

E X E R C I S E
M E D I C I N E

Physiological Principles and Clinical Applications

Edited by

Alfred A. Bove
David T. Lowenthal

EXERCISE MEDICINE

Physiological Principles
and Clinical Applications

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Preface

Although much attention has been given to athletes and their medical problems and to exercise in the cardiac patient, little attention has been directed toward the exercise-related problems confronting the average person or those who might have a chronic illness and wish to exercise. Our clinical experience indeed was forcing us to deal more and more with chronically ill patients who wanted to improve their physical condition. Much of our approach to dealing with hypertension, congenital heart disease, chronic renal disease, various endocrine disorders, and neurologic disorders has been empirical since few data have been available specifically addressing exercise in these diseases. Since the majority of the exercising population are casual athletes, we found the need for a book addressing the interaction of exercise and common problems found in most medical practice. This work provides a spectrum of information ranging from basic exercise physiology to how to deal with geriatric patients who exercise. The basic exercise physiology is provided so that clinical judgments can be based on physiologic principles. Since it is impossible to cover every medical problem, solutions to uncommon problems can be deduced from a knowledge of basic exercise physiology. Mirkin's chapter on nutrition reflects his extensive experience with a multitude of sport and exercise problems. He has provided useful insight into nutritional misconceptions and problems that arise in certain sports. Two chapters on women and exercise are included because of the pressing need by female athletes for advice. Carey's chapter on physiology and Shangold's clinical chapter should provide answers to most questions that arise concerning women and exercise. The series of clinical chapters reflects the experiences of each author in dealing with aspects of sports and exercise by medical specialty.

The chapters on youth and the elderly have been included because of the frequent questions that arise when people at the extremes of life become involved with exercise. The recent developments in physiological aspects of exercise are considered in Chapter 17. A chapter on diving medicine is included because there are a number of unique problems associated with the sport of diving, and several important and potentially lethal combinations of chronic illness and diving that are often overlooked by the physician not familiar with this sport. Treatment of the neurological injuries associated with diving requires special facilities, and an understanding of these disorders will avoid mistreatment of the occasional diving injury one may encounter.

We included a final chapter on developing exercise programs and providing prescriptions for exercise so that specific information could be provided for those who wish to exercise. The guidelines set forth in this chapter are well established and have been found to be safe for patients with a variety of diseases and for persons of any age.

We have not included the orthopedic aspects of sports medicine because this topic has received considerable attention in the past, and we have not discussed cardiac rehabilitation because of numerous books, papers, and reports available on this subject. The guidelines of Chapter 19, however, are applicable to the cardiac patient and are used for cardiac rehabilitation.

This book will provide physicians and others involved in exercise programs with a reference for advising patients and well persons about exercise. The current trend in exercise dictates that we should not deny an individual the opportunity to exercise but, instead, should tailor an exercise program to fit individual capacity and preferences. With this approach, many patients will become active and functional and well persons may reduce their risk for cardiovascular disease.

ALFRED A. BOVE

DAVID T. LOWENTHAL

Contents

Contributors

xiii

Preface

xv

I

Physiological Aspects of Sports and Exercise

1. Structure and Functional Organization of Skeletal Muscle

KENNETH M. BALDWIN

I. Introduction	3
II. Mechanical Properties of Skeletal Muscle	4
III. Gross Morphology and Fiber Architecture	6
IV. Subcellular Organization of a Typical Muscle Fiber	6
V. Energy Production in Skeletal Muscle	10
VI. Organization of Muscle Fibers into Functional Units	12
VII. Effects of Altered Muscle Activity on Skeletal Muscle	14
References	17

2. Cardiovascular Physiology of Exercise

RUSSELL T. DOWELL

I. Overview and Limitations	19
II. Mechanisms Supporting Substrate Oxidation during Exercise	20
III. Circulatory Regulation during Exercise	22
IV. Summary	26
References	27

3. Pulmonary Physiology of Exercise

DANIEL C. DuPONT AND ALLAN P. FREEDMAN

I. Introduction	29
II. Resting Pulmonary Physiology	31
III. Exercise Pulmonary Physiology	35
References	41

4. Exercise Metabolism

PAUL A. MOLÉ

I. Energy Metabolism during and following Exercise	43
II. Carbohydrate and Fat Metabolism during Exercise	62
III. Concluding Remarks	81
References	81

5. Foods and Nutrition for Exercise

GABE MIRKIN

I. Introduction to Nutrients	90
II. Carbohydrates	90
III. Proteins	95
IV. Fats	97
V. Vitamins	98
VI. Minerals	101
VII. The Four Food Groups	105
References	107

II

Women, Youth, and the Elderly

6. Physiological Aspects of Women and Exercise

RITA A. CAREY

I. Introduction	113
II. Response to Strength and Endurance Training: Comparison of Females and Males	115
III. Sports-Related Injuries: Comparison of Females and Males	125
IV. Performance in Hot and Cold Environments: Comparison of Females and Males	129
V. Does Exercise Influence Osteoporosis in Aged Women and Men?	133

VI. Are the Effects of Physical Activity on Blood Lipid Chemistry Different in Women than Men?	134
VII. Are Female Athletes More Likely to Have Gynecological Problems than Nonathletes? Does Athletic Performance Have an Impact on Female Sexuality?	135
VIII. Does Physical Training Have Any Effect on Fertility or Pregnancy in Women?	137
IX. Is Male Sexuality Affected by Athletic Performance?	138
References	138
7. Gynecological and Obstetrical Aspects of Exercise	
MONA M. SHANGOLD	
I. Introduction	145
II. Basic Review of Menstrual Physiology	146
III. Menstrual Irregularity and Amenorrhea: Causes, Evaluation, and Treatment	147
IV. Hormone Changes Related to Exercise	151
V. Other Menstrual Problems	151
VI. Other Gynecological Problems	153
VII. Puberty	156
VIII. Menopause	157
IX. Pregnancy	158
X. Conclusion	159
References	159
8. Exercise in the Young	
BONITA FALKNER	
I. Introduction	163
II. Asthma	164
III. Cystic Fibrosis	165
IV. Cardiac Disease	166
V. Hypertension	167
VI. Obesity	168
VII. Summary	169
References	169
9. Exercise in the Elderly	
ALFRED A. BOVE	
I. Cardiovascular Responses with Aging	174
II. Special Considerations in Prescribing Exercise in the Elderly	177
References	179

III Medical Aspects of Sports and Exercise

10. Neurology of Sports and Exercise

OTTO APPENZELLER AND RUTH ATKINSON

I. Introduction	186
II. Physical Activity and Nervous System Aging	188
III. Temperature Regulation	189
IV. Altitude, Performance, and Nervous System Activity	202
V. Sports and the Peripheral Nervous System	206
References	226

11. Cardiovascular Disorders and Exercise

ALFRED A. BOVE

I. Basic Principles	230
II. Cardiac Work, Oxygen Consumption, and Blood Flow	231
III. Coronary Artery Disease	233
IV. Exercise Programs for Patients with Coronary Disease	236
V. Cardiovascular Drugs and Exercise	239
VI. Exercise in Patients with Chronic Heart Failure	240
VII. Valvular and Congenital Heart Disease	244
VIII. Cardiac Arrhythmias	247
IX. Conduction Abnormalities	249
X. Preexcitation Syndromes	249
XI. Assessment of Arrhythmias and Conduction System Abnormalities	250
XII. Cardiac Surgery	251
References	253

12. Pulmonary Disorders and Exercise

DANIEL C. DUPONT AND ALLAN P. FREEDMAN

I. The Clinical Exercise Test	259
II. Exercise and Pulmonary Disease	262
References	274

13. Gastrointestinal Disorders and Exercise

STANLEY H. LORBER

I. Physiology: Exercise and Gastrointestinal Function	280
II. Gastrointestinal Symptoms and Exercise	282
III. Influence of Exercise on Gastrointestinal Disease	283
IV. Gastrointestinal Diseases or Disorders Resulting from Participation in Sports	286

V. Conclusions	287
References	288
14. Exercise in Renal and Hypertensive Disease	
DAVID T. LOWENTHAL AND SUSAN J. BRODERMAN	
I. Hemodynamics and Hypertension	292
II. Hemodynamics of Hypertension during Exercise	293
III. Exercise in Patients with End-Stage Renal Disease	297
IV. Conclusion	299
References	300
15. Metabolic and Endocrine Disorders and Exercise	
PHILIP FELIG	
I. Introduction	305
II. Metabolic Response to Exercise in Normal Man	306
III. Exercise and Diabetes	311
IV. Exercise and Thyroid Disorders	316
V. Exercise and Menstrual Dysfunction	317
References	318
16. The Effects of Exercise on Genitourinary Function	
DAVID T. LOWENTHAL AND SUSAN J. BRODERMAN	
I. Renal Hemodynamics during Exercise	322
II. The Renin-Angiotensin System in Exercise	322
III. Antidiuresis during Exercise	323
IV. Sodium Balance during Exercise	324
V. Changes in Total Body Water during Exercise	324
VI. Potassium Balance in Exercise	325
VII. Alterations in Other Serum Cations	326
VIII. Hematuria during Exercise	326
IX. Exercise Hemoglobinuria	328
X. Proteinuria Related to Exercise	328
XI. Rhabdomyolysis and Acute Nephropathy as a Consequence of Severe Exercise	330
XII. Conclusions	331
References	331
17. Psychological Aspects of Exercise	
RONALD M. LAWRENCE	
I. Introduction	335
II. Depression and Anxiety	336

I

**Physiological Aspects of
Sports and Exercise**

Structural and Functional Organization of Skeletal Muscle

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I. Introduction	3
II. Mechanical Properties of Skeletal Muscle	4
III. Gross Morphology and Fiber Architecture	6
IV. Subcellular Organization of a Typical Muscle Fiber	6
A. Sarcolemma	7
B. Sarcoplasmic Reticulum	8
C. Myofibrils	9
D. Summary of Events Involved in Contraction	9
V. Energy Production in Skeletal Muscle	10
A. High Energy Stores	10
B. Substrate Energy Storage and Metabolism	11
VI. Organization of Muscle Fibers into Functional Units	12
A. Slow-Oxidative (Type I)	12
B. Fast-Oxidative-Glycogenolytic (Type IIa)	12
C. Fast-Glycogenolytic (Type IIb)	13
D. Motor Unit Recruitment	14
VII. Effects of Altered Muscular Activity on Skeletal Muscle	14
A. Endurance Exercise	14
B. Strength Training	16
C. Compensatory Hypertrophy	16
D. Limb Immobilization	17
References	17

I. INTRODUCTION

Muscles are biological machines that convert chemical energy, derived from the reaction between food substrate and oxygen, into force production and me-

chanical work. The goal of this chapter is to discuss some fundamental structural, biochemical, and physiological properties of contracting skeletal muscle which will form a background for the various topics presented in subsequent chapters. The material in this chapter is organized into seven major topics: (1) mechanical properties of skeletal muscle; (2) architectural features of skeletal muscle; (3) the role of subcellular organelles in regulating the contraction process; (4) organization of key metabolic pathways involved in energy production; (5) functional organization of skeletal muscle fibers; (6) normal recruitment of muscle fiber types; and (7) the adaptability of muscle fibers in response to physical activity and inactivity.

II. MECHANICAL PROPERTIES OF SKELETAL MUSCLE

In examining the physiological properties of skeletal muscle during contraction, it is important at the outset to distinguish between two fundamentally important, yet distinctly different properties, namely strength and endurance. The strength of a muscle refers to its ability to generate force or tension when stimulated to contract. Although the factors that regulate the force output of a muscle during a given contraction are complex, the maximal force production (P_0) of a muscle is related to its physiological cross section of contractile material. Endurance, on the other hand, refers to the ability of a muscle to sustain a given amount of contractile output (force), or to repeat contractions over and over, regardless of the magnitude of force being generated. Generally, a muscle's endurance capacity is related to its effectiveness in maintaining energy to support the mechanical process of contraction. These two properties ultimately dictate one's performance capacity for most activities. Consequently, any program of physical conditioning designed to improve the performance capacity of muscle must consider these two properties.

The mechanical properties of skeletal muscle are expressed in terms of both its force and contractile speed generating capability. The force (tension) output of a muscle can be varied in two primary ways. The first involves stimulating a given fiber at different frequencies. As stimulation frequency increases, force production increases until the muscle fiber attains its peak tetanic tension (P_0) (11,13). Fast-twitch muscles (described in more detail later) achieve peak tetanic force at high stimulation frequencies, whereas slow-twitch muscles reach tetanic tension at low stimulating frequencies (11,13). However, both fast-twitch and slow-twitch muscles attain similar peak tetanic tensions when normalized for cross-sectional area (13). The different tetanic tension patterns generated by fast and slow contracting muscles are thought to relate to differences in (1) the kinetic properties of the sarcoplasmic reticulum for releasing and sequestering calcium, and (2) myosin ATPase in these types of muscle. Calcium levels in the cytoplasm