EXERCISE MEDICINE

Physiological Principles and Clinical Applications

Edited by

Alfred A. Bove
David T. Lowenthal

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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
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I

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CHAPTER 1

Structural and Functional Organization of Skeletal Muscle

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I. INTRODUCTION

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

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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

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