conclusions are supported by fair evidence, known as a limited body of data. The evidence is less convincing because either the results of well-designed studies are inconsistent or the results are consistent but obtained from a limited number of randomly controlled trials or studies with weaker designs.

Grade III (Level C; Limited): The conclusions are supported by limited evidence. Confidence in the results of the research studies is limited by their size and design (for example, nonrandomized trials or observational studies) or by the size of the cumulative body of literature that consists of a small number of studies.

Grade IV (Level D; Expert opinion only): The conclusions are supported by expert opinion, known as panel consensus judgment, as a result of the review of the body of experimental research. This category includes recommendations made by sports nutrition experts based on their clinical experience.

In a perfect world, Grade I (Level A) evidence would be available to answer all questions regarding the nutrition and training needs of athletes. However, in many cases, recommendations are supported by only fair or limited evidence. In some cases, expert opinion is relied upon until more research can be conducted. Although dietary supplements are widely used by athletes, the scientific evidence available may be limited or nonexistent in many cases. Lack of scientific research makes it difficult to evaluate claims regarding safety and effectiveness. When making sports nutrition, training, or dietary

FOCUS ON RESEARCH

Designing a Research Study to Test the Effect of a Sports Drink on Performance

Scientific research is a systematic process of gathering information (data) for the purpose of answering a specific question or solving a specific problem. Researchers have the best opportunity to obtain accurate and relevant information, and thus to most accurately answer the research question, if (1) the question/problem is clearly defined, (2) the research study is well-designed and carefully conducted, and (3) the results are appropriately analyzed and interpreted. The first Focus on Research in this text will examine the process of designing a research study to answer a specific research question in sports nutrition.

Consumption of sports drinks—carbohydrate-containing beverages—has been shown repeatedly in the research literature to help athletes in certain sports to improve their performance. Use of sports drinks in training and competition has become routine practice for many athletes, but athletes in endurance sports of relatively long duration, for example, marathon running, benefit the most from ingesting carbohydrate during exercise. Muscles use carbohydrate in the form of glucose, and most research studies have shown that sports drinks that contain mostly glucose are the most effective. There appears to be a limit as to how much glucose an athlete can consume during exercise—more is not necessarily better. Too much glucose intake does not help performance and may even lead to gastrointestinal (GI) problems.

Some research, however, has shown that adding fructose to a glucose-containing sports drink likely results in more total carbohydrate being absorbed from the GI tract and used during exercise. This is thought to occur because fructose is absorbed by a different transport mechanism than glucose (Chapter 4) and may provide a route for more carbohydrate to enter the body after the glucose transporters are saturated. Although it seems promising that more carbohydrate can be taken up and used during exercise when fructose is added to a sports drink, it is not known if this in turn would result in improved athletic performance.

Scientists and sports nutritionists are confident the consumption of glucose (for example, a sports drink) during prolonged endurance exercise will help improve performance in events such as marathon running, bicycling races, and triathlons. A valid research question is as follows: Will consuming a sports drink containing fructose and glucose improve performance more than when athletes consume a sports drink containing only glucose?

We will examine how a research study was designed specifically to answer that research question:

Triplett, D., Doyle, J. A., Rupp, J. C., & Benardot, D. (2010). An isocaloric glucose-fructose beverage's effect on simulated 100-km cycling performance compared with a glucose-only beverage. *International Journal of Sport Nutrition and Exercise Metabolism, 20,* 122–131.

What was the measure of performance? If the purpose of the study is to determine the effect of a sports drink on performance, one of the first tasks in designing the study is to determine the specific method for testing performance. Because sports drinks are most effective in long-duration endurance events where carbohydrate stores may be depleted, the performance task needed to be one that would take the subjects in excess of 2 hours to complete. For the results to be most applicable to competitive athletes, the performance task should also mimic the physical demands of a competitive event as closely as possible while still maintaining the ability to control the exercise conditions in the laboratory. Rather than invent one on their own, Triplett et al. (2010) chose an endurance performance test performed on a cycle ergometer in the laboratory (100 km/62 mile time trial) that had been used in previous studies and had been shown to be a reliable and accurate measure of cycling performance that simulated the demands of a competitive bicycling road race (Figure 1.15).

What subjects were selected? To be able to physically complete the prolonged endurance performance test, and for the results of the study to be most applicable to competitive athletes, subjects recruited for this study needed to have current experience in competitive cycling races. Because of the likely difference in performance between male and female cyclists, the researchers chose to restrict the subject population to a single sex to reduce the potential variability in subjects' performance results. In other words, the more similar all of the subjects are to one another in performance, the better chance the researchers have to see if an experimental intervention such as a new sports drink has an effect on the results.

supplement recommendations to athletes, it is important to indicate the relative strength of the research or the absence of scientific studies.

Anecdotal evidence. Anecdotes are personal accounts of an incident or event and are frequently used as a basis for testimonials. Anecdotal evidence is based on the experiences of one person and then stated as if it had been scientifically proven. Often anecdotal evidence is cited to show that the current recommendations are not correct. Anecdotal evidence is not necessarily false (it may be proven in the future), but it should not be used as proof.

Anecdotal evidence and testimonials are often used to market dietary supplements (Figure 1.16). For example, a well-known athlete may appear in a supplement advertisement and endorse the product. It is not illegal to include endorsements in advertisements, but it is deceptive if the consumer is led to believe that the endorsement is made voluntarily when the person is being paid to promote the product. The Federal Trade Commission (FTC) is responsible for regulating the advertisement of dietary supplements, and more information can be found on its website.

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FIGURE 1.15 An experimental study of carbohydrate consumption and endurance cycling performance.

What was the experimental sports drink? A typical research study such as this might test the effect of an experimental sports drink against a placebo beverage. In this case, the researchers were interested in the effect a new sports drink (one with fructose and glucose) might have compared to a traditional sports drink (one with glucose only). The composition of the two drinks was designed to be similar to those used in the studies that showed improved carbohydrate uptake when fructose was added. In order to make sure that the total amount of carbohydrate in the drinks was not an influencing factor, the two drinks had the same amount of carbohydrate and differed in only one respect—one contained only glucose, and the other contained glucose and fructose in equal amounts. The drinks looked the same and had very similar taste. The researchers chose not to include a placebo beverage because it is already very clear from the research literature that this type of performance will improve when consuming a sports drink over consuming a placebo, and the inclusion of a placebo trial would require the subjects to perform yet another rigorous performance trial.

What was the experimental design? Nine male cyclists with current bicycling road race experience were subjects in this study. They performed a trial run of the cycling performance test to familiarize them with the procedures and because previous research has shown this type of familiarization trial to improve reliability of endurance performance tests. During the familiarization trial, the subjects drank only water. After the familiarization trial, the subjects completed two experimental trials of cycling endurance performance, once while drinking a sports drink with only glucose and once while drinking a beverage with both fructose and glucose. The type of sports drink was given in random order (some got glucose-only first; others got glucose-fructose first) and in a double-blind fashion (neither the researcher nor the subjects knew which beverage they were consuming). The subjects acted as their own control subjects by completing a performance trial with both experimental sports drinks (crossover design). At the conclusion of the study, the average (mean) time it took the subjects to complete the performance test when they drank the glucose-only sports drink was statistically compared to the average time it took the subjects to complete the same performance test when they drank the glucose and fructose sports drink.

What did the researchers find? Triplett et al. (2010) reported that when subjects consumed the sports drink with fructose and glucose in it, they improved their endurance cycling performance, completing the performance test nearly 3.5 minutes faster on average than when they consumed the sports drink that contained only glucose. They also found that the mean power output throughout the performance test on the cycle ergometer (a measure of cycling intensity) was higher when they consumed the glucose and fructose sports drink.

Answering the question: Will consuming a sports drink containing fructose and glucose improve performance more than when the athletes consume a sports drink containing only glucose? Based on the results of their research study, Triplett et al. (2010) concluded that the answer to this research question is yes, endurance exercise performance is improved with a sports drink that contains fructose along with glucose. Researchers and athletes can have a high degree of confidence in this conclusion because the research study carefully considered previous research, adhered to good experimental design principles, and was published in a peerreviewed journal.

Conclusions from scientific studies can be misinterpreted

One scientific study does little by itself to answer critical questions about sports nutrition issues. As shown earlier, it is both the quality and quantity of scientific research that allows practitioners to make sound nutrition and training recommendations to athletes. Critical thinking skills are needed to correctly interpret scientific research and properly communicate their

Image Courtesy of The Advertising Archives

FIGURE 1.16 Many ads for dietary supplements include testimonials by elite athletes.

SPOTLIGHT ON...

Wikipedia

Wikipedia (www.wikipedia.org) is an open-access, free, collaborative encyclopedia that is written and edited by volunteers. It is the most used online heath care resource in the world by both professionals and consumers (Heilman, 2013). Wikipedia has always valued accuracy, verifiability (referencing of reliable sources), and an unbiased (neutral) point of view, but wide-spread readership of health-related articles has underscored the importance of the quality of the content. Articles are rated for quality as follows (low to high): Stub, Start, C-class, B-class, Good Article, A-class, and Featured Articles. Articles classified as Good, A-class, or Featured are considered high quality. Studies of health-related articles have shown that Wikipedia articles contain no more mistakes or inaccuracies than more traditional sources of general information such as Encyclopedia Britannica (Heilman et al., 2011). The number of Featured Articles is small compared to the total number of articles, and much of the information on Wikipedia could be more complete. However, Wikipedia provides freely accessible and generally reliable information. Similar to other encyclopedias, Wikipedia gives an overview of a topic, but it is a secondary, not a primary, source of information. Secondary sources of information compile and summarize information that has been originally published in primary sources. Peer-reviewed research articles are primary sources of information.

results to athletes. Here are some issues that need special attention when drawing conclusions from scientific studies.

Distinguish between correlation and causation. One of the fundamental differences between epidemiological and experimental studies is the establishment of **causation**. Epidemiological studies can establish only a correlation (that is, that a relationship exists between two variables, and the strength of that relationship). It takes experimental research to establish causation—that the variable studied produces a particular effect. It is very important in both written and oral communications that professionals do not use the word *causes* if in fact the study or the body of research shows only an association or correlation. For example, epidemiological studies clearly show that people with lower aerobic fitness levels have an increased risk of premature death, particularly from cardiovascular disease and cancer (Blair et al., 1989; Harber et al., 2017). This knowledge is based on the strong inverse relationship between fitness levels and premature all-cause mortality. So it is correct to say that there is an association between aerobic fitness levels and premature death. However, based on this type of research, it is not valid to suggest that low fitness levels cause premature death or that having higher fitness levels will cause one to live longer.

Understand the importance of replicating results. Recommendations should not be made based on the results of one research study. Preliminary studies, many of which are performed in very small study populations, often produce surprising results, but many of these studies are never replicated. Unfortunately, the results of single studies are often widely reported as “news” by the media and then become falsely established as fact.

Extrapolate results of scientific research with caution, if at all. Extrapolation takes known facts and observations about one study population and applies them to other populations. This can lead to erroneous conclusions because only the original study population was tested directly. In the area of sports nutrition, data may be extrapolated in many ways, including animals to humans, males to females, adults to adolescents, children and younger adults to older adults, or people with disease(s) to healthy people. Sports nutritionists work with athletes of all levels, from recreational to elite, and must carefully consider the validity of extrapolating research results to these populations. For example, a dietary intervention or manipulation that shows positive results in a sedentary population with diabetes may not be applicable to well-trained runners. Other factors that are powerful influences and should be extrapolated with caution, if at all, are the presence or absence of training, the type of sport, laboratory or field conditions, and competition or practice conditions.

Interpret results correctly. The results of research studies are often misinterpreted or applied to an inappropriate population. Professionals must be able to evaluate the results of research studies and be able to recognize when recommendations are being made in an inappropriate way. One important consideration is to evaluate the characteristics of the subject population studied and to determine if the results observed in this group can reasonably be expected in other groups. Many studies of specific sport or exercise performance have used physically active college students as subjects. Results of these studies should be considered with great caution when making recommendations to other groups, such as highly trained athletes. Many sports nutritionists and physiologists who work with elite athletes will use only the results of studies that have used highly trained athletes who are similar to their client population.

Another important consideration in evaluating research results is how closely the laboratory experimental design mimics the "real" demands of the athletic event (Figure 1.17). Scientists study athletes in the laboratory so that they can carefully control as many experimental conditions as possible. In studying endurance performance, it is common to use "time to exhaustion" protocols in which athletes run or ride at a fixed exercise intensity until they are no longer able to maintain the required pace. Although these types of protocols are useful for studying metabolic responses during these types of activities, they do not reflect the demands or strategy of a real race and may therefore be less useful for predicting performance. Field-based research is not as common because it is more difficult to conduct and does not offer the same control of research conditions.

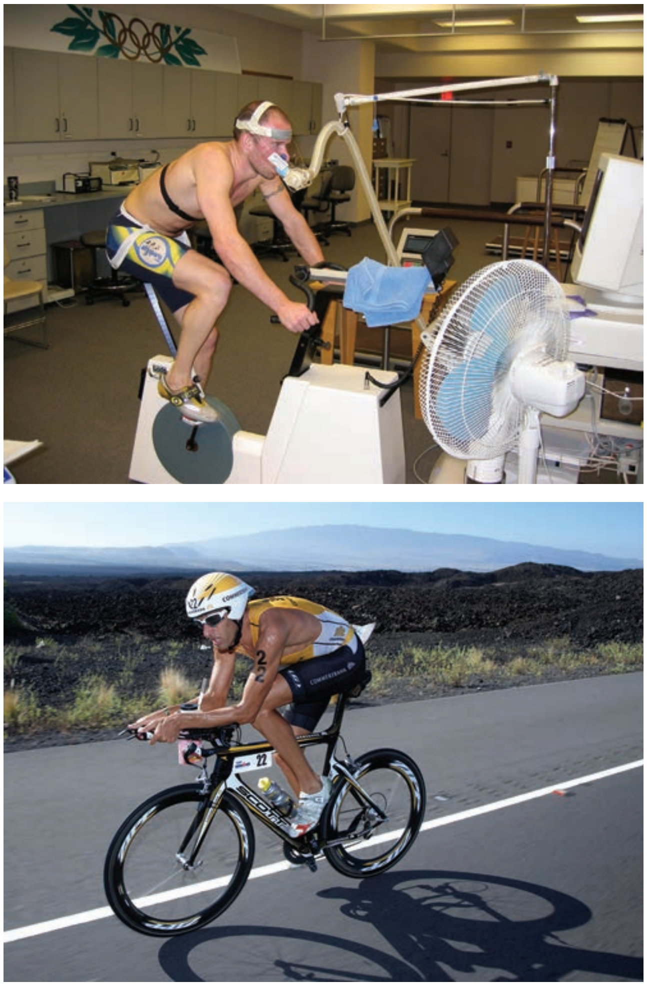

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FIGURE 1.17 Does the laboratory research study accurately reflect the demands or strategy of a competitive event?

Focus on cumulative results and consensus. There is much excitement when a new study is published, especially when the results contradict current sports nutrition recommendations or long-held theories. But startling breakthroughs are the exception, not the rule. Cumulative results, not single studies, are the basis for sound recommendations. It is imperative that any new study be considered within the context of the current body of research.

Whereas some topics may be subject to healthy debate among experts, many topics have good scientific agreement, known as **consensus.** One of the best ways to know the consensus opinion is to read review articles or position statements. Review articles help students understand the body of literature on a particular topic. These articles also help practitioners put the results of new research studies in the proper context and remain up to date with the current body of research. Sports nutrition position statements are often issued by professional organizations such as the Academy of Nutrition and Dietetics, the American College of Sports Medicine, and the International Olympic Committee.

Recognize the slow evolution of the body of scientific knowledge. Occasionally, landmark research studies are published that increase knowledge in a particular field in a quantum leap, such as Watson and Crick elucidating the structure of DNA. However, for the most part, knowledge in scientific areas such as sports nutrition increases gradually as additional research studies are completed and evaluated in the context of the existing research. The process can move slowly, as it takes time for research studies to be proposed, funded, completed, published, and evaluated by the scientific community. At times, it may seem to be a slow and cumbersome process. However, a deliberate, evaluative approach is an important safeguard for the integrity of the information. The scientific process is similar to building a brick wall; it takes time and must be done one brick at a time, but if done correctly, the end product has considerable strength.

Recognize that a research study may be used as a marketing tool. The results of research studies are frequently used as a marketing tool, some of them prior to

Causation: One variable causes an effect. Also known as causality.

Consensus: General agreement among members of a group.