Kinesiology

THIRD EDITION

The Mechanics and Pathomechanics of Human Movement

CAROL A. OATIS

Wolters Kluwer

Kinesiology

THE MECHANICS AND PATHOMECHANICS OF HUMAN MOVEMENT

THIRD EDITION

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This book is dedicated to my family:

To my late parents, Betty and Jack, who gave me opportunities and believed in my abilities; to my brothers and sisters, John, Ginny, Susan, and Dave, whom I am lucky to call my friends; and to my partner, Maggie, who has supported and encouraged me throughout this process.

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FOREWORD

A noteworthy development in Physical Therapy was the official adoption of an identity, the Human Movement System [1]. The definition is "The human movement system comprises the anatomic structures and physiologic functions that interact to move the body or its component parts" [2]. The recognition of this system of physiological organ systems that effect and that are affected by movement further emphasizes the importance of the underlying science of kinesiology.

Now, even more than 7 years ago at the time of the last edition of *Kinesiology: The Mechanics and Pathomechanics of Human Movement*, physical inactivity has been linked to a variety of diseases including cancer, cardiovascular disease, and diabetes [3–7]. Similarly, exercise and physical activity are major treatments for these conditions and even for dementia [8–10]. But you cannot exercise if you are injured. That is where knowledge of kinesiology and pathokinesiology is so important. There is not enough recognition of how daily activities, no matter the level of intensity, alter the precision of joint motion. The general belief is that if you can move in a way that does not cause pain, that is acceptable. This belief is analogous to the belief that you can eat whatever and as much as you want without experiencing consequences.

Of course, the irony of the situation is that now that there is a great deal of evidence of the health costs of obesity, the problem continues to increase. As the health care community increases its efforts to promote exercise and physical activity, all levels of exercise providers must augment their understanding of kinesiology to provide the highest level of guidance to prevent the development of musculoskeletal pain problems.

With the adoption of the identity of the Human Movement System, the physical therapy community is going to place even greater emphasis than in the past on movement and on understanding the factors that alter the precision of joint movement. Small alterations in movement induced by cartilage or ligament injury can lead to osteoarthritis [11,12]. Evidence is growing that, rather than strengthening exercises being the primary treatment mode movement, pattern training is being shown to be more effective [13–15]. At the same time, in the orthopedic surgery community, there is growing recognition that such things as shoulder impingement are not a pathoanatomic problem but are caused by movement patterns [16]. Similarly, there is a growing body of evidence that structural variations of the hip joint causing femoroacetabular impingement are related to excessive force from intensive sports activity [17]. Here again, knowledge of kinesiology is going to play a key role in developing safe guidelines for protecting joints while participating in sports activities as well as during daily activities.

This book provides the necessary information for the practitioner to understand normal movement as well as pathokinesiologic movement and, if used optimally, kinesiopathologic movement. That means the book can be used as the guide to help individuals avoid the development of pathology caused by movement impairments, which has as much if not more importance than recognizing how movement becomes altered by pathology in one of the contributing systems.

The scope of information in this text—from basic biomechanics to coverage of all body regions in chapters written by experts in the respective regions—provides the insights and guidance that will serve all levels of students and practitioners well. The material is here, and the only necessary step is for the reader to take advantage of the expert information that is in this book. If they do, they will be enhancing their knowledge of the human movement system and offering the best care to their patients and clients.

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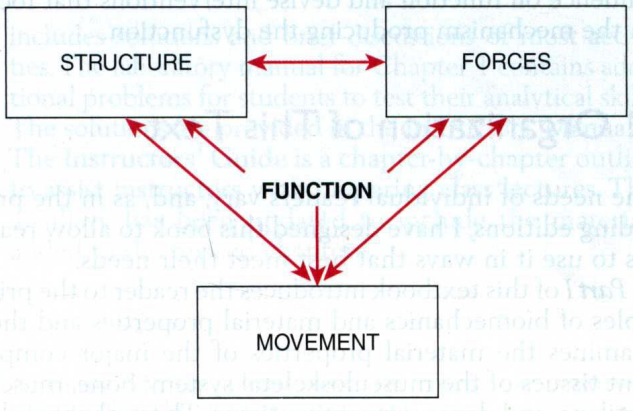
PREFACE

Movement is a core function of most living creatures. As humans, we understand that movement can be impaired for many reasons including injury or pain. We also recognize a common desire to improve or optimize a movement. Normal movement results from an exquisite interplay within the nervous, muscular, and skeletal systems and is heavily influenced by other systems including the respiratory, cardiovascular, integumentary, and immune systems. Taken as a whole, movement can itself be considered a "system" [1]. The Human Movement System integrates the functions of the other physiologic systems to produce movement. **Kinesiology** is the scientific study of movement of the human body or its parts and is the foundational science needed to understand the movement system. Restoration of normal movement, reduction of movement dysfunction, or optimization of movement each requires a firm foundation in kinesiology. This third edition of *Kinesiology: The Mechanics and Pathomechanics of Human Movement* builds on the first two editions to provide the most current scientific data and clinical applications to help movement specialists understand the complex interactions within the movement system. As in the previous editions, it focuses on the musculoskeletal components of the movement system.

To evaluate and treat a movement disorder effectively, the clinician must consider two central questions: *what is required to perform the movement and what effects does the movement produce on the individual?* Consider a jogger who typically runs 2 or 3 miles three times weekly and has now decided to train for a marathon or one who has begun to complain of lateral knee pain after a 2-mile run. To effectively guide the runner in training for a 26.2 mile (42.2 km) run or to help the runner eliminate the knee pain, the clinician must understand the requirements of running and recognize the loads applied to the musculoskeletal system while running. This textbook helps the reader develop knowledge and enhance skills that permit him or her to assist individuals to optimize movement or to reduce movement dysfunction.

Two general factors govern the movement of a structure: the composition of the structure and the forces applied to it. A central principle in kinesiology is that the form or shape of a biological structure is directly influenced by its function. In fact, the relationship among movement, structure, and force is interdependent and multidirectional. Structure influences a body's movement. Movement affects the forces applied to the structure. The forces, in turn, influence the structure (*see Figure*). Function is the purposeful application of movement and, consequently, depends on the interactions of structure, force, and movement. The jogger who wants to run a marathon will be flexing and extending both knees thousands of times daily during training. The unique structure of the tibiofemoral joint produces complex three-dimensional motion as the knee flexes and extends. That complex motion leads to intricate loading patterns on the tibia and femur in which the loads are distributed unevenly across the bony surfaces. These loads can lead to normal adaptation with increased bone mineralization and thickening of articular cartilage or can lead to bony edema and articular degradation.



An abnormal structure produces abnormal movement and abnormal forces on that or neighboring structures, contributing to further alterations in structure. The runner with lateral knee pain may exhibit hip muscle weakness that leads to faulty knee motion, overuse of hip musculature, and inflammation of the muscle's tendon or at the site of muscle attachment. The clinician needs to understand these interrelationships to design and direct interventions for restoring or optimizing human movement.

An understanding of the relationships among structure, force, and movement requires a detailed image of the structure of a region as well as a grasp of the fundamental laws of motion and the basic material properties of the tissues comprising the musculoskeletal system. The purposes of this textbook are to

- Provide a detailed analysis of the structures of the musculoskeletal system within individual functional regions
- Discuss how the structures affect function within each region
- Analyze the forces sustained at the region during function

This textbook will help the clinician recognize the relationships between form and function, and between abnormal structure and dysfunction. This foundation should lead to improved evaluation and intervention approaches to movement dysfunction.

This book uses terminology that is standard within health care to describe elements of disablement based on a classification of function developed by the World Health Organization (WHO). In this classification scheme, a disease process, or **pathology**, alters a body structure or function, producing an **impairment**. The impairment may cause an individual to have difficulty executing a task or activity, producing an **activity limitation** or **dysfunction**. When the dysfunction alters the individual's ability to participate in life functions, the individual has **participation restriction** or a **disability** [2].

Although improving activity and participation is usually the primary objective in rehabilitation, the WHO model of disease provides a framework for clinicians to improve function not only by intervening directly at the level of the dysfunction but also by addressing the underlying impairments. By understanding the detailed structure and precise movement of an anatomical region, the clinician has tools to identify impairments and their influence on function and devise interventions that focus on the mechanism producing the dysfunction.

Organization of This Text

The needs of individual readers vary, and, as in the preceding editions, I have designed this book to allow readers to use it in ways that best meet their needs.

Part I of this textbook introduces the reader to the principles of biomechanics and material properties and then examines the material properties of the major component tissues of the musculoskeletal system: bone, muscle, cartilage, and dense connective tissue. These chapters lay out the biomechanical foundation for examining human movement.

Parts II through IV explore movement by anatomical region, investigating the detailed structure of the bones, joints, and muscles in that region and examining how their structures influence its movement. The ability of the region to sustain the forces generated during movements and function also is explored in Parts II through IV.

Part V considers more global, or whole-body, movements, specifically posture and locomotion.

Detailed discussions of forces at joints are presented in separate chapters so that readers may access that information as they need it. Although many readers will be interested in delving into the mathematical analyses used to determine forces on joint structures, others will find little need for such detail. The actual calculations are set apart in boxes that accompany the chapters. Conclusions based on the calculations are contained within the chapters' text so that readers can read the chapters and glean the essential information and return to the specific analyses as desired.

Conclusions regarding structure, function, and dysfunction in this text are based on the best available evidence, and each chapter is extensively referenced using both current and classic resources. I believe that the clinician is best equipped to evaluate current practice and to debunk long-held beliefs by having access to the classic resources that have established a concept and to the most current evidence that confirms or refutes standard impressions. Throughout this book, common clinical beliefs that are unsupported—or actually refuted—by strong evidence are explicitly identified so that the clinician hones the skill of healthy skepticism and develops the practice of demanding evidence to support a concept. The book also notes where evidence is meager or inconclusive or the conclusion is the opinion of the author. A strong, evidence-based background in kinesiology also helps develop clinician scholars who can contribute to our understanding of movement and movement dysfunction through the systematic, thoughtful observation and reporting of clinical phenomena. Despite the comment made long ago by a fellow graduate student that there was "nothing left to learn in gross anatomy," there is much to be learned yet in functional anatomy and kinesiology.

New and Updated Features in the Third Edition

A new edition of a book allows us the opportunity to directly apply the wisdom of Maimonides:

> *Today one can discover the errors of yesterday,*
> *And tomorrow obtain a new light on what seemed certain today.*
>
> *—Prayer of Maimonides*

This third edition does indeed "correct the errors of yesterday" and sheds light on emerging knowledge by including the most up-to-date science in kinesiology and biomechanics. The science in these areas continues to expand, and we have worked diligently to ensure that each chapter reflects that growth of understanding. Chapter authors have reviewed the literature and added **updated references** to provide the most current perspectives. Just one example of this is the inclusion of more muscle physiology in the chapter on muscle biomechanics *(Chapter 4)* to help readers understand muscle function in light of the growing understanding of muscle biology. In response to requests by users, we also have added a section on the basic mechanics of running to the chapter on gait *(Chapter 48)*.

Additional **Clinical Relevance** boxes (with new **Clinical Bottom Lines**) have been added to most chapters to assist the reader in understanding the applicability of detailed kinesiological and biomechanical information. **Videos** of clinical cases demonstrating the use of a kinesiological perspective to the assessment of a patient have been added to the already extensive video collection.

As in the second edition, **Muscle Action tables** introduce the discussion of muscle actions for each muscle. Actions of each muscle are introduced in table format and include the conclusions drawn from the evidence regarding each action. The evidence is discussed in detail after

the table. This format allows the reader to identify at a glance which reported actions are supported by evidence, which are refuted, and which remain controversial.

Muscle Attachment boxes provide muscle innervation and attachment information, and also include brief descriptions of palpation strategies.

Thought problems have been added to the end of each chapter to allow the reader to practice applying the principles discussed in the chapter to clinical scenarios. Answers to these thought problems are available on thePoint® (http://thePoint.lww.com), where students and instructors can also find additional practice questions and problems to solve.

A strong understanding of the effects of forces on joint function is critical to the analysis of movement. However, movement specialists are often unfamiliar with the analysis techniques needed to understand the forces generated during motion. All of the biomechanical analyses (**Examining the Forces Boxes**) have been revised to provide more detailed explanations of the analyses. These revisions are designed to make the analyses more understandable and accessible to those less familiar with biomechanical principles.

Finally, and perhaps most obviously, virtually all of the artwork is in full color to enhance the visual appeal of the book and to make the principles demonstrated by the artwork more accessible to a whole new generation of readers.

I have made these changes because I firmly believe that people with musculoskeletal disorders or those who want to optimize their already normal function require the wisdom and guidance of individuals who have a clear, evidence-based understanding of musculoskeletal structure and function, a firm grasp of biomechanical principles, and the ability to observe and document movement. This third edition is designed to enhance the ability of exercise and rehabilitation specialists to serve in this role.

—Carol A. Oatis

Online Resources for Students and Instructors

- **Approximately 150 video clips** provide dynamic illustrations of concepts discussed in the textbook and demonstrate movement disorders that can occur as a result of impairments. The clips also include demonstrations of palpations of bony landmarks for each anatomical region. A **video icon** is used throughout the text to identify concepts with related video material. These elements will help the reader integrate the relationships among structure, force, movement, and function and provide examples for students and teachers to analyze and discuss.
- **Laboratory Manuals** for both students and instructors continue to offer activities for students to enhance learning and applications. The instructors' laboratory manual includes solutions and brief discussions of most activities. The laboratory manual for Chapter 1 contains additional problems for students to test their analytical skills. The solutions are provided in the Instructors' Manual.
- The **Instructors' Guide** is a chapter-by-chapter outline to assist instructors with preparing class lectures. This ancillary has been updated to include the materials added to the revised chapters.

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Completion of this third edition required the work and commitment of several individuals. First I am most thankful for the wonderful work and creativity of the contributing authors. The authors continuing from the original book include Drs. Beattie, Karduna, Lockard, Mansour, McGill, and Topoleski. They each willingly reviewed their work and listened to suggestions we received from readers. They updated information and added clinical examples to help the information be even more relevant to rehabilitation specialists. New contributors include Drs. Ebaugh, Eckenrode, Keitrys, Osmotherly, Spitznagle, and Wise. These authors also carefully updated chapters and added clinical perspectives. Together, the efforts of all of the authors to identify changes in knowledge or perspective help ensure that this textbook remains at the forefront of kinesiologic science.

The team at Lippincott Williams & Wilkins (Wolters Kluwer) has provided invaluable developmental, managerial, and technical support throughout the project. Linda Francis, Managing Editor, has been patient, persistent, and enthusiastic—frequently at the same time! She has provided the organization and help I needed to manage the complexities of revising this book. She worked with me to create a timetable that worked for both me and the publishers and then has helped me stick to it! Throughout the process, Linda has remained positive and encouraging for which I am very grateful! I also want to thank David Orzechowski, Production Project Manager at Wolters Kluwer, and Dhinakaran Arumugam, Senior Project Manager at SPi Global, whose careful attention to detail as well as their patient tolerance of my mistakes were essential in the final production process.

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The art program underwent a complete overhaul in this third edition. These extensive revisions were expertly overseen by Jennifer Clements, Art Director. Jen kept us on schedule but also was patient and accepting as I requested "tweaks" to new and old figures needing to be fine-tuned. I am also most grateful to her for allowing me to continue my collaboration with the original artist, Kim Battista, and with the original photographer, Gene Smith. These two artists continue to create images that bring kinesiology and biomechanics to life. Kinesiology is a visual science and without the images created by these two, I would never be able to "tell the story."

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Carol A. Oatis, PT, PhD

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UNIT 5 — SPINE UNIT

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UNIT 7 — KNEE UNIT

UNIT 8 — ANKLE AND FOOT UNIT

PART V Posture and Gait

Videos

All videos may be found at http://thePoint.lww.com. Please refer to the code on the inside front cover of this text for access information.

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Chapter 2	Fatigue Fracture Stress—Strain Curve Types of Forces
Chapter 3	Anisotropy
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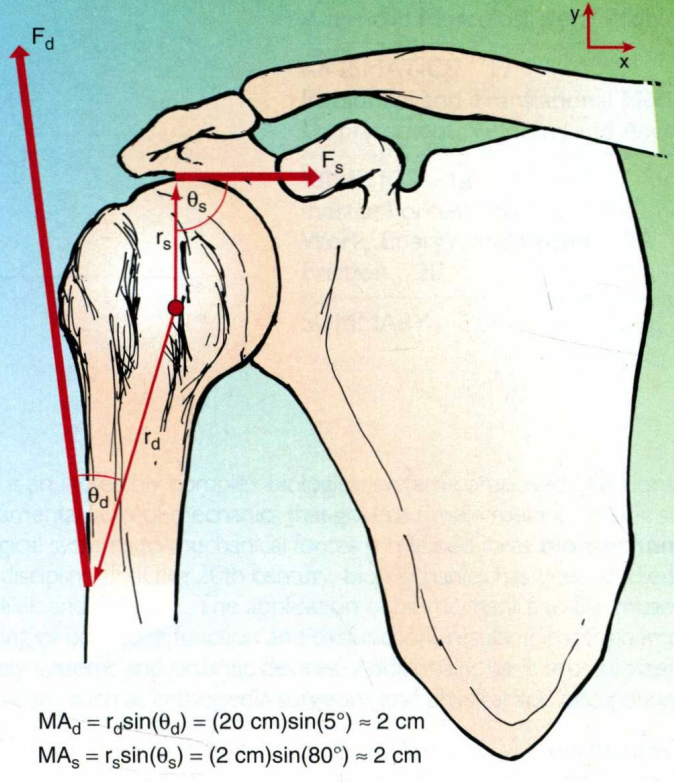
PART I

Biomechanical Principles



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$MA_s = r_s \sin(\theta_s) = (2\text{ cm})\sin(80°) \approx 2\text{ cm}$

1. Introduction to Biomechanical Analysis
2. Mechanical Properties of Materials
3. Biomechanics of Bone
4. Biomechanics of Skeletal Muscle
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