

Eleventh Edition

NUTRITION

for Health, Fitness & Sport

MELVIN H. WILLIAMS
ERIC S. RAWSON
J. DAVID BRANCH

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FOR HEALTH, FITNESS & SPORT

Melvin H. Williams

Old Dominion University

J. David Branch

Old Dominion University

Eric S. Rawson

Bloomsburg University

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To Jeanne,
Sara, Nik, Katy, Lucy, and Jake May
Serena, Jeff, Daniel, and David Newsom
—*Melvin H. Williams*

To Carol, David, Anne Randolph, Ellie,
Gracie, and the rest of my family
—*J. David Branch*

To Debbie, Christopher, Matthew,
and Erica
—*Eric S. Rawson*

and

To our teachers, colleagues,
and students
Mel, David and Eric

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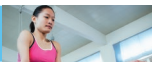
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Preface

According to the World Health Organization, better health is the key to human happiness and well-being. Many factors influence one's health status, including some provided by various government and health agencies, such as safe living environments and access to proper health care. However, in general, one's personal health over the course of a lifetime is dependent more on personal lifestyle choices, two of the most important being proper exercise and healthy eating.

In the twenty-first century, our love affair with fitness and sports continues to grow. Worldwide, although physical inactivity is still very prevalent in developed nations, more of us are joining fitness facilities or initiating fitness programs, such as bicycling, running, swimming, walking, and weight training. Improvement in health and fitness is one of the major reasons that more and more people initiate an exercise program, but many may also become more interested in sports competition, such as age-group road racing; running and walking race competitions have become increasingly popular, and every weekend numerous road races can be found within a short drive. Research has shown that adults who become physically active also may become more interested in other aspects of their lifestyles—particularly nutrition—that may affect their health in a positive way. Indeed, according to all major health organizations, proper exercise and a healthful diet are two of the most important lifestyle behaviors to help prevent chronic disease.

Nutrition is the study of foods and their effects upon health, development, and performance. Over the years, nutrition research has made a significant contribution to our knowledge of essential nutrient needs. During the first part of the twentieth century, most nutrition research focused on identification of essential nutrients and amounts needed to prevent nutrient-deficiency diseases, such as scurvy from inadequate vitamin C. As nutrition science evolved, medical researchers focused on the effects of foods and their specific constituents as a means to help prevent the major chronic diseases, such as heart disease and cancer, that are epidemic in developed countries. *Nutraceutical* is a relatively new term used to characterize the drug, or medical, effects of a particular nutrient. Recent research findings continue to indicate that our diet is one of the most important determinants of our health status. Although individual nutrients are still being evaluated for possible health benefits, research is also focusing on dietary patterns, or the totality of the diet, and resultant health benefits. However, we should note that research relative to the effects of diet, including specific nutrients, on health is complex and dietary

recommendations may change with new research findings. For example, as shall be noted later in the text, the guidelines regarding dietary intake of cholesterol have been modified after being in effect for more than 50 years.

Other than the health benefits of exercise and fitness, many physically active individuals also are finding the joy of athletic competition, participating in local sports events such as golf tournaments, tennis matches, triathlons, and road races. Individuals who compete athletically are always looking for a means to improve performance, be it a new piece of equipment or an improved training method. In this regard, proper nutrition may be a very important factor in improving sports performance. Various sports governing agencies indicate today's athletes need accurate sports nutrition information to maximize sports performance. Although the effect of diet on sports and exercise performance was studied only sporadically prior to 1970, subsequently numerous sports scientists and sports nutritionists have studied the performance-enhancing effects of nutrition, such as diet composition and dietary supplements. Results of these studies have provided nutritional guidance to enhance performance in specific athletic endeavors. In the United States, many universities and professional sports teams, such as those in Major League Baseball and the National Football League, employ registered dietitians as well as culinary chefs to provide dietary guidance to their athletes.

With the completion of the Human Genome Project, gene therapies are being developed for the medical treatment of various health problems. Moreover, some contend that genetic manipulations may be used to enhance sports performance. For example, gene doping to increase insulin-like growth factor, which can stimulate muscle growth, may be applied to sport.

Our personal genetic code plays an important role in determining our health status and our sports abilities, and futurists speculate that one day each of us will carry our own genetic chip that will enable us to tailor food selection and exercise programs to optimize our health and sports performance. Such may be the case, but for the time being we must depend on available scientific evidence to provide us with prudent guidelines.

Each year thousands of published studies and reviews analyze the effects of nutrition on health or exercise and sports performance. The major purpose of this text is to evaluate these scientific data and present prudent recommendations for individuals who want to modify their diet for optimal health or exercise/sports performance.

Textbook Overview

This book uses a question-answer approach, which is convenient when you may have occasional short periods to study, such as riding a bus or during a lunch break. In addition, the questions are arranged in a logical sequence, the answer to one question often leading into the question that follows. Where appropriate, cross-referencing within the text is used to expand the discussion. No deep scientific background is needed for the chemical aspects of nutrition and energy expenditure, as these have been simplified. Instructors who use this book as a course text may add details of biochemistry as they feel necessary.

Chapter 1 introduces you to the general effects of exercise and nutrition on health-related and sports-related fitness, including the importance of well-controlled scientific research. Chapter 2 provides a broad overview of sound guidelines relative to nutrition for optimal health and physical performance. Chapter 3 focuses on energy and energy pathways in the body, the key to all exercise and sports activities.

Chapters 4 through 9 deal with the six basic nutrients—carbohydrate, fat, protein, vitamins, minerals, and water—with emphasis on the health and performance implications for the physically active individual. Chapters 10 through 12 review concepts of body composition and weight control, with suggestions on how to gain or lose body weight through diet and exercise, as well as the implications of such changes for health and athletic performance. Chapter 13 covers several drug foods, such as alcohol and caffeine, and other related dietary supplements regarding their effects on health and exercise performance. Several appendixes complement the text, providing data on caloric expenditure during exercise; detailed metabolic pathways for carbohydrate, fat, and protein; methods to determine body composition; nutritional value of fast foods; and other information pertinent to physically active individuals.

New to the Eleventh Edition

The first edition of this textbook, titled *Nutrition for Fitness and Sport*, was published in 1983. I am joined in this eleventh edition by two professors who are actively involved in the disciplines of exercise physiology and sports nutrition, and who have used this text over the years to teach their university classes. J. David Branch is an associate professor in the Department of Human Movement Sciences at Old Dominion University in Virginia. His e-mail address is dbranch@odu.edu. Eric Rawson is a professor in the Department of Exercise Science at Bloomsburg University in Pennsylvania. His e-mail address is erawson@bloomu.edu. Dr. Branch revised chapters 6, 9, 10, 11, 12, and 13; Dr. Rawson revised chapters 4, 5, and 6; and I revised chapters 1, 2, 3, and 8.

The content throughout each chapter of the book has been updated, where merited, based on contemporary research findings regarding the effects of nutritional practices on health, fitness, and sports performance. Many sections throughout the text were completely rewritten in attempts to improve presentation

and clarity, such as the use of bullet points to summarize key points. More than 700 new references, including clinical studies, reviews, and meta-analyses, have been added to the text. Major changes include incorporation of the new *Dietary Guidelines for Americans*. The MyPlate model is designed to be more user friendly for the American population and is discussed in several chapters. New information from authoritative position statements dealing with exercise and nutrition issues has been incorporated into various chapters where relevant. These position statements have been developed by such prominent groups as the Academy of Nutrition and Dietetics, the American College of Sports Medicine, the American Academy of Pediatrics, the American Heart Association, the American College of Cardiology, the European College of Sport Science, the European Food Safety Authority, and Sports Dietitians Australia. Additionally, numerous Websites have been listed to help students explore various exercise and nutrition issues in more depth.

Chapter 1—Introduction to Nutrition for Health, Fitness, and Sports Performance

- New information on the use of various applications for health promotion
- Increased discussion of the use of various exercise gadgets, such as fitness bands and fitness watches, to help document daily amounts of physical activity and other aspects of lifestyle
- Update on the role of exercise to enhance health
- Introduction of high-intensity interval training (HIIT) and its possible application to exercise for health
- Introduction of the Compendium of Physical Activities, which is used in various chapters referring to energy expenditure during physical activities
- Increased use of reputable Websites to provide more detailed information on exercise and diet for health
- Discussion of new position stands, as related to a healthy diet by the Academy of Nutrition and Dietetics, the new name for the American Dietetic Association
- Introduction to the *2015 Dietary Guidelines for Americans*, the most recent report of the 2015 Dietary Guidelines Advisory Committee
- New application exercise for diet appraisal using several Website-based diet analyses by the Academy of Nutrition and Dietetics and other health profession groups
- Over 40 new references added and numerous dated citations deleted

Chapter 2—Healthful Nutrition for Fitness and Sport: The Consumer Athlete

- Updated discussion of dietary guidelines, including the debate over research with saturated fatty acids and the proposed new guidelines for cholesterol
- Introduction to the Academy of Nutrition and Dietetics position stand on the total diet approach to healthy eating
- Discussion of several smartphone applications (apps) to help you eat a healthier diet
- More details on how to use the MyPlate program to plan a healthier diet

- How to become an ambassador for ChooseMyPlate and healthy eating on your college campus
- Presentation of the Harvard Medical School modified MyPlate to present more specific recommendations for healthy eating
- Discussion of the proposed new food labels designed to make food shopping easier to select healthier foods
- An update on the controversy concerning use of GMO foods
- Use of various Websites to stay current, such as fruits and vegetables that fall into those with the lowest and highest pesticide content
- Over 40 new references, most of them reviews and meta-analyses

Chapter 3—Human Energy

- Enhanced discussion of techniques to measure energy expenditure, including the use of various commercial apps
- Presentation of more details on the use of the MET system to measure energy expenditure
- Presentation of a link to calculate your daily energy expenditure via five methods
- Over 30 new references

Chapter 4—Carbohydrates: The Main Energy Food

- Updated information on the role of the glycemic index in the risk of cardiovascular disease
- New data on the effectiveness of carbohydrate mouthrinse on endurance exercise performance
- New information on the effects of carbohydrate supplementation on exercise performance
- Updated information on the role of carbohydrate ingestion and resistance training
- New data on the effects of cycling carbohydrate intake on training adaptations and performance
- Update on approved sugar substitutes and artificial sweeteners and the effects on performance and weight gain
- Latest data on the effects of dietary fiber on morbidity and mortality
- Over 20 new references

Chapter 5—Fat: An Important Energy Source during Exercise

- Update on the effect of saturated fat on health
- New data on the effects of conjugated linoleic acid supplementation on body composition
- Update on the effects of omega fatty acid consumption on disease
- New data on avocado intake and cardiovascular health
- New research on the effects of dietary medium-chain triglycerides on weight loss and body composition
- Update on the effects of ketogenic diets on satiety and appetite
- Updated information on low-carbohydrate diets and weight loss
- Discussion of the potential effects of high-fat diets in endurance athletes
- Update on fasting and endurance exercise performance
- Over 20 new references

Chapter 6—Protein: The Tissue Builder

- Updated data on the effects of protein supplements on muscle mass, strength, and power
- New information on the effects of protein supplements on muscle damage, soreness, and recovery

- New data on the effects of protein plus carbohydrate ingestion on acute and repeated endurance exercise performance
- The latest protein intake recommendations on postexercise and before-sleep protein supplementation
- Update on the importance of dietary protein in satiety and weight loss
- Newest data on the safety of high protein intakes
- New data on creatine supplementation and muscle strength
- Latest information on beta-alanine supplementation
- Updated information on the effectiveness of HMB supplementation
- Update on the role of beetroot/nitrate ingestion on endurance exercise performance
- Over 20 new references

Chapter 7—Vitamins: The Organic Regulators

- New data on deficiency prevalence rates for folate and vitamins B₆, D, B₁₂, A, C, and E
- New information on vitamin D status, deficiency, and supplementation in athletes
- New information on vitamin E status and exercise performance
- New information on the effects of certain medications on vitamin B₁₂ deficiency
- New information on pantothenic acid and choline supplementation and performance
- Link to current comments from the American College of Sports Medicine regarding vitamin/mineral supplementation and exercise
- New information on the role of antioxidant supplementation in the older athlete
- New reviews on the ergogenic effects of coenzyme Q₁₀ and quercetin
- New studies of the role of vitamin B supplementation on homocysteine levels and primary and secondary stroke prevention
- New information on vitamin supplementation and the management of age-related macular degeneration and cataracts
- New information on the roles of antioxidant vitamins and vitamin D in mental health
- Over 50 new references

Chapter 8—Minerals: The Inorganic Regulators

- New information on who may be at risk for calcium deficiency.
- New data on research involving the ergogenic aspects of phosphate salt supplementation, including new studies and reviews
- New information on all trace minerals, including iron, zinc, copper, chromium, and others
- New section on manganese as a trace mineral
- New discussion of the metal hypothesis of Alzheimer's disease, which suggests some minerals may be protective but others may increase the risk
- Over 100 new references

Chapter 9—Water, Electrolytes, and Temperature Regulation

- Extensive revision to introduction and other parts of the text
- Several revised or new figures
- Updated information on U.S. and global sodium intake.

- Updated discussion of theoretical mechanisms of heat-related central nervous fatigue
- Updated information on glycerol’s status as a WADA banned substance
- Updated U.S. and global prevalence rates for hypertension
- Updated information on evolving guidelines for dietary sodium intake
- Over 70 new references

Chapter 10—Body Weight and Composition for Health and Sport

- Several revised or new figures
- Updated global prevalence rates for obesity
- New photograph of bioelectrical impedance procedure for body-composition assessment
- Inclusion of BMI categories representing apparent chronic energy deficiency
- Inclusion of body fat categories by gender and age, modified from *American College of Sports Medicine’s Guidelines for Exercise Testing and Prescription*, 9th edition, and The Cooper Institute, Dallas, Texas
- Updated discussion of brown adipose tissue
- Updated discussion of non-exercise activity thermogenesis (NEAT)
- Updated discussion of genetic contributions to obesity from genome-wide association studies (GRAS)
- Discussion of socioeconomic factors contributing to energy balance, such as more fast-food restaurants and unhealthy food choices in low-income areas
- New information on Calories consumed as sugar-sweetened beverages
- Expanded discussion of stress, environmental, viral exposure, and epigenetic factors and the built environment as contributors to obesity
- Discussion of the role of disruptions of normal intestinal bacteria in obesity
- Discussion of models other than the set-point theory as theoretical regulators of energy balance
- Expanded discussion of “screen-based” behaviors in impacting energy expenditure (sedentary activity) and intake (advertisements for energy-dense foods) in children and adults
- Expanded discussion of the health impacts of obesity to include increased risk for Alzheimer’s disease and other dementia
- Updated information on prescription weight-loss drugs approved by the U.S. Food and Drug Administration
- Updated information reflecting the four clinical eating disorders currently described in the American Psychiatric Association’s *Diagnostic and Statistical Manual of Mental Disorders—V*
- Discussion of the controversy surrounding replacing the term “female athlete triad” with “relative energy deficiency in sport (RED-S)”
- Over 140 new references

Chapter 11—Weight Management and Loss through Proper Nutrition and Exercise

- New information on a gastric stimulation device approved by the U.S. Food and Drug Administration

- New and revised figures throughout the chapter
- Incorporation of the Compendium of Physical Activities, which lists MET intensity values of many leisure and recreational activities as well as activities of daily living
- Discussion of the conversion of MET values into caloric expenditure to complement appendix B
- Incorporating the energy expenditure based on MET values from the Compendium with Physical Activity Levels and Coefficients in the National Academy of Sciences Estimated Energy Requirement formulas
- Inclusion of a web link to 171 small steps to a healthier diet and increased physical activity
- Inclusion of the proposed requirement by the U.S. Food and Drug Administration to include “added sugars” on Nutrition Facts labeling
- Inclusion of selected Websites listing caloric and nutritive value of fast-food restaurant foods to complement appendix E
- Inclusion of the current list of risk factors and signs/symptom of possible disease according to the American College of Sports Medicine
- Discussion of high-intensity interval training (HIIT) as a physical activity component of weight loss and weight maintenance
- Expanded discussion and figure for the “fat burning” myth in the selection of exercise intensity for fat loss and weight loss
- Recent studies comparing the efficacy of commercial weight-loss programs
- Over 90 new references

Chapter 12—Weight Gaining through Proper Nutrition and Exercise

- Updated *Healthy People 2020* information on the prevalence of resistance training among U.S. adults
- Added information on the importance of the branch-chain amino acid leucine in muscle growth
- New research on the effects of resistance training in the older adult
- New research on the efficacy of creatine supplementation combined with resistance training in the older adult
- Additional information on regulatory factors and cell signaling pathways in adaptations to resistance training
- New research on nutrient timing to facilitate postexercise muscle growth
- Revised sample weekly resistance training record sheet
- New research on the potential efficacy of higher protein intake in maintaining lean mass and reducing fat mass
- Over 20 new references

Chapter 13—Food Drugs and Related Supplements

- Revised figures throughout the chapter
- Updated World Health Organization data on the global effects of alcohol abuse on health and mortality
- Information on potential interactions between alcohol and prescribed pharmacological agents, especially in older adults
- Information on a potential role of coffee in decreasing alcoholic cirrhosis
- A link to recent alcohol-impaired traffic safety data

- Updated data on the health, academic, and psychological effects of alcohol in high school and college students
- Updated information from studies by the World Cancer Research Fund (WCRF)/ American Institute of Cancer Research (AICR) and the International Agency for Research of Cancer (IARC) on the link between alcohol and breast and other cancers
- Discussion of American Psychiatric Association's *Diagnostic and Statistical Manual of Mental Disorders—V* alcohol use disorder (AUD) diagnosis
- Links to online screening questionnaires for possible alcohol use disorder
- New information on the association of alcohol and Alzheimer's disease, mental health, and cognitive function
- Updated information on the role of alcohol and other ingredients in alcoholic drinks (e.g., polyphenols) on lipid metabolism, vascular function
- Research on the role of genetic variants in alcohol dehydrogenase in cardiovascular disease risk
- Updated data on the prevalence of coffee/caffeine use in the United States
- Updated information on the prevalence of energy drink use and concerns about the use of such products that also contain alcohol
- Updated research on the role of coffee/caffeine consumption and blood pressure and cardio-metabolic health
- Updated research on the role of coffee/caffeine in mental health, cognitive function, and multiple sclerosis
- Updated information on caffeine use in pregnancy and in infant health
- Updated information in recent discovery of amphetamine isomers in over-the-counter dietary supplements
- Updated status of pseudoephedrine (in addition to ephedrine, ephedra, and ma huang) as substances that are prohibited for use in competition by the WADA
- Updated information on U.S. Food and Drug Administration–mandated warnings about testosterone replacement therapy and increased risk for heart attacks and strokes
- Updated Centers for Disease Control and Prevention data on the prevalence of steroid use by teenagers
- Updated information on the efficacy of various herbals in improving body composition or performance
- Updated Australian Institute of Sports Classification System of Nutritional Supplements
- Over 110 new references

Appendices

- Updated several appendices, including those dealing with energy expenditure during exercise and the nutrient composition of products sold in fast-food restaurants

Enhanced Pedagogy

Each chapter contains several features to help enhance the learning process. **Chapter Learning Objectives** are presented at the beginning of each chapter, highlighting the key points and serving

as a studying guide. **Key Terms** also are listed at the beginning of each chapter, along with the page number on which they are first highlighted and defined. Although some terms may appear in the text before they are defined, a thorough glossary includes the key terms as well as other terms warranting definition. **Key Concepts** provide a summary of essential information presented throughout each chapter. Students are encouraged to participate in several practical activities to help reinforce learning. **Check for Yourself** includes individual activities, such as checking food labels at the supermarket or measuring one's own body fat percentage. The **Application Exercise** at the end of each chapter may require more extensive involvement, such as a case study in weight control involving yourself or a survey of an athletic team. Students may wish to peruse all application exercises at the beginning of the course, as some may take several weeks or months to complete.

The reference lists have been completely updated for this edition, with the inclusion of more than 700 new references, and provide the scientific basis for the new concepts or additional support for those concepts previously developed. These references provide greater in-depth reading materials for the interested student. Although the content of this book is based on appropriate scientific studies, a reference-citation style is not used, that is, each statement is not referenced by a bibliographic source. However, names of authors may be used to highlight a reference source where deemed appropriate.

This book is designed primarily to serve as a college text in professional preparation programs in health and physical education, exercise science, athletic training, sports medicine, and sports nutrition. It is also directed to the physically active individual interested in the nutritional aspects of physical and athletic performance.

Those who desire to initiate a physical training program may also find the nutritional information useful, as well as the guidelines for initiating a training program. This book may serve as a handy reference for coaches, trainers, and athletes. With the tremendous expansion of youth sports programs, parents may find the information valuable relative to the nutritional requirements of their active children.

In summary, the major purpose of this book is to help provide a sound knowledge base relative to the role that nutrition, complemented by exercise, may play in the enhancement of both health and sports performance. We hope that the information provided in this text will help the reader develop a more healthful and performance-enhancing diet. Bon appetit!

Acknowledgments

This book would not be possible without the many medical/health scientists and exercise/sports scientists throughout the world who, through their numerous studies and research, have provided the scientific data that underlie its development. We are fortunate to have developed a friendship with many of you, and we extend our sincere appreciation to all of you.

We would like to acknowledge deep gratitude to Mandy Clark, Product Developer at McGraw-Hill, for her dedicated support throughout the revision process. Mandy was always available to address queries regarding various facets of the production process, and her responses were very prompt. We would also like to thank Anna Hoppmann, Digital Asset Librarian, for her assistance in navigating the photo database of McGraw-Hill, and Jessica Portz, our project manager. Our deep gratitude to Marija Magner, Brand Manager.


*Melvin H. Williams
Norfolk, Virginia*

*J. David Branch
Norfolk, Virginia*

*Eric S. Rawson
Bloomsburg, Pennsylvania*

Instructor Resources

Available at www.mhhe.com/williams are a number of instructor and student resources to accompany the text. For students, these include a BMI calculator, animations, daily food log, and more. For instructors, resources include PPT lecture outlines, image PowerPoint files, and more.

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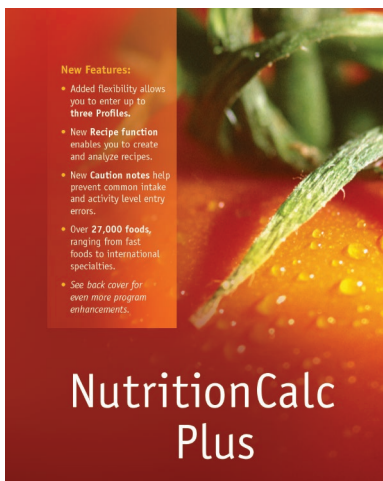
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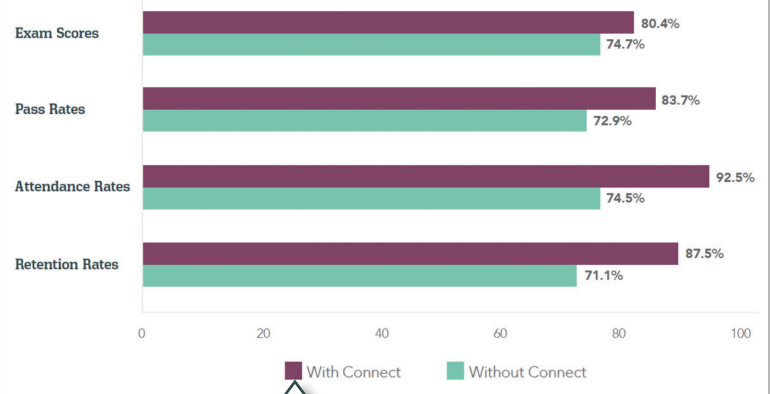
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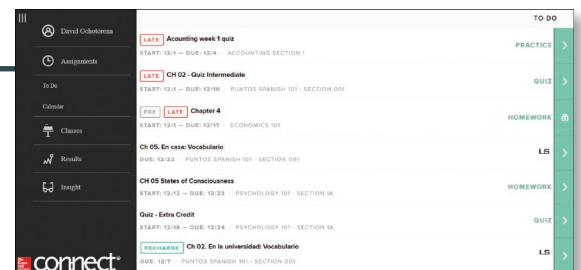
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Introduction to Nutrition for Health, Fitness, and Sports Performance

K E Y T E R M S

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cytokines 7
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epidemiological research 28
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epigenome 2
ergogenic aids 21
exercise 4
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health-related fitness 4
high-intensity interval training (HIIT) 9
malnutrition 20
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nutrient 12

CHAPTER ONE

LEARNING OBJECTIVES

After studying this chapter, you should be able to:

1. Explain the role of both genetics and environment, particularly nutrition and exercise, in the determination of optimal health and successful sport performance.
2. List each of the components of health-related fitness and then identify the potential health benefits of an exercise program designed to enhance both aerobic and musculoskeletal fitness.
3. Define sports-related fitness and compare it to health-related fitness, noting similarities and differences.
4. List the seven principles of exercise training and explain the importance of each.
5. List the 12 guidelines underlying the Prudent Healthy Diet and discuss, in general, the importance of proper nutrition to optimal health.
6. Understand the importance of proper nutrition, including the role of dietary supplements as ergogenic aids, to sports performance.
7. Define nutritional quackery and understand the various strategies you can use to determine whether claims regarding a dietary supplement are valid.
8. Explain what types of research have been used to evaluate the relationship between nutrition and health or sport performance, and evaluate the pros and cons of each type.

nutrition 12
physical activity 4
physical fitness 4
promoters 13
Prudent Healthy Diet 15
quackery 24
risk factor 2
Sedentary Death Syndrome (SeDS) 6
sports nutrition 18
sports-related fitness 17
sports supplements 22
structured physical activity 4
unstructured physical activity 4

Introduction

There are two major focal points of this book. One is the role that nutrition, complemented by physical activity and exercise, may play in the enhancement of one's health status. The other is the role that nutrition may play in the enhancement of fitness and sports performance. Many individuals today are physically active, and athletic competition spans all ages. Healthful nutrition is important throughout the life span of the physically active individual because suboptimal health status may impair training and competitive performance. In general, as we shall see, the diet that is optimal for health is also optimal for exercise and sports performance.

Nutrition, fitness, and health. Health care in most developed countries has improved tremendously over the past century. Although some rather rare diseases, such as Ebola, are a cause for concern, primarily because of the dedicated work of medical researchers we no longer fear the scourge of major acute infectious diseases such as polio, smallpox, or tuberculosis. However, we have become increasingly concerned with the treatment and prevention of chronic diseases. The World Health Organization (WHO) indicates that chronic diseases are now the major cause of death and disability worldwide. According to the U.S. Department of Health and Human Services (HHS), unhealthy eating and physical inactivity are leading causes of death in the United States. Given with rank in parentheses, they include (1) diseases of the heart, (2) cancer, (3) stroke, (4) chronic lung diseases, (6) diabetes, (8) Alzheimer's disease, and (9) chronic kidney diseases. These diseases cause more than 85 percent of all deaths, and this figure is destined to rise as the U.S. population becomes increasingly older, particularly during the first quarter of this century when the baby boomers of the 1940s and 1950s reach their senior years.

The two primary factors that influence one's health status are genetics and lifestyle. According to Simopoulos, all diseases have a genetic predisposition. The Human Genome Project, which deciphered the DNA code of our 80,000 to 100,000 genes, has identified various

genes associated with many chronic diseases, such as breast and prostate cancer. Genetically, females whose mothers had breast cancer are at increased risk for breast cancer, while males whose fathers had prostate cancer are at increased risk for prostate cancer.

Completion of the Human Genome Project is believed to be one of the most significant medical advances of all time. Although multiple genes are involved in the etiology of most chronic diseases and research regarding the application of the findings of the Human Genome Project to improve health is still in its initial stages, the future looks bright. For individuals with genetic profiles predisposing them to a specific chronic disease, such as cancer, genetic therapy eventually may provide an effective treatment or cure.

Although genetic influences may play an important role predisposing an individual to a chronic disease, so, too, does lifestyle. The CDC notes that although chronic diseases are among the most common and costly health problems, they are also among the most preventable by adopting a healthy lifestyle. Over the years, scientists in the field of epidemiology have identified a number of lifestyle factors considered to be health risks; these lifestyle factors are known as risk factors. A **risk factor** is a lifestyle behavior that has been associated with a particular disease, such as cigarette smoking being linked to lung cancer.



A major risk factor is being overweight or obese, a condition which affects almost two-thirds of Americans and is increasing worldwide.

The Department of Health and Human Services recently

listed the leading lifestyle-related causes of premature death in the United States. The combination of an unhealthy diet and physical inactivity, which may contribute to being overweight or obese, was ranked as the leading cause, followed by tobacco use and alcohol abuse.

In a recent review, Hall noted that our genes harbor many secrets to a long and healthy life but also noted that genes alone are unlikely to explain all the secrets of longevity. The role of a healthful diet and exercise are intertwined with your genetic profile. What you eat and how you exercise may influence your genes. **Epigenetics** is a relatively new field of research involving the role of the **epigenome**, a structure located just outside the genome that may activate or deactivate DNA and subsequent genetic and cellular activity. Cloud noted that various factors in our environment, such as substances in the foods we eat, may interact with the epigenome and thus modify cell functions—either in a positive or negative manner. Exercise, as noted later, also stimulates release of substances from muscle cells that may affect the epigenome. Cloud notes that comparable to the Human Genome Project, a Human Epigenome Project is under way,

and epigenetics may eventually lead to many beneficial health-related applications. For example, if personal genetic code indicates that your genetic profile predisposes you to certain forms of cancer, and if your genetic profile indicates that you will respond favorably to specific nutritional or exercise interventions, then a preventive diet and an exercise plan may be individualized for you. Genomics represents the study of genetic material in body cells, and the terms *nutrigenomics* and *exercisgenomics* have been coined to identify the study of the genetic aspects of nutrition and exercise, respectively, as related to health benefits. *Sportomics* involves study of the metabolic response of the athlete in an actual sport environment, not in a laboratory.

Treatment of chronic diseases is very expensive. Foreseeing a financial health-care crisis associated with an increasing prevalence of such diseases during the first half of this century, most private and public health professionals have advocated health promotion and disease prevention as the best approach to address this potential major health problem. Martinez-Perez and others note that with more than 1 billion smart phones around the world, the use of various applications for health promotion has great potential. The HHS, beginning in the 1980s, has published a series of reports designed to increase the nation's health; the latest version is entitled *Healthy People 2020: National Health Promotion/Disease Prevention Objectives*. Physical activity/fitness and overweight/obesity are two of the major focus areas. These reports emphasize that lifestyle behaviors that promote health and reduce the risk of chronic diseases are basically under the control of the individual. The role of diet and

exercise in health promotion has become a worldwide priority, as documented in the WHO report *Global Strategy on Diet, Physical Activity and Health*. The guidelines presented in these reports underlie the recommendations presented in this book. For both reports, see web addresses below.

As we shall see, proper exercise and proper nutrition, both individually and combined, may reduce many of the risk factors associated with the development of chronic diseases. These healthful benefits will be addressed at appropriate points throughout the book.

Nutrition, fitness, and sport. *Sport* is now most commonly defined as a competitive athletic activity requiring skill or physical prowess, for example, baseball, basketball, soccer, football, track, wrestling, tennis, and golf. As with health status, athletic ability and subsequent success in sport are based primarily upon genetics and epigenetics. In a review of epigenetics in sport, Ehlert and others note that natural genetic endowment with characteristics important to a specific sport must be maximized through epigenetic modifications by appropriate type and amount of training.

To be successful at high levels of competition, athletes must possess the appropriate biomechanical, physiological, and psychological genetic characteristics associated with success in a given sport. International-class athletes have such genetic traits. In recent reviews, Tucker and others highlighted the genetic basis for elite running performance while Eynon and others discussed the role of genes for elite power and sprint performance. Moreover, Wolfarth and others have

assembled a human gene map for performance and health-related fitness.

To be successful at high levels of competition, athletes must also develop their genetic characteristics maximally through proper biomechanical, physiological, and psychological coaching and training. Whatever the future holds for genetic enhancement of athletic performance, specialized exercise training will still be the key to maximizing genetic potential for a given sport activity. Training programs at the elite level have become more intense and individualized, sometimes based on genetic predispositions. Modern scientific training results in significant performance gains, and world records continue to improve. David Epstein, in his book *The Sports Gene*, provides a fascinating account of the role both genes and the training environment play relative to elite performance.

Proper nutrition also is an important component in the total training program of the athlete. Certain nutrient deficiencies can seriously impair performance, whereas supplementation of other nutrients may help delay fatigue and improve performance. Over the past 50 years, research has provided us with many answers about the role of nutrition in athletic performance, but unfortunately some findings have been misinterpreted or exaggerated so that a number of misconceptions still exist.

The purpose of this chapter is to provide a broad overview of the role that exercise and nutrition may play relative to health, fitness, and sport, and how prudent recommendations may be determined. More detailed information regarding specific relationships of nutritional practices to health and sports performance is provided in subsequent chapters.



www.health.gov/healthypeople Check for the full report of *Healthy People 2020*.

www.who.int/dietphysicalactivity/en/ Check for the World Health Organization report on diet and physical activity for health.

www.ncbi.nlm.nih.gov/genome/guide/human/ For the interested reader, this site accesses the human genome map and the National Institutes of Health Epigenetics Roadmap.

Key Concepts



- ▶ Many chronic diseases in major developed countries (heart diseases, cancer, stroke, lung diseases, and diabetes) may be prevented by appropriate lifestyle behaviors, particularly proper exercise and a healthy diet.
- ▶ The two primary determinants of health status are genetics and lifestyle.

- ▶ Several of the key health promotion objectives set by the U.S. Department of Health and Human Services in *Healthy People 2020* are increased levels of physical activity, a healthier diet, and reduced levels of overweight and obesity.
- ▶ Sports success is dependent on biomechanical, physiological, and psychological genetic characteristics specific to a given sport, but proper training, including proper nutrition, is essential to maximize one's genetic potential.

Check for Yourself



- ▶ Discuss with your parents any health problems they or your grandparents may have, such as high blood pressure or diabetes, to determine whether you may be predisposed to such health problems in the future. Having such knowledge may help you develop a preventive exercise and nutrition plan early in life. Please use the following website to create your own family history.
www.hhs.gov/familyhistory Create your own family health history.

Health-Related Fitness: Exercise and Nutrition

Physical fitness may be defined, in general terms, as a set of abilities individuals possess to perform specific types of physical activity. The development of physical fitness is an important concern of many professional health organizations, including the Society of Health and Physical Educators (SHAPE), which has classified fitness components into two different categories. In general, these two categories may be referred to as health-related fitness and sports-related fitness. Both types of fitness may be influenced by nutrition and exercise.

Exercise and Health-Related Fitness

What is health-related fitness?

As mentioned previously, one's health status or wellness is influenced strongly by hereditary predisposition and lifestyle behaviors, particularly appropriate physical activity and a high-quality diet. As we shall see in various sections of this book, one of the key factors in preventing the development of chronic disease is maintaining a healthful body weight.

Proper physical activity may certainly improve one's health status by helping to prevent excessive weight gain, but it may also enhance other facets of health-related fitness as well. **Health-related fitness** includes not only a healthy body weight and composition but also cardiovascular-respiratory fitness, adequate muscular strength and muscular endurance, and sufficient flexibility (figure 1.1). As one ages, other measures used as markers of health-related fitness include blood pressure, bone strength, postural control and balance, and various indicators of lipid and carbohydrate metabolism.

Several health professional organizations, such as the American College of Sports Medicine (ACSM) and American Heart Association (AHA), have indicated that various forms of physical activity may be used to enhance health. In general, **physical activity** involves any bodily movement caused by muscular contraction that results in the expenditure of energy. For purposes of studying its effects on health, some epidemiologists classify physical activity as either unstructured or structured.

Unstructured physical activity, also known as leisure-time activity, includes many of the usual activities of daily living, such as leisurely walking and cycling, climbing stairs, dancing, gardening and yard work, various domestic and occupational activities, and games and other childhood pursuits. These unstructured activities are not normally planned to be exercise. However, as will be noted in chapter 11, these so-called nonexercise activities may play an important role in body weight control.

Structured physical activity, as the name implies, is a planned program of physical activities usually designed to improve physical fitness, including health-related fitness. For the purpose of this book, we shall refer to structured physical activity as **exercise**, particularly some form of planned moderate or vigorous exercise, such as brisk, not leisurely, walking.

What are the basic principles of exercise training?

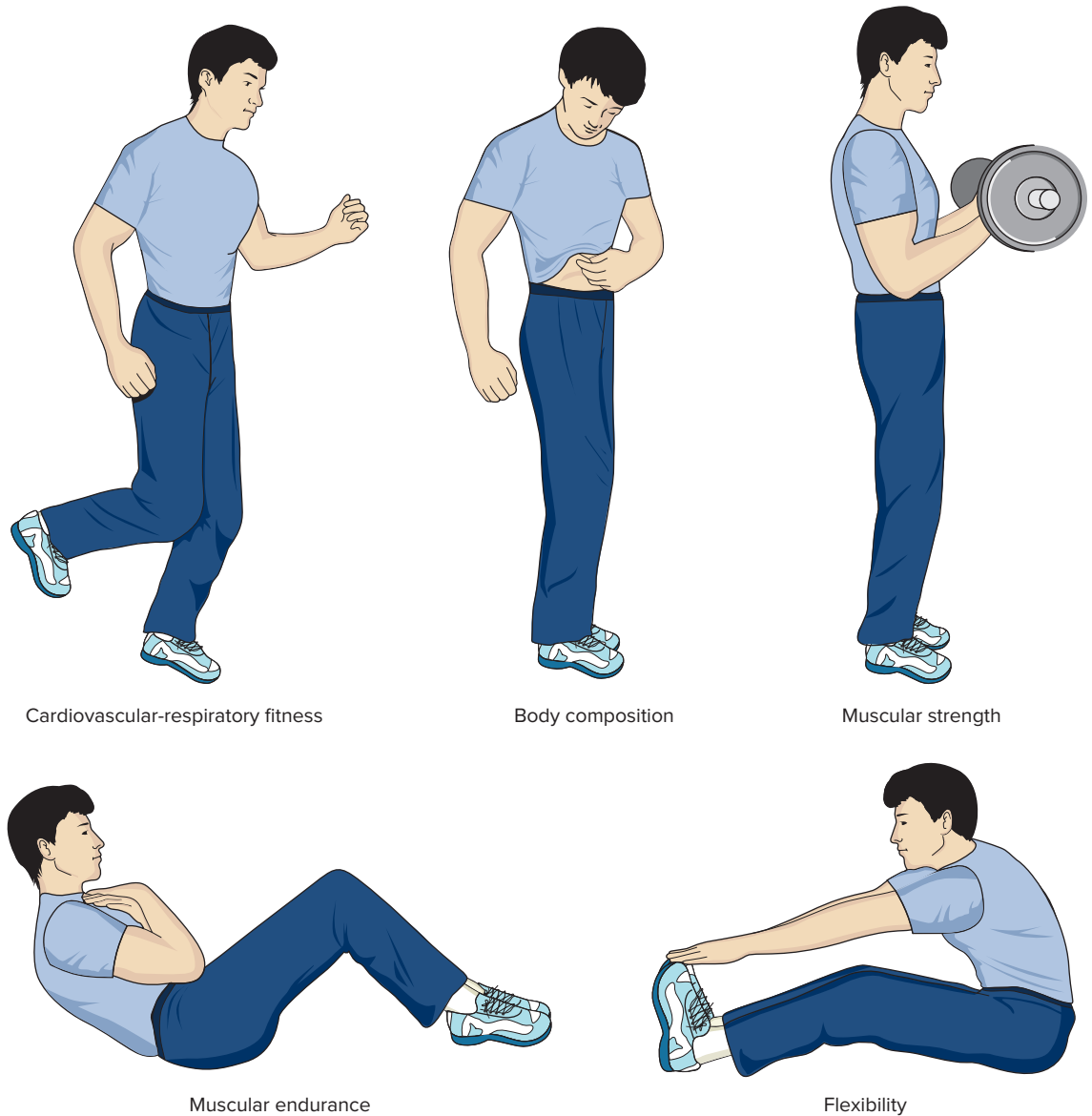
Exercise training programs may be designed to provide specific types of health-related fitness benefits and/or enhance specific types of sports-related fitness. However, no matter what the purpose, several general principles are used in developing an appropriate exercise training program.

Principle of Overload Overload is the basic principle of exercise training, and it represents the intensity, duration, and frequency of exercise. For example, a running program for cardiovascular-respiratory fitness could involve training at an intensity of 70 percent of maximal heart rate, a duration of 30 minutes, and a frequency of 5 times per week. The adaptations the body makes are based primarily on the specific exercise overload. The terms *moderate* exercise and *vigorous* exercise are often used to quantify exercise intensity and are discussed later in this chapter and in more detail in chapter 11.

Principle of Progression Progression is an extension of the overload principle. As your body adapts to the original overload, the overload must be increased if further beneficial adaptations are desired. For example, you may start lifting a weight of 20 pounds, increase the weight to 25 pounds as you get stronger, and so forth. The overloads are progressively increased until the final health-related or sports-related goal is achieved or exercise limits are reached.

Principle of Specificity Specificity of training represents the specific adaptations the body will make in response to the type of exercise and overload. For example, running and weight lifting impose different demands on muscle energy systems, so the body adapts accordingly. Both types of exercise may provide substantial, yet different, health benefits. Exercise training programs may be designed specifically for certain health or sports-performance benefits.

FIGURE 1.1 Health-related fitness components. The most important physical fitness components related to personal health include cardiovascular-respiratory fitness, body composition, muscular strength, muscular endurance, and flexibility.



Principle of Recuperation Recuperation is an important principle of exercise training. Also known as the principle of recovery, it represents the time in which the body rests after exercise. This principle may apply within a specific exercise period, such as including rest periods when doing multiple sets during a weight-lifting workout. It may also apply to rest periods between bouts of exercise, such as a day of recovery between two long cardiovascular workouts.

Principle of Individuality Individuality reflects the effect exercise training will have on each individual, as determined by genetic characteristics. The health benefits one receives from a specific exercise training program may vary tremendously among individuals. For example, although most individuals with high blood pressure may experience a reduction during a cardiovascular-respiratory fitness training program, some may not.

Principle of Reversibility Reversibility is also referred to as the principle of disuse, or the concept of *use it or lose it*. Without the

use of exercise, the body will begin to lose the adaptations it has made over the course of the exercise program. Individuals who suffer a lapse in their exercise program, such as a week or so, may lose only a small amount of health-related fitness gains. However, a total relapse to a previous sedentary lifestyle can reverse all health-related fitness gains.

Principle of Overuse Overuse represents an excessive amount of exercise that may induce some adverse, rather than beneficial, health effects. Overuse may be a problem during the beginning stages of an exercise program if one becomes overenthusiastic and exceeds her capacity, such as developing shin splints by running too far. Overuse may also occur in elite athletes who become over-trained, as discussed in chapter 3.

Specific exercise programs for healthy body weight and composition, cardiovascular-respiratory fitness, and muscular strength and muscular endurance are detailed in chapters 11 and 12, and several of these principles are discussed in more detail.

What is the role of exercise in health promotion?

The beneficial effect of exercise on health has been known for centuries. For example, Plato noted that “lack of activity destroys the good condition of every human being while movement and methodical physical exercise save and preserve it.” Plato’s observation is even more relevant in contemporary society. Frank Booth, a prominent exercise scientist at the University of Missouri, has coined the term **Sedentary Death Syndrome**, or **SeDS**, and he and his colleagues recently noted that physical inactivity is a primary cause of most chronic diseases, the major killers in the modern era. Slentz and others discussed the cost of physical inactivity over time. The *short-term* cost of physical inactivity is metabolic deterioration and weight gain; the *intermediate-term* cost is an increase in disease, such as type 2 diabetes, whereas the *long-term* cost is increased premature mortality.

To help promote the health benefits of physical activity, the American College of Sports Medicine and the American Medical Association (AMA) launched a program, entitled *Exercise Is Medicine™*, designed to encourage physicians and other health-care professionals to include exercise as part of the treatment for every patient. Clinical, epidemiological, and basic research evidence clearly supports the inclusion of regular physical activity as a tool for the prevention of chronic disease and the enhancement of overall health. Booth and others note that physical activity/exercise has been studied as a primary prevention against 35 chronic health problems, and numerous studies and reviews have documented the manifold health benefits, which are highlighted in the following list and in figure 1.2.

- Control body weight
- Reduce risk of metabolic syndrome
- Reduce risk of high blood pressure
- Reduce risk of type 2 diabetes
- Enhance blood lipid profile
- Reduce risk of heart disease
- Promote recovery from heart disease
- Reduce risk of stroke
- Reduce risk of breast cancer
- Reduce risk of colon cancer
- Improve self-image
- Reduce risk of mental depression
- Enhance cognitive functions in the elderly
- Reduce risk of falls in the elderly
- Delay onset and severity of Alzheimer’s disease
- Strengthen bones and muscles
- Reduce arthritis pain
- Improve immune functions



FIGURE 1.2 Exercise is medicine. Here are some of the benefits of regular moderate physical activity and exercise. See text for discussion.

- Promote healthy pregnancy of mother and fetus
- Improve quality of sleep
- Improve quality of life
- Increase longevity

These benefits may accrue to males and females of all races across all age spans. You are never too young or too old to reap some of these health benefits of exercise.

In essence, physically active individuals enjoy a higher quality of life, a *joie de vivre*, because they are less likely to suffer the disabling symptoms often associated with chronic diseases, such as loss of ambulation experienced by some stroke victims. As noted in the next section, physical activity may also increase the quantity of life. As quoted by Greider, James Fries, an emeritus professor who studies healthy aging at the Stanford University School of Medicine’s Center on Longevity, said, “If you had to pick one thing, one single thing that came closest to the fountain of youth, it would have to be exercise.”

How does exercise enhance health?

Recent news reports made headlines around the world, such as one entitled *Exercise Benefits: Rivals Drugs for Stroke, Heart Disease Treatment*. The question is, How?

The specific mechanisms whereby exercise may help to prevent the development of various chronic diseases are not completely understood but are involved with changes in gene expression that modify cell structure and function. Physical inactivity is a major risk factor for chronic diseases. As noted previously, Booth and Neuffer indicated physical inactivity causes genes to misexpress proteins, producing the metabolic dysfunctions that result in overt clinical disease if continued long enough. In contrast, exercise may cause the expression of genes with favorable health effects.

Most body cells can produce and secrete small proteins known as **cytokines**, which are similar to hormones and can affect tissues throughout the body. Cytokines enter various body tissues, influencing gene expression that may induce adaptations either favorable or unfavorable to health (figure 1.3). Two types of cytokines are of interest to us. Muscle cells produce various cytokines called *myokines* (referred to as *exerkines* when produced during exercise), whereas fat (adipose) cells produce cytokines called *adipokines*. Muscle cells also produce *heat shock proteins (HSPs)*, which may have beneficial health effects. The following represent several important cytokines produced in muscle and fat cells:

Muscle Cells	Fat Cells
Interleukin-6 (IL-6)	Tumor Necrosis Factor-alpha (TNF- α)
Brain-Derived Neurotrophic Factor (BDNF)	Adiponectin

Overall, Brandt and Pederson theorize that exercise-induced cytokine effects on genes reduce many of the traditional risk factors associated with development of chronic diseases; Geiger and others note similar effects for HSPs. In particular, McAtee notes

that one of the common causes of various chronic diseases is an inflammatory environment created by the presence of excess fat, particularly within blood vessels. Local inflammation is thought to promote the development of heart disease, cancer, diabetes, and dementia. According to Nimmo and others, exercise produces an anti-inflammatory cytokine that may help cool inflammation and reduce such health risks. They note that the most marked improvements in the inflammatory profile are conferred with exercise performed at higher intensities, with combined aerobic and resistance exercise training potentially providing the greatest benefit.

Cytokines and heat shock proteins may prevent chronic diseases in other ways as well, such as increasing the number of glucose receptors in muscle cells, improving insulin sensitivity, and helping to regulate blood glucose and prevent type 2 diabetes.

There are also other health-promoting mechanisms of exercise. One of the most significant contributors to health problems with aging is sarcopenia, or loss of muscle tissue. In their review, Landi and others conclude that regular exercise is the only strategy found to consistently prevent frailty and improve sarcopenia and physical function in older adults. The following are some other examples:

- Loss of excess body fat may reduce production of cytokines that may impair health.
- Loss of excess body fat may reduce estrogen levels, reducing risk of breast cancer.
- Reduction of abdominal obesity may decrease blood pressure and serum lipid levels.
- Increased mechanical stress on bone with high-impact exercise may stimulate increases in bone density.
- Production of some cytokines, such as BDNF, may enhance neurogenesis and brain functions.

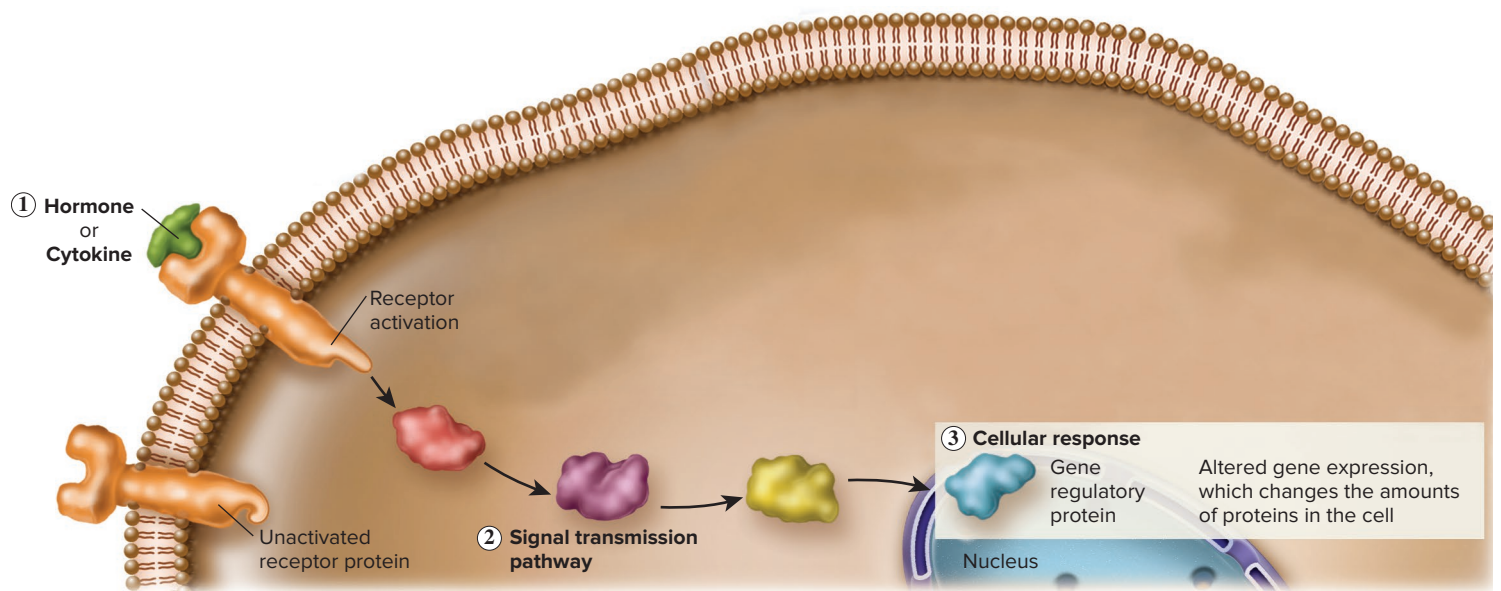


FIGURE 1.3 Exercise may induce adaptations that have favorable health effects in various body tissues. One suggested mechanism is the effect that various hormones or cytokines, which are produced during exercise, may have on gene regulation in body cells. (1) The hormone or cytokine binds to a cell receptor that activates a signal within the cell, (2) the signal is transmitted along a specific pathway, (3) the signal may alter gene expression and induce changes within the cell. Cell signals may also affect enzymes or other cell structures that may induce beneficial health effects.

Some healthful adaptations may occur with a single bout of exercise. Nimmo and others reported that single bouts of exercise have a potent anti-inflammatory influence, while others have noted that a single exercise session can acutely improve the blood lipid profile, reduce blood pressure, and improve insulin sensitivity, all beneficial responses. However, such adaptations will regress unless exercise becomes habitual. Thus, to maximize health benefits, exercise should be done most days of the week because many of its benefits stem from the most recent exercise sessions. The role that exercise may play in the prevention of some chronic diseases, such as heart disease and diabetes, and associated risk factors, such as obesity, are discussed throughout this book where relevant.

Do most of us exercise enough?

In general, NO. Surveys reveal that most adult Americans and Canadians have little or no physical activity in their daily lives. For example, the *Healthy People 2020* report from the United States Department of Health and Human Services indicates that more than 80 percent of adults do not meet the guidelines for both aerobic and muscle-strengthening activities. Similarly, a recent study by Song and others indicated more than 80 percent of adolescents do not do enough aerobic physical activity to meet the guidelines for youth. Harvey and others reported the majority of older adults are sedentary, many sitting for prolonged periods. Thus, one of the major goals of *Healthy People 2020* is to decrease the amount of physical inactivity, such as television viewing, and increase the amount of physical activity in both adults and youth.

How much physical activity is enough for health benefits?

In general, there is a curvilinear relationship between the amount of physical activity (dose) and related health benefits (response), as depicted by the dose-response graph in figure 1.4. A sedentary lifestyle has no health benefits, but health benefits increase rapidly with low to moderate levels of weekly activity. Beyond moderate levels of weekly physical activity, the increase in health benefits will continue to increase gradually and then plateau. Excessive exercise may actually begin to have adverse effects on some health conditions.

However, as noted by Bouchard, there may be other specific dose-response curves. Some health conditions may improve rapidly with low to moderate weekly levels of physical activity, whereas others may necessitate increased levels. As an example of the latter, the ACSM Position Stand on physical activity and weight loss has noted that while moderate-intensity exercise between 150 and 250 minutes weekly will provide only modest weight loss, greater amounts of physical activity, averaging more than 250 minutes weekly, have been associated with clinically significant weight loss. Dependent on the desired health outcome, the dose (intensity, duration, frequency) of physical activity may vary accordingly, as will type of physical activity. To reap the health benefits of exercise, most health professionals recommend a comprehensive program of physical activity, including aerobic exercise and resistance training. Flexibility and balance exercises become increasingly important for older adults. In general, the

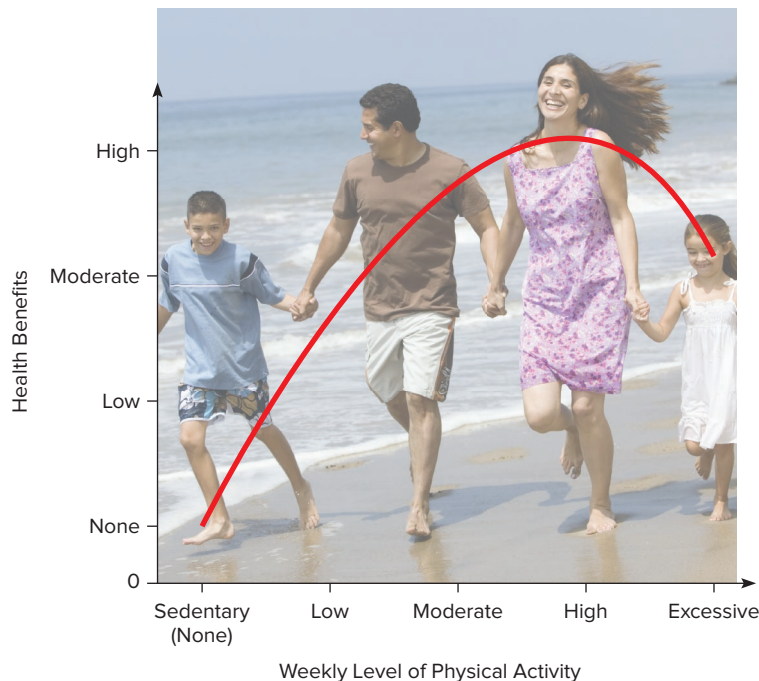


FIGURE 1.4 Significant health benefits may occur at low to moderate levels of physical activity with diminishing returns at higher levels. Excessive amounts or intensity of exercise, depending on the individual, may predispose to various types of health problems. See text for discussion.

following recommendations for adults have been formatted into a MyActivity Pyramid, a graphic depicting exercise guidelines. The latest version, developed by Stephen Ball at the University of Missouri, is presented in figure 1.5.

Numerous reports providing exercise recommendations for health benefits have been released by various professional and governmental health-related organizations, including the *Physical Activity Guidelines for Americans* from the U.S. Department of Health and Human Services and the *National Physical Activity Plan*, a coalition report from the American Heart Association, the American College of Sports Medicine, the Centers for Disease Control and Prevention, and many other such organizations. Here are some of the key points to help you reap the many health benefits of physical activity.

- **Individualization.** Exercise programs should be individualized based on physical fitness level and health status. Claude Bouchard, an expert in genetics, exercise, and health, noted that due to genes, physical activity may benefit some, but not others. For example, although most sedentary individuals will respond favorably to an aerobic exercise training program, such as an improved insulin sensitivity, others will not respond and have no change in insulin sensitivity. Currently, there is no gene profile for responders and nonresponders to exercise training, but that may change in the future so that specific exercise programs may be designed for individuals.
- **Leisure-time activity.** A key component of a fitness plan is simply to reduce the amount of daily sedentary activity. One important modification to your daily lifestyle is to sit less and

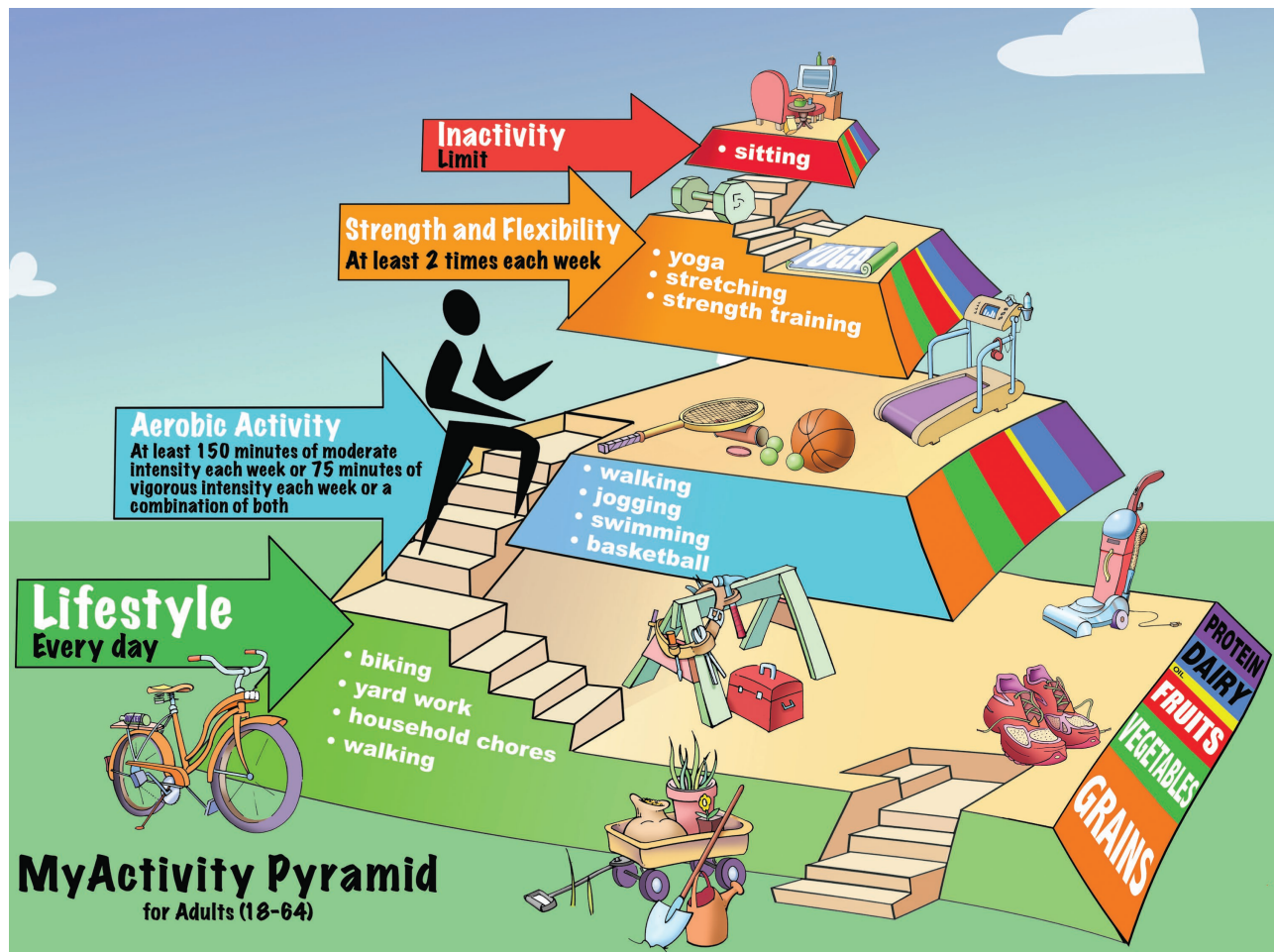


FIGURE 1.5 One version of a physical activity pyramid. See text for more specific information regarding exercise intensity and duration for adults and older adults.

Courtesy of Dr. Stephen D. Ball, Department of Nutrition and Exercise Physiology, University of Missouri, Columbia, MO.

move more. Here are some examples to help build light physical activity into your daily schedule:

- If you sit all day at work, take a short break every hour and walk around for several minutes.
- Take a walk after lunch and dinner.
- Walk to the store instead of driving.
- Stand instead of sit when you can.
- Get up and move during commercial breaks when watching television.
- Take the stairs instead of the elevator.
- Walk your dog instead of letting him out into the backyard (your dog needs exercise too).

Accumulating more daily unstructured physical activity may be very helpful in maintaining a healthy body weight. Additionally, leisurely walking may be adequate physical activity for elderly individuals with compromised health status or very low fitness levels.

- **Aerobic exercise.** For important health benefits, both adults and older adults should engage in moderate-intensity aerobic (endurance) exercise, such as brisk walking, for a minimum

of 150 minutes every week, or about 30 minutes for 5 days. Alternatively, both may engage in vigorous-intensity exercise, such as jogging or running, for 75 minutes every week. Gibala and others noted the term **high-intensity interval training (HIIT)** should be used to describe protocols in which the training stimulus is “near maximal” or the target intensity is between 80 and 100 percent of maximal heart rate. They also suggest *sprint interval training (SIT)* be used for protocols that involve supramaximal efforts, in which target intensities correspond to workloads greater than what is required to elicit 100 percent of maximal oxygen uptake (VO_2 max). These supramaximal exercise tasks may be accomplished in much less time as compared to moderate-intensity exercise, and Kilpatrick and others indicate 75 minutes weekly of such exercise could provide significant health benefits. Additionally, adults may engage in an equivalent mix of moderate- and vigorous-intensity exercise over the course of the week.

Children and adolescents should do 60 minutes of moderate to vigorous physical activity daily. Short bursts of vigorous activity in games are included. Exergames, interactive video games that promote physical activity, may hold promise to promote aerobic physical activity in youth.