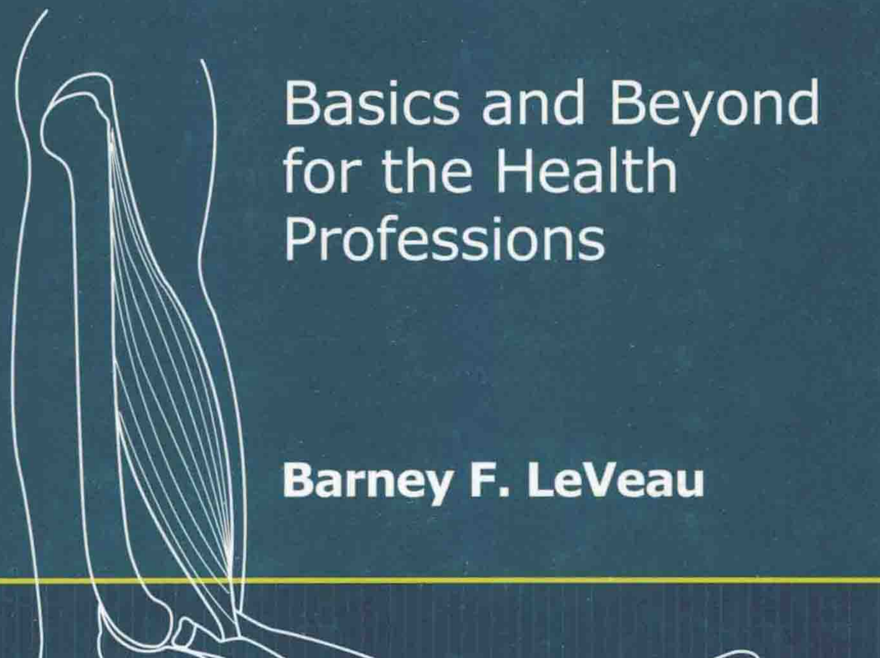
Biomechanics of Human Motion

Basics and Beyond for the Health Professions



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SLACK Incorporated

Biomechanics of Human Motion

Basics and Beyond for the Health Professions

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Dr. Barney F. LeVeau has not disclosed any relevant financial relationships

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Basics and Beyond for the Health Professions

Dedication

To my parents who, although they were share croppers and had limited formal education, worked extra jobs to provide opportunities and encouragement for all of their children to obtain postgraduate degrees.

ACKNOWLEDGMENTS

I would like to thank the Mechanical Kinesiology classes at Alabama State University who gave criticism and support for the development of this edition. I would like to thank my wife for her patience as I took time away from vacations and weekends with her.

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About the Author

Dr. LeVeau earned his BS degree in Education with emphasis in mathematics, physics, and physical education at the University of Colorado in Boulder, CO; his Certificate in Physical Therapy from the Mayo Clinic in Rochester, MN; his MS in Physical Education from the University of Colorado; and his PhD in Biomechanics from Pennsylvania State University in University Park, PA.

He has taught mathematics and science at Horace Mann Jr. High School in Colorado Springs, CO, and served as faculty in physical education and physical therapy departments at West Chester State College in West Chester, PA; University of North Carolina at Chapel Hill, NC; University of Texas Southwestern Medical Center at Dallas, TX; Georgia State University in Atlanta, GA; and Alabama State University in Montgomery, AL.

He has published several research articles, book chapters, and 2 textbook editions related to biomechanics content. His texts have been translated in Spanish, French, and Italian. He has lectured nationally and internationally on topics covering biomechanics.

INTRODUCTION

The focus of this book is on force. Force is always with you. Force is involved with large objects, such as the interaction among the sun, moon, and earth, or in very small objects, such as interactions among cells. Many disciplines are involved in the study of force and its effects on objects. This book will provide a basic background for many of these disciplines, including exercise science, physical therapy, occupational therapy, sports medicine, prosthetics and orthotics, orthopedics, rehabilitation medicine, dentistry, veterinary medicine, and ergonomics. Some areas of study relevant to biomechanics include anatomy, growth process, external loads, trauma, ergonomics, clinical evaluation, clinical treatment, protective equipment, prosthetics, orthotics, and body movement.

The purpose of this book is to present the basic principles of biomechanics and to provide techniques and examples for approaching biomechanical situations. Based upon the concept of force, the book illustrates how force is applied to the human body and how the body applies force to various objects. The emphasis is on the pertinent factors that guide the reader to an understanding of biomechanics at a beginning level. The recent articles listed at the end of each chapter should provide the reader with information beyond the basics.

When studying mechanics, you will become involved with mathematical formulas. Don't be afraid of formulas. They are just a shorthand method for writing definitions and showing relationships among variables. You should remember the units for each variable. You can then use unit analysis to show relationships.

Various disciplines do not use the same system of units. Although the International System of Units (SI) has become widely accepted, its use by practitioners in the United States is still not widespread. Practitioners and clinicians are more likely to use the English measurement system, while researchers and scientists rely on the SI system. Because this is a basic text, the English system will be presented. However, the conversion table in the appendix will allow the reader to convert units from English to SI and SI to English with little difficulty. By using the conversion table and unit analysis, for example, you may convert miles per hour (mph) to meters per second (m/sec) or (msec-1).

$$55 \text{ mph} \times 1 \text{ hr}/60 \text{ min} \times 1 \text{ min}/60 \text{ sec} \times 5280 \text{ ft}/1 \text{ mi} \times 0.3048 \text{ m}/1 \text{ ft} = 24.587 \text{ m/sec}$$

The units of miles, hours, minutes, and feet all cancel out, leaving the units of m/sec.

The problems in the text should not be considered exact. Several assumptions occur when we attempt to determine force acting on the body or the body acting on an object. In this text:

1. Only 2-dimensional figures are used.
2. Calculations of muscle force often refer to a muscle group and not necessarily the force of a single muscle.
3. The mass and weight of body segments are estimates based upon reported research. (See Appendix.)
4. The lengths of lever arms are estimates based upon reported research. (See Appendix.)
5. The minimal amount of friction in the joints is disregarded.
6. Effects of ligaments, synergists, antagonists, co-contractions, and other soft tissues are disregarded in the calculations.

An Instructor's Manual has been developed that provides questions and problems for worksheets, quizzes, and examinations.

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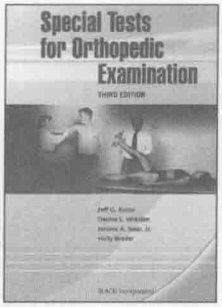

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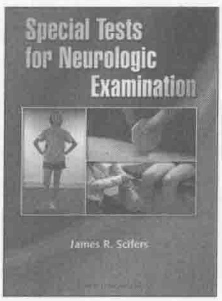

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CONTENTS

chapter 1

Force

Objectives

1. Present and discuss examples of biomechanics in the clinic and everyday life.
2. Define basic terms.
3. Draw and label the 4 characteristics of a force.
4. Describe and give examples of 8 types of force.
5. Describe an exercise for each type of force.
6. Differentiate isometric, concentric, and eccentric contractions.
7. Discuss the concept of pressure.
8. Relate mass and moment of inertia.
9. Relate the concepts of energy, work, and power.
10. Explain Newton's 3 laws.

Definition, Description, and Scope

Biomechanics is the study of forces and their effect on living organisms. It is basic to the understanding of human movement; mechanics of injury; and the principles of prevention, evaluation, and treatment of musculoskeletal problems. Concepts of biomechanics are not limited to the study of the range of motion of joints, posture, and analysis of locomotion or gait. Everything we do involves biomechanics in some form or degree. The principles of biomechanics are at work in the "couch potato" as well as the elite athlete. Biomechanical principles apply to disabled as well as able-bodied individuals. They are employed throughout the lifespan from the womb until death. Because biomechanics is the study of the effect of forces on the human body, whenever a force is present, biomechanical principles are involved.

Biomechanics applies principles and concepts that are very important to the disciplines including exercise science, physical therapy, occupational therapy, sports medicine, prosthetics and orthotics, orthopedics, rehabilitation medicine, podiatry, dentistry, and veterinary medicine. These are health professionals who use biomechanical concepts to evaluate and treat patients and to improve motor performance. In addition, professionals such as bioengineers, ergonomists, and human factors specialists use biomechanical concepts to understand how individuals physically interact with their environments (eg, the workplace, vehicles, and tools) and to explore the efficiency and safety with which this interaction takes place.

LeVeau BF.
Biomechanics of Human Motion: Basics and Beyond for the Health Professions (pp 1-34).

Biomechanics is based on the content areas of anatomy, physiology, motor learning, mathematics, physics, and clinical sciences. This basic knowledge level allows the individual to understand how forces and anatomy interrelate. A general course in biomechanics can serve as a foundation for both clinical and sports-related biomechanics. Individuals with more advanced knowledge will be able to analyze and evaluate how forces specifically act on the body and how the body exerts forces on other objects. They will also be able to research and establish programs to enhance rehabilitation and prevent injuries. The advanced biomechanist will be able to design an environment that allows disabled individuals to live an efficient and safer lifestyle and possibly to participate in recreational and competitive sporting activities.

Additional content areas in biomechanics include specific rehabilitation techniques, wheelchair design, anthropology, specific tissue repair, surgical techniques, and architecture. Because force, the basis of biomechanics, is everywhere, the scope of biomechanics is only limited by one's imagination and the needs of specific populations.

The biomechanist must know how the body responds in normal situations in order to set goals for the injured or disabled individual. The biomechanist must understand the specific activities of the individual in order to help prevent injuries from occurring. Normal patterns of movement and their variations for healthy individuals must be understood in order for the movement pattern of an injured or disabled individual to be directed toward a more normal pattern. If movement cannot return to normal, the movement pattern must be directed toward the most efficient and safe pattern for that individual. To analyze these movement patterns, the biomechanist uses instrumentation and techniques, such as video analysis, electromyography (EMG), electrogoniometry (elgon), accelerometry, and force plate and force transducer analysis.

Force

Force is an important concept to grasp in studying biomechanics. Forces can be separated, combined, and manipulated. An understanding of how force acts on objects and what can result when forces are applied to various materials is central to the study of biomechanics.

Force can be defined simply as a push or pull. Force can be considered as the entity that tends to produce motion, to halt motion, or to change the direction of motion. When motion occurs, force is the factor that causes a mass to accelerate. This relationship is depicted in the equation $F = ma$. F stands for force; m stands for mass of the object; and a represents the acceleration (+ or -) of the object. This formula may be rearranged to be $a = \frac{F}{m}$. This formula represents Newton's Second Law of Motion or the law of acceleration. Acceleration of an object is directly proportional to the force applied and inversely proportional to its mass.

Force is a vector quantity (has magnitude and direction) and not scalar (has only magnitude). To define force, however, it must be described by 4 characteristics: point of application, line of application, direction of pull or push, and magnitude (Figure 1-1). Force must have a point of application. Examples of points of application are contact between bones at joints, attachments of muscles to bones, the center of mass of a limb, and the point of contact of a dumbbell (Figure 1-2). Force acts anywhere along a line of application, but this line can be redirected by a fixed pulley. For example, the peroneus longus tendon traversing behind the lateral malleolus provides an example inside the body of a fixed pulley changing the line of application of the force produced by a muscle (Figure 1-3). The third characteristic of force is its direction of pull or push. In Figure 1-1, an arrowhead placed at the end of the line of application shows the direction of the force. The force of gravity, for example, provides a downward direction on the human body. Magnitude, which is the quantity of force, is the fourth characteristic of a force. Every force

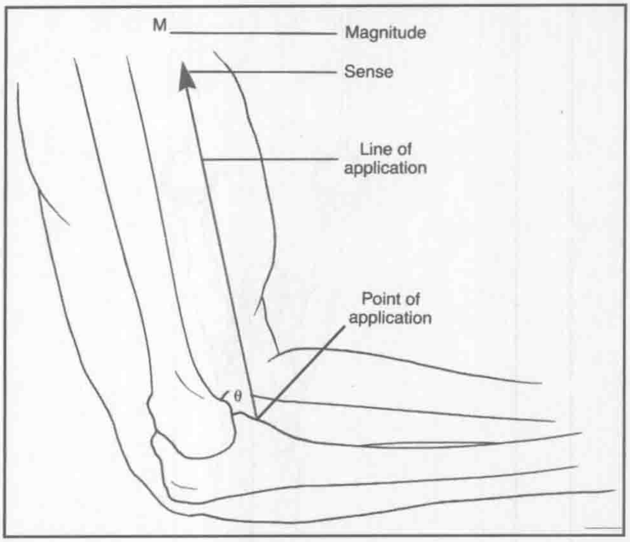

Figure 1-1. A force vector and the 4 characteristics of force.

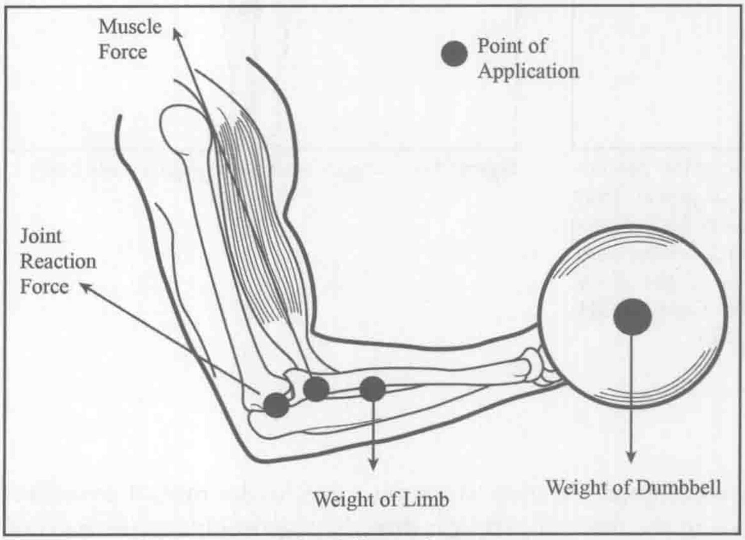

Figure 1-2. Characteristics of 4 different forces.

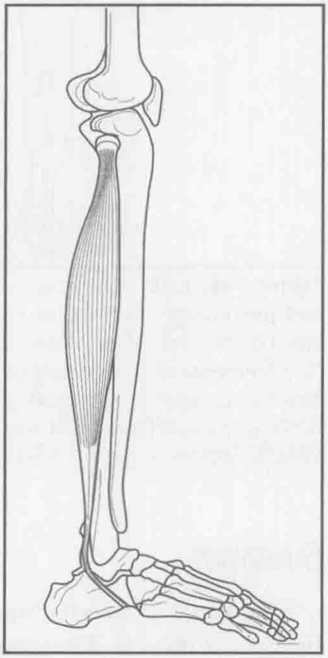

Figure 1-3. The lateral malleolus as a pulley.

has these 4 characteristics, and all 4 characteristics must be considered when studying a force or forces. The unit of force is the Newton or pound.

Types of Force

Several types of forces exist. Some scientists classify forces into only 2 categories: contact forces and action-at-a-distance (non-contact) forces. Others consider the natural forces as gravitational, electromagnetic, strong nuclear, and weak nuclear. In this text, we will address the forces that are common to the health and exercise professional. These forces include gravitational, contact, frictional, muscular, inertial, elastic, buoyant, and electromagnetic.