Introduction To

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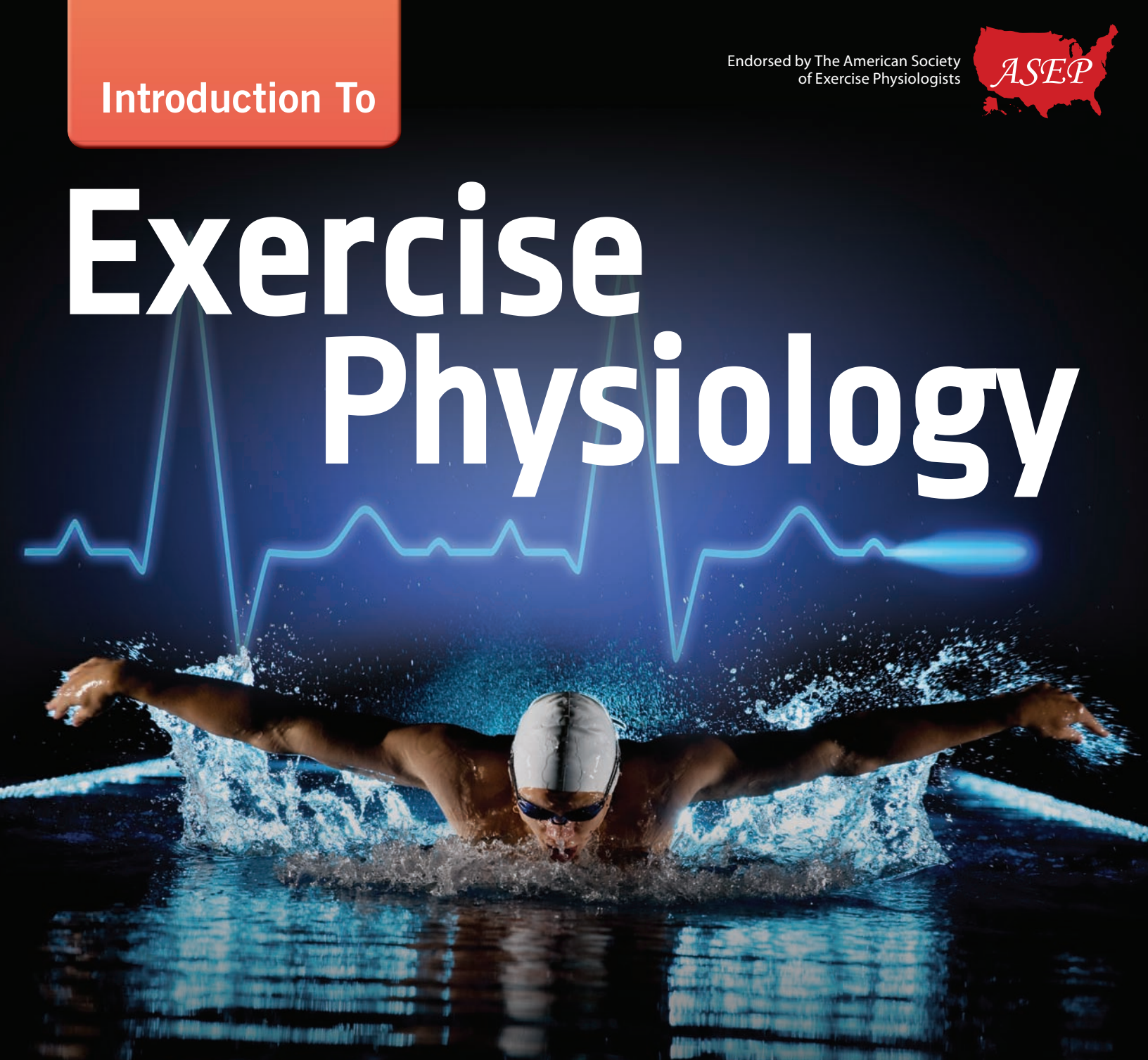
ASEP

Exercise Physiology



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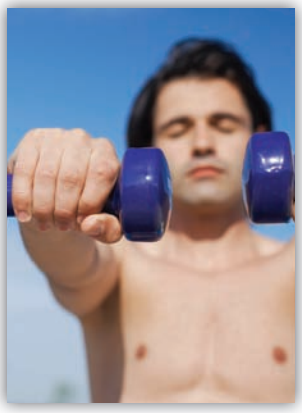
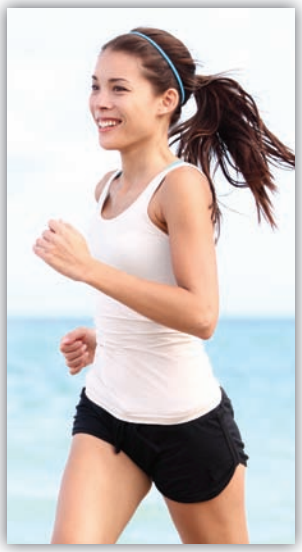
I dedicate this book to my family and friends, whose support and encouragement sustain me, and to my colleagues, who continue to motivate and inspire me. Their commitment to ASEP has shaped the foundational concepts of professionalism in exercise physiology. Finally, I dedicate this book to my students, undergraduate through doctoral, both past and present.

Brief Contents

Contents





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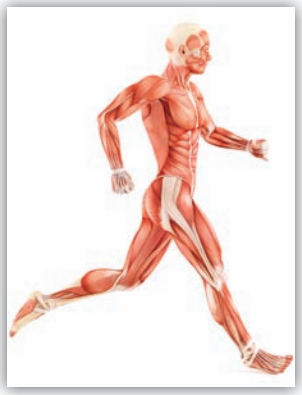


Preface

During the past several decades, exercise physiologists have emphasized the importance of regular exercise in the prevention of chronic diseases associated with a sedentary lifestyle. Obesity, type II diabetes, metabolic syndrome, cardiac dysfunction, hypertension, and osteoporosis can be helped or even reversed with properly prescribed exercise. The information in this book serves as the foundation of an evolutionary concept that "exercise is medicine."

Introduction to Exercise Physiology is designed to educate the reader about the human body and how to care for it. This knowledge encourages critical reflection about the scientific basis of exercise physiology as a healthcare profession. This book combines scientific principles and calculations that support its use as an entry-level text to help exercise physiology students understand career options that use exercise as medicine in addition to the more traditional focus on the development of exercise training programs for enhanced athletic performance.

Exercise physiology is the identification of physiological mechanisms that facilitate positive healthcare changes in the human body. It includes the comprehensive delivery of treatment services concerned with the analysis, improvement, and maintenance of health and fitness; the rehabilitation of heart disease and other diseases and/or disabilities; and the professional guidance and counsel of athletes and others interested in athletics, sports training, and human adaptability to acute and chronic physical activity.

The text teaches exercise physiology students about the importance of accreditation, board certification, and standards of practice. Instructors are introduced to the American Society of Exercise Physiologists (ASEP), the organization that represents and promotes professionalism in exercise physiology. ASEP is committed to the professional development of exercise physiologists, their advancement, and their credibility in the healthcare field. ASEP has defined an exercise physiologist as a healthcare professional who either has an academic degree in exercise physiology or who is board certified by ASEP to practice exercise physiology. This book also discusses ASEP strategies that clarify misinformation about the profession of exercise physiology.

The chapters are designed to encourage the reader to integrate scientific content with creative, entrepreneurial thinking and opportunities to improve athletic performance, quality of life, and longevity.

The text presents an introduction to the scientific disciplines that undergird the everyday practice of exercise physiology. It encourages the reader to consider exercise physiology as a profession, understand its scientific foundation, and appreciate its healthcare connection as a service to society. Each chapter emphasizes the crucial connections between basic biochemistry, biomechanics, and anatomy that are the building blocks of exercise physiology. The book also provides current information that spans several disciplines, systematically organized to help ensure successful preparation for the Board Certified Exercise Physiologist certification exam.

The 23 chapters introduce the primary physiologic systems and the significance of exercise, electrocardiography and cardiovascular calculations, biomechanics and its connection to anatomical movement, and professional development in exercise physiology. Each chapter builds upon the previous one, so the student should start at the beginning and work through the chapters sequentially.

The book is divided into seven parts. Part I addresses the scientific aspects of exercise physiology. The reader is introduced to factors that regulate ventilation and influence the cardiovascular system and its role in maximum oxygen uptake, as well as the integrity of the neuromuscular system.

Part II describes the principles of training and adaptations that result from aerobic and anaerobic training. Part III discusses ethical thinking, sports nutrition concerns, and various agents used to enhance athletic performance. Part IV highlights complex and basic elements essential to the practice of exercise physiology.

Part V explores the role biomechanics plays in performance and its effects on well-being. Basic concepts in exercise biomechanics are examined, together with the science of levers and biomechanical calculations. This approach is critical to the reader's grasp of the interrelationship of the variables that influence the quality of human movement. Part VI focuses on the knowledge required of the exercise physiologist. Essential to this goal is an understanding of the muscular system and the many ways in which it influences the body. The more the reader learns about the anatomy of human movement, the more relevant the study and application of the physiologic systems become in the management of athletics, health, and well-being.

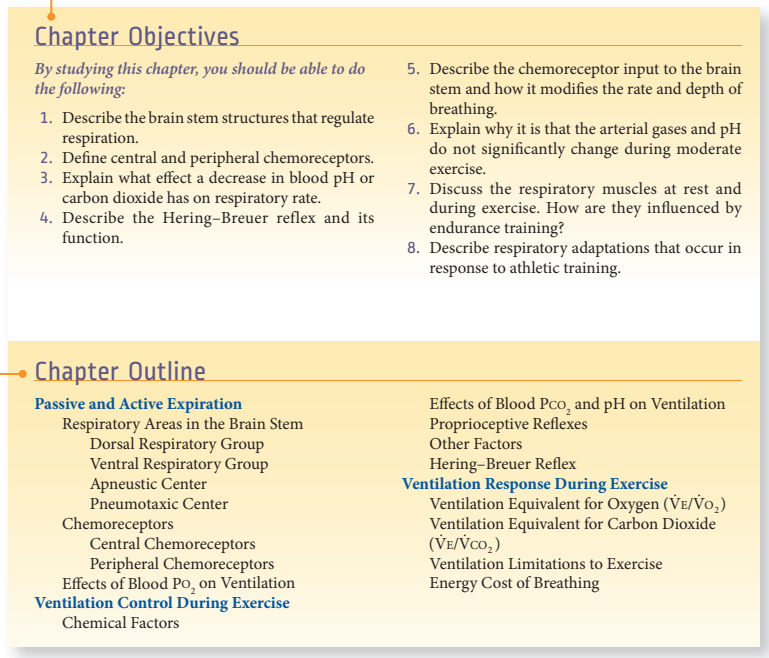
Part VII considers exercise physiology from a big picture point of view. The final chapters define an exercise physiologist and examine the discipline of exercise physiology and the difficult issues that challenge the profession. Topics discussed include why exercise physiologists need their own professional organization, a code of ethics, accreditation, board certification, and standards of practice. The final chapter examines exercise physiology research, types of statistical tests, and the scientific method.

In summary, this book's content reflects the evolution and significance of the profession of exercise physiology. *Introduction to Exercise Physiology* is intended for students of exercise physiology and other healthcare professionals. It is a useful reference work for studying the related disciplines of human movement. No other contemporary exercise physiology text addresses specifically the distinct disciplines of the systematic knowledge of exercise physiology.

Pedagogical Features

Introduction to Exercise Physiology incorporates a number of engaging pedagogical features to help the student understand and retain the material.

Each chapter starts with **Chapter Objectives**, which highlight the critical points of the chapter, followed by a **Chapter Outline** to guide student study.



Chapter Objectives

By studying this chapter, you should be able to do the following:

1. Describe the brain stem structures that regulate respiration.
2. Define central and peripheral chemoreceptors.
3. Explain what effect a decrease in blood pH or carbon dioxide has on respiratory rate.
4. Describe the Hering–Breuer reflex and its function.
5. Describe the chemoreceptor input to the brain stem and how it modifies the rate and depth of breathing.
6. Explain why it is that the arterial gases and pH do not significantly change during moderate exercise.
7. Discuss the respiratory muscles at rest and during exercise. How are they influenced by endurance training?
8. Describe respiratory adaptations that occur in response to athletic training.

Chapter Outline

Passive and Active Expiration
- Respiratory Areas in the Brain Stem
  - Dorsal Respiratory Group
  - Ventral Respiratory Group
  - Apneustic Center
  - Pneumotaxic Center
- Chemoreceptors
  - Central Chemoreceptors
  - Peripheral Chemoreceptors
- Effects of Blood P_{O_2} on Ventilation

Ventilation Control During Exercise
- Chemical Factors
- Effects of Blood P_{CO_2} and pH on Ventilation
- Proprioceptive Reflexes
- Other Factors
- Hering–Breuer Reflex

Ventilation Response During Exercise
- Ventilation Equivalent for Oxygen ($\dot{V}_E/\dot{V}_{O_2}$)
- Ventilation Equivalent for Carbon Dioxide ($\dot{V}_E/\dot{V}_{CO_2}$)
- Ventilation Limitations to Exercise
- Energy Cost of Breathing

Net $\dot{V}O_2$ Oxygen consumption for only the exercise portion that is consistent with the work required of the exercise itself minus the resting component.

Gross $\dot{V}O_2$ The total oxygen consumption either at rest or during exercise including the resting oxygen consumption.

Resting $\dot{V}O_2$ Resting oxygen consumption is the measure of resting energy expenditure, which is the same as "resting metabolic rate" (RMR) or a slightly different term "basal metabolic rate" (BMR).

Kilogram-meters per minute The physiologic cost of work in oxygen consumption on the bicycle ergometer.

Key terms are defined in sidebars throughout the chapter and compiled in a **Glossary** at the end of the text.

Each chapter concludes with **Study Questions** to test comprehension of the concepts discussed in the chapter.

Study Questions

1. Why is eating a well-balanced diet more important for athletes than consuming sports supplements, vitamins, and minerals?
2. Explain the role of carbohydrates, fats, and proteins in athletic training.
3. What particular foods should be consumed before exercise, during exercise, and immediately after exercise?
4. Explain what is meant by carbohydrate loading and its significance in endurance sports.
5. What is lipolysis and what role does the cardiorespiratory system play in its use at the cell level?
6. How critical is it for non-strength-building athletes to consume protein?
7. Is it necessary for athletes to consume vitamins and minerals beyond eating a normal diet?
8. What are the different kinds of minerals, and how do they promote athletic performance?
9. Dehydration is a potential threat to all athletes. How can it be avoided?
10. What are the nutrition needs of young athletes versus those of college-age athletes?

Suggested Readings provide recommendations for further student study.

Suggested Readings

Blake, J. S. (2012). *Nutrition and you* (2nd ed.). San Francisco, CA: Pearson Benjamin Cummings.

Burke, L. M. (2007). Nutrition strategies for the marathon: Fuel for training and racing. *Sports Medicine, 37*, 344–347.

Burke, L. M., Loucks, A. B., & Broad N. (2006). Energy and carbohydrate for training and recovery. *Journal of Sports Sciences, 24*, 675–685.

Clark, N. (2008). Proper nutrition for athletes: The missing link. *Journal of Exercise Science and Fitness, 6*, 130–134.

Eichner, E. R. (2000). Minerals: iron. In R. J. Maughan (Ed.), *Nutrition in sport* (pp. 326–338). Oxford, UK: Blackwell.

Fairchild, T. J., Fletcher, S., Steele, P., Goodman, C., Dawson, B. & Fournier, P. A. (2002). Rapid carbohydrate loading after a short bout of near maximal-intensity exercise. *Medicine and Science and Sports Exercise, 34*, 980–986.

Hargreaves, M., Hawley, J. A., & Jeukendrup, A. (2004). Pre-exercise carbohydrate and fat ingestion: Effects on metabolism and performance. *Journal of Sports Sciences, 22*, 31–38.

Jentjens, R. L., Achten, J., & Jeukendrup, A. E. (2004). High oxidation rates from combined carbohydrates ingested during exercise. *Medicine and Science and Sports Exercise, 36*(9), 1551–1558.

Maughan, R. J. (2005). Contamination of dietary supplements and positive drug tests in sport. *Journal of Sports Sciences, 23*(9), 883–889.

Petrie, H. J. Stover, E. A., & Horswill, C. A. (2004). Nutritional concerns for the child and adolescent competitor. *Nutrition, 20*(7-8), 620–631.

Wismann, J., & Willoughby, D. (2006). Gender differences in carbohydrate metabolism and carbohydrate loading. *Journal of the International Society of Sports Nutrition, 3*(1), 28–35.

Wright, D. A., Sherman, W. M., & Dernbach, A. R. (1991). Carbohydrate feedings before, during, or in combination improves cycling endurance performance. *Journal of Applied Physiology, 71*(3), 1082–1088.

References used in the chapter are also listed.

References

Boisseau, N., and Delamarche, P. (2000). Metabolic and hormonal responses to exercise in children and adolescents. *Sports Medicine, 30*, 405–422.

Bonci, L. (2010). Sports nutrition for young athletes. *Pediatric Annals, 39*(5), 300–306.

Buford, T. W., Kreider, R. B., Stout, J. R., Greenwood, M., Campbell, B., Spano, M., et al. (2007). International Society of Sports Nutrition position stand: Creatine supplementation and exercise. *Journal of the International Society of Sports Nutrition, 4*, 6:1–8.

Burke, L. M., Kiens, B., & Ivy, J. (2004). Carbohydrates and fat for training and recovery. *Journal of Sports Sciences, 22*, 15–30.

Burke, L. M., Millet, G., & Tarnopolsky, M. A. (2007). Nutrition for distance events. *Journal of Sports Sciences, 25*, S29–S38.

Campbell, B., Kreider, R. B., Ziegenfuss, T., La Bounty, P., Roberts, M., Burke, D., et al. (2007). International Society of Sports Nutrition position stand: Protein and exercise. *Journal of the International Society of Sports Nutrition, 4*(8), 1–7.

Campbell, C., Prince, D., Braun, M., Applegate, E., & Casazza, G. A. (2008). Carbohydrate-supplement form and exercise performance. *International Journal of Sport Nutrition and Exercise Metabolism, 18*, 179–190.

Coyle, E. F., Hagberg, J. M., Hurley, B. F., Martin, W. H., Ehsani, A. A., & Holloszy, J. O. (1983). Carbohydrate feeding

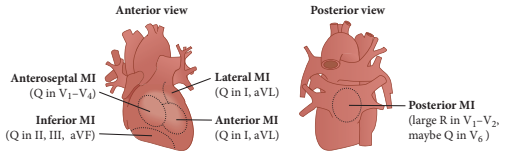


Figure 11-24 Lead identification of specific types of heart attack.

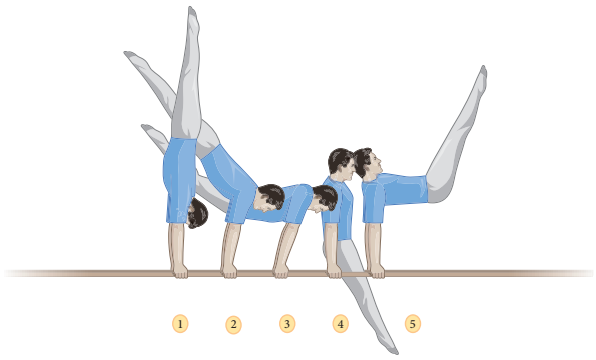


Figure 14-1 Handstand, lower to front uprise, followed by backflip or return to handstand.

Figure 19-3 Lat pull-down.

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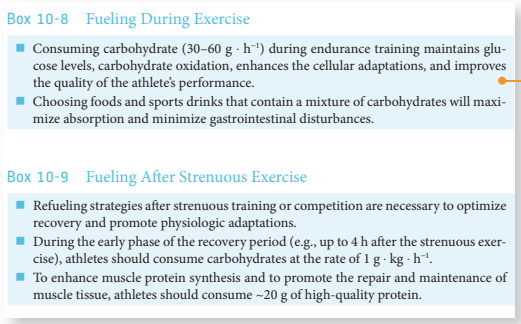

Box 10-8 Fueling During Exercise

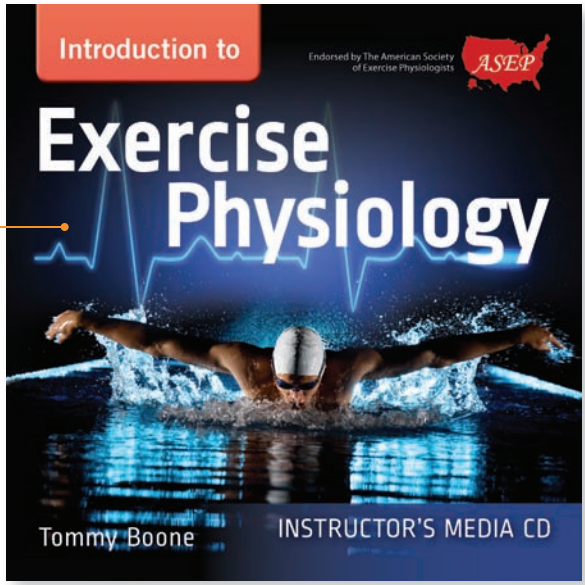
- Consuming carbohydrate (30–60 g · h^{-1}) during endurance training maintains glucose levels, carbohydrate oxidation, enhances the cellular adaptations, and improves the quality of the athlete's performance.
- Choosing foods and sports drinks that contain a mixture of carbohydrates will maximize absorption and minimize gastrointestinal disturbances.

Box 10-9 Fueling After Strenuous Exercise

- Refueling strategies after strenuous training or competition are necessary to optimize recovery and promote physiologic adaptations.
- During the early phase of the recovery period (e.g., up to 4 h after the strenuous exercise), athletes should consume carbohydrates at the rate of 1 g · kg · h^{-1}.
- To enhance muscle protein synthesis and to promote the repair and maintenance of muscle tissue, athletes should consume ~20 g of high-quality protein.

Boxes address singular points featured throughout the book.

The **Instructor's Media CD** is a comprehensive teaching resource available to adopters of the book. It includes PowerPoint Lecture Presentation Slides and an Image and Table Bank, which provides art and tables that can be imported into PowerPoint presentations and tests or used to create transparencies.



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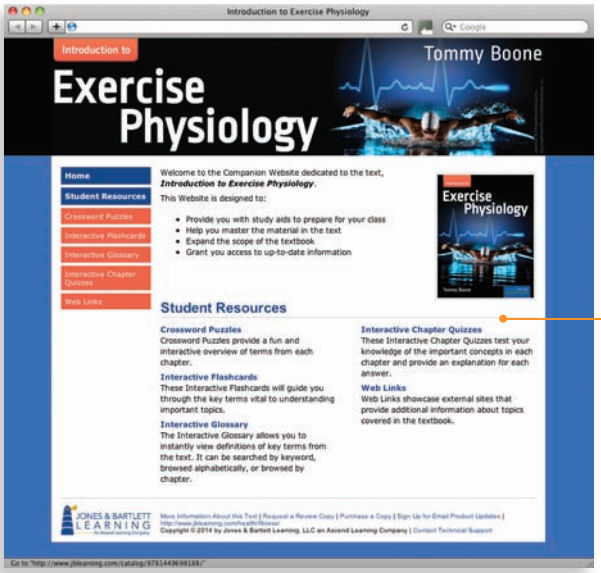

The **Companion Website** for *Introduction to Exercise Physiology*, **go.jblearning.com/boone**, offers students and instructors an unprecedented degree of integration between the text and the online world through many useful study tools, activities, and supplementary information. Study tools include Practice Quizzes, Web Links, Flashcards, an Interactive Glossary, and Crossword Puzzles. This interactive and informative website is accessible to students through the redeemable access code provided in every new text.

Acknowledgments

This is my first opportunity to author a text at this level and, frankly, I did not realize how many individuals would be involved. While there are numerous people to thank at Jones & Bartlett Learning, it is appropriate that I begin with Shoshanna Goldberg, who was Executive Editor at the time, for her incredible support and dedication to this book. Shoshanna's assistance early in the project was extremely helpful. She provided unwavering support and guidance. Managing Editor, Amy L. Bloom, provided assistance with preparing the text for submission early in the process. Prima Bartlett, Editorial Assistant, reviewed individual chapters and helped with the writing and updating of the chapters.

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About the Author

TOMMY BOONE was born and raised in Leesville, Louisiana. Following high school, where he participated in football, track, and baseball, he entered Northwestern State University in Natchitoches, Louisiana, to become a gymnast. Four years later, he was an All-American. After receiving his BS and MEd in Health and Physical Education from Northwestern in 1967 and 1968, respectively, he was hired as the gymnastics coach at Northeast Louisiana State University in Monroe. After one year, he accepted an instructor position at the University of Florida, Gainesville, where he stayed for three years.

During 1971 and 1972, Dr. Boone was enrolled in the doctoral program at Florida State University, Tallahassee. After completing his PhD course work in exercise physiology, he was offered an academic position at Wake Forest University in Winston-Salem, North Carolina, where he completed his dissertation and obtained his PhD in 1975. From 1973 to 1981, he taught exercise physiology courses and developed the anatomy laboratory with cadavers for the graduate students in the department. He was also the Exercise Coordinator of the WFU Cardiac Rehabilitation Program.

In 1981 and 1982, Dr. Boone was the Graduate Coordinator in the School of Human Performance and Recreation at the University of Southern Mississippi (USM) in Hattiesburg. He was responsible for updating the master's and doctoral degree programs across five departments. He developed the gross anatomy laboratory with cadaver dissection for doctoral students. He was promoted to professor in 1985 and also served as the Director of the Anatomy Laboratory. During his 12 years of tenure at USM, he taught exercise physiology courses at the undergraduate and graduate levels and worked with master's and doctoral students. Prior to leaving USM, Dr. Boone completed the Master of Public Health (MPH) degree in 1993 to further integrate exercise physiology with health and disease prevention strategies.

In 1993, Dr. Boone was appointed Chair of the Department of Exercise Science at The College of St. Scholastica (CSS) in Duluth, Minnesota. In 1994, he was successful in changing the name of the department to Exercise Physiology. In 1995, he developed a master's level graduate exercise physiology program. He is currently Professor of Exercise Physiology and has served as Department Chair for 16 years.

While at CSS, he completed his Master of Arts in Management (MAM) in 1999 and his Master of Business Administration (MBA) in 2010.

Together with Dr. Robert A. Robergs, Dr. Boone co-founded the American Society of Exercise Physiologists (ASEP) in 1997. Dr. Boone served as the first ASEP President and organized the first ASEP National Meeting at CSS in October 1998. He has worked with the ASEP presidents to build the professional infrastructure for exercise physiology as a healthcare profession. He founded the Journal of Exercise Physiology-online (JEPonline) in 1998 and is currently the Editor-in-Chief. In addition to JEPonline, he is the founder and Editor of the Professionalization of Exercise Physiology-online (PEPonline), which publishes articles pertaining to the professionalization of the discipline of exercise physiology.

Since 1975, Dr. Boone has served as advisor for more than 100 MS and PhD graduate students at three academic institutions and served as a committee member of numerous other graduate students. Many of these students have become college professors, researchers, textbook writers, and entrepreneurs, and consultants to different health- and fitness-related businesses and cardiac rehabilitation settings. Dr. Boone has taught approximately 6,000 students in more than 250 academic courses. He has published 18 books, 3 content sections/chapters in two different encyclopedias, 8 book chapters, 75 print copy papers (50 were refereed journal articles), 360 articles in PEPonline, and 50 articles in the *Journal of Professional Exercise Physiology*. He has either presented or assisted in 88 national presentations and 22 local and/or regional presentations and published numerous abstracts with colleagues.

About the American Society of Exercise Physiologists

The American Society of Exercise Physiologists (ASEP) is a national nonprofit professional organization committed to the advancement of exercise physiologists. Founded in 1997 in the state of Minnesota, ASEP provides a forum for leadership and exchange of information to stimulate discussion and collaboration among exercise physiologists.

The ASEP Academic Accreditation Guidelines establishes standards for the exercise physiology profession and verifies the credibility, integrity, and quality of academic programs. The ASEP Board Certification for exercise physiologists (EPC) ensures that the most highly trained and qualified exercise physiologists are providing care in health and wellness programs, cardiac and other rehab settings, and athletics.

The ASEP Code of Ethics further protects the public safety as well as the profession of exercise physiology. Adherence to the code is expected, and is based on the belief that exercise physiologists are self-regulated, critical thinkers who are accountable and responsible for high-quality competence in the practice and the delivery of exercise physiology concepts, ideas, and services.

The ASEP Standards of Practice define professional competencies required for accepted and safe exercise physiology practice in the United States. The standards inform and assist EPCs in their interaction with the general public, the healthcare community, and with the fitness and athletics industry by identifying the specifics of the exercise physiology practice as a healthcare professional.

Since 1998, the American Society of Exercise Physiologists has published two electronic journals. The Journal of Exercise Physiology-online is a professional peer-reviewed, Internet-based journal devoted to original research and reviews in exercise physiology. The Professionalization of Exercise Physiology-online is a peer-reviewed journal that publishes articles about professionalism in exercise physiology and the professional development of exercise physiologists.