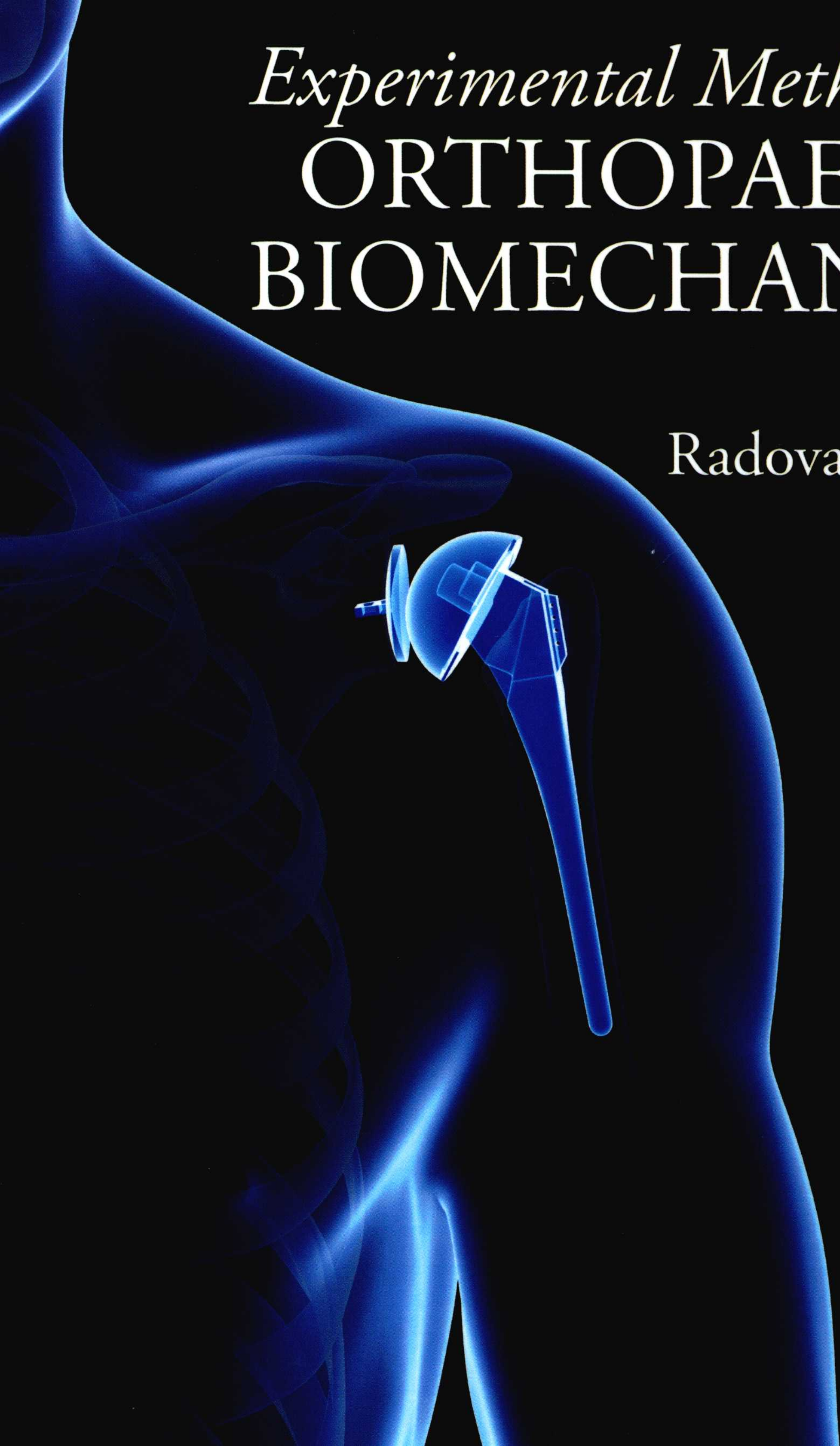
Experimental Methods in ORTHOPAEDIC BIOMECHANICS

Edited by

Radovan Zdero



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For my parents: Obrad and Ana Ždero
За моје родитеље: Обрад и Ана Ждеро

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What Is Orthopaedic Biomechanics?

Radovan Zdero
Western University, London, ON, Canada

WHAT IS THE MUSCULOSKELETAL SYSTEM?

To understand what this book is really about and how to best use it, some basic background information must first be considered. The musculoskeletal system is a complex network of hard tissues, soft tissues, and biofluids that interact with each other to provide both form and function to the human body. Bones bestow shape and size to the body while also being involved in performing a variety of tasks. Muscles generate forces that move limbs and other body segments. Tendons connect muscles to bones, thereby transmitting force from the former to the latter. Ligaments connect bones to other bones, thus allowing appropriate relative positioning and/or motion between neighboring bones. Cartilage and meniscus are like shock absorbers, which modulate stresses transferred across the interfaces of articulating joints. Biofluids, such as blood, marrow, and synovial fluid, deliver nourishment to hard and soft tissues, as well as being involved in lubricating joints.

WHAT IS BIOMECHANICS?

Biomechanics is the field of study that uses the engineering tools of statics, dynamics, and strength of materials to analyze the kinetics (i.e., loads) and kinematics (i.e., motions) experienced by the musculoskeletal system. These loads and motions may be generated during a whole host of very different activities of daily living, disease conditions, or injury events. So, biomechanics can be divided into five or more primary subfields, although some overlap exists (Fig. 1). Occupational biomechanics addresses workplace tasks, ergonomic design of tools and workspaces, and injuries. Sports biomechanics deals with physical training, athletic activities, and injuries. Transportation biomechanics focuses on passenger comfort and safety during vehicle operation, ergonomic design of vehicle interiors, and accidents causing injury. Rehabilitation biomechanics concerns the recovery of musculoskeletal strength and function after disease, injury, or surgery. And, finally, orthopaedic biomechanics, which is the focus of this book, uses engineering analysis tools in order to (1) characterize the mechanical properties of bones, joints, and soft tissues; (2) develop new implants and biomaterials for artificial joint replacement, bone fracture fixation, and soft tissue repair; and (3) optimize orthopaedic surgical techniques.

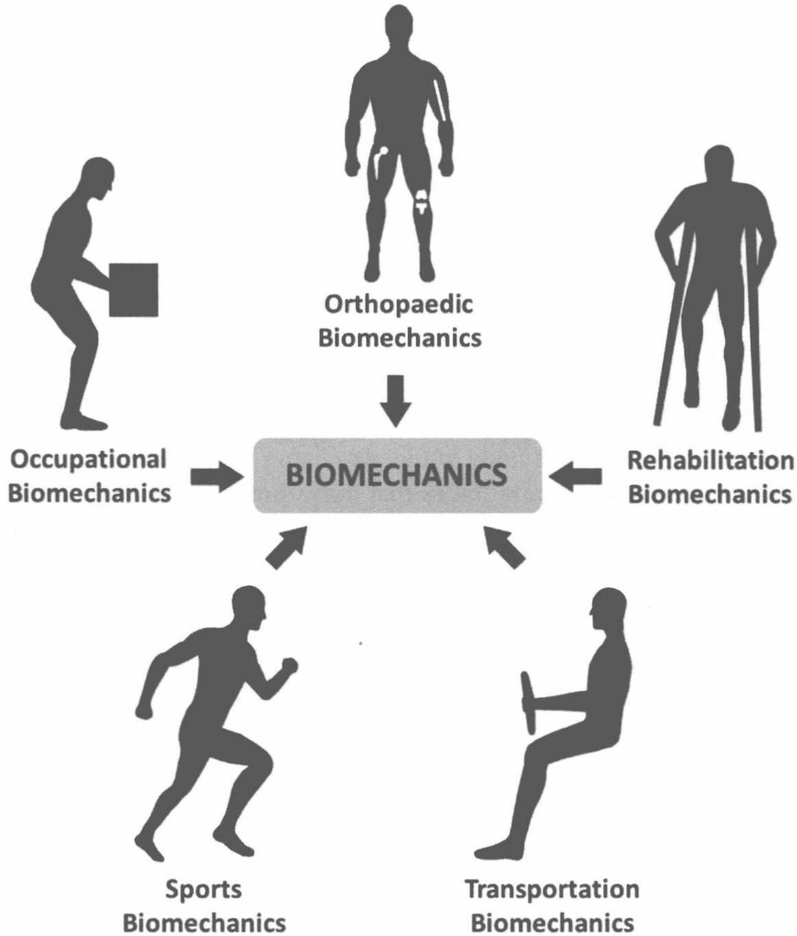

FIGURE 1

Biomechanics is a field of study dealing with loads and motions on the musculoskeletal system. The subfield of orthopaedic biomechanics is the focus of this book.

WHAT IS ORTHOPAEDIC BIOMECHANICS?

Orthopaedic biomechanics is about discovering and potentially optimizing the mechanical stresses experienced by normal, diseased, injured, or surgically treated bones, joints, and soft tissues. This subfield of study is particularly influenced by two groups of specialists, namely, orthopaedic surgeons and biomechanical engineers. Orthopaedic surgeons are on the "clinical frontline," as they treat patients by performing procedures like total or partial joint replacement, bone fracture repair, soft tissue repair, limb deformity correction, and bone tumor removal. Biomechanical engineers are on the "technological frontline," as they discover the basic mechanical properties of human tissues, design and test the structural stress limits of

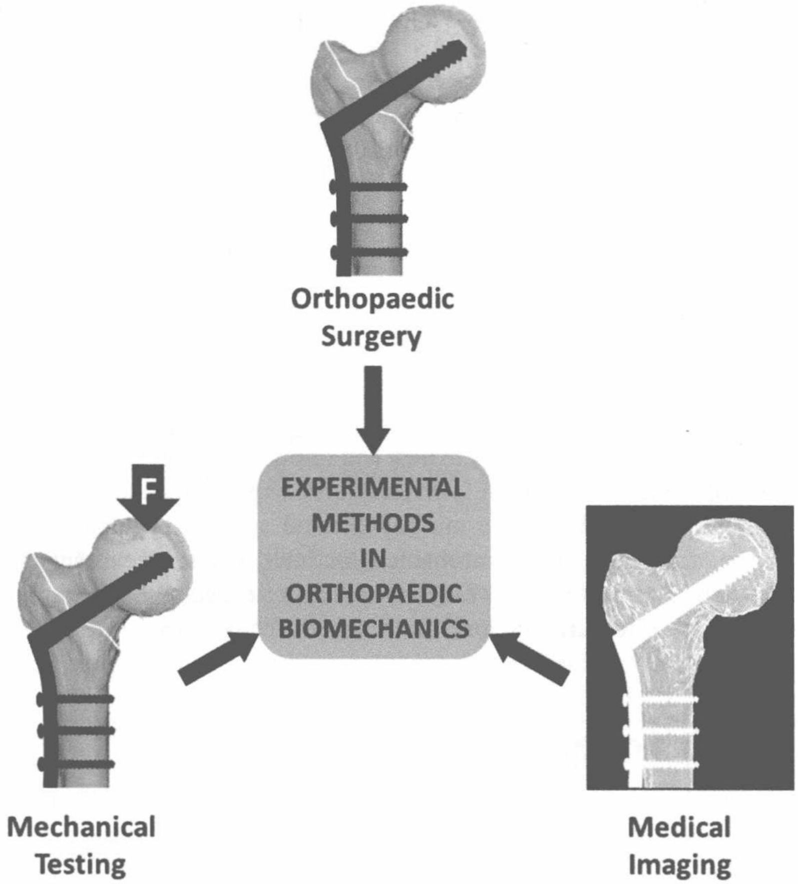

FIGURE 2

Experimental research activities in orthopaedic biomechanics.

orthopaedic implants, and develop new and improved biological and artificial biomaterials. Consequently, the strategy for conducting cutting-edge experimental research in orthopaedic biomechanics in hospitals, universities, and industry, includes a combination of orthopaedic surgery, mechanical testing, and medical imaging (Fig. 2).

WHAT IS THE PURPOSE OF THIS BOOK?

Much of the valuable material published in the field of orthopaedic biomechanics, including textbooks, peer-reviewed journal articles, and conference proceedings, is still of limited practical use in learning about laboratory experimentation. So, the aim of this book is to give the reader step-by-step, hands-on, do-it-yourself, practical instructions for performing experiments in orthopaedic biomechanics. This is not a book about foundational concepts in orthopaedic biomechanics,[1–6] the principles and practice of orthopaedic surgery,[7–9] highly specialized experiments for one type of tissue or material used in orthopaedics,[10,11] or computational modeling in orthopaedic biomechanics,[12–14] for which there are some excellent recommended resources created by experienced biomechanical engineers and orthopaedic surgeons. Rather, the motivating question for this work is, "After reading this book, can even an inexperienced reader go into the lab and successfully perform a wide variety of orthopaedic biomechanics experiments from start to finish?" Since practical factors limit the range of experimental methods that can be described, the book focuses on *in vitro* test methods on cadaveric tissue or artificial material. Even so, the large variety of techniques explored represent many of the most widely used approaches—some of which are considered "classic" techniques in the field—while recognizing that the progress of science and technology may eventually give way to new and improved modalities. Consequently, several types of readers will benefit from this book: engineering students learning to apply their analytical skills to the musculoskeletal system, orthopaedic surgeons growing in their knowledge of biomechanical methods, young researchers establishing their academic or professional careers, and experienced researchers expanding their teaching and/or research beyond their current focus.

WHAT IS THE FORMAT OF THIS BOOK?

Part 1 provides chapters on experimental methods for bones, such as whole bones with or without implants, bone tissues, and bone cells. Part 2 offers chapters on experimental methods for assessing the properties of human and artificial articulating joints. Part 3 gives chapters on experimental methods applied to soft tissues like cartilage/meniscus, ligament/tendon, and muscle. Obviously, some chapters could easily be classified as belonging to another part of the book, but the chosen groupings are sufficient for the aims of this volume. Each chapter presents content in a generic and rational way in order to emphasize underlying principles that can be easily adapted to a range of research questions. To this end, each chapter follows a standardized structure to make learning more effective and logical: Background, Research Questions, Methodology, Results, Discussion, Summary, Quiz Questions, and References. Note that the Methodology and Results sections deliberately provide only "mock" graphs and/or "empty" tables in order to illustrate the typical data trends and parameters measured during experiments; thus, the graphs and tables do not show actual numerical data. But, representative numerical data reported in the scientific literature are summarized in each Discussion section. And, finally, gray boxes, which highlight special content, are scattered throughout each chapter to make learning more memorable and enjoyable: Glossary, Safety First, Tips and Tricks, The Gold Standard, Engineer's Toolbox, and Alternatives and Adaptations.

WHAT IS THE BEST WAY TO USE THIS BOOK?

Some science textbooks sit on shelves collecting dust, or perhaps they are read but without making any practical difference. Other science textbooks, however, are used for the advancement of teaching, research, and technology. And so, there are many ways to get the most out of this book, rather than just reading it, which can be applied to university, industry, or hospital contexts:

- Design a new university-level course, using this book as the course textbook.
- Create undergraduate student lab tasks, homework assignments, and class projects.
- Formulate hypotheses and/or methodologies for graduate student thesis projects.
- Train lab managers, technicians, and other staff in experimental techniques.
- Expand the research programs of experienced researchers into new areas.
- Develop "gold standard" test methods that are recognized internationally.
- etc.

Another helpful idea for practical hands-on training and teaching using this book can be summarized by the acronym S.H.O.E (Fig. 3). S stands for "show," meaning that the mentor performs a task, while the mentee only watches carefully. H stands for "help," meaning that the mentor helps the mentee perform the task themselves. O stands for "observe," meaning that the mentee performs the task by themselves, while the mentor only watches and makes helpful verbal comments. E stands for "exit," meaning that the mentor now physically leaves the context, trusting that the mentee will be able to carry on with the task by themselves. While teacher-to-student transfer of theoretical information through lectures, books, videos, etc., has a pivotal role in modern education, the mentor-to-mentee

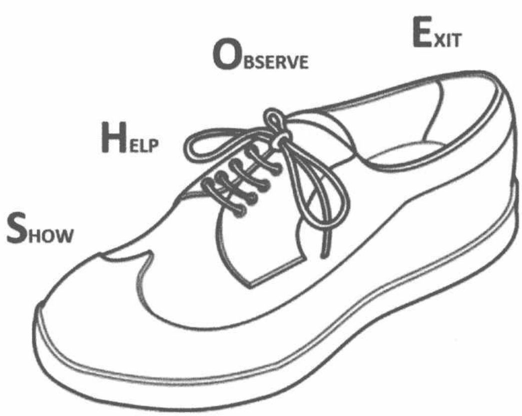

FIGURE 3

The S.H.O.E. system of mentoring.

apprenticeship approach has also been used effectively and extensively over the course of human civilization for many different endeavors. Now equipped with a basic background, may the reader expectantly turn to the content of the book!

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