Research Methods in Biomechanics

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Douglas Gordon Robertson
University of Ottawa

Joseph Hamill
University of Massachusetts Amherst

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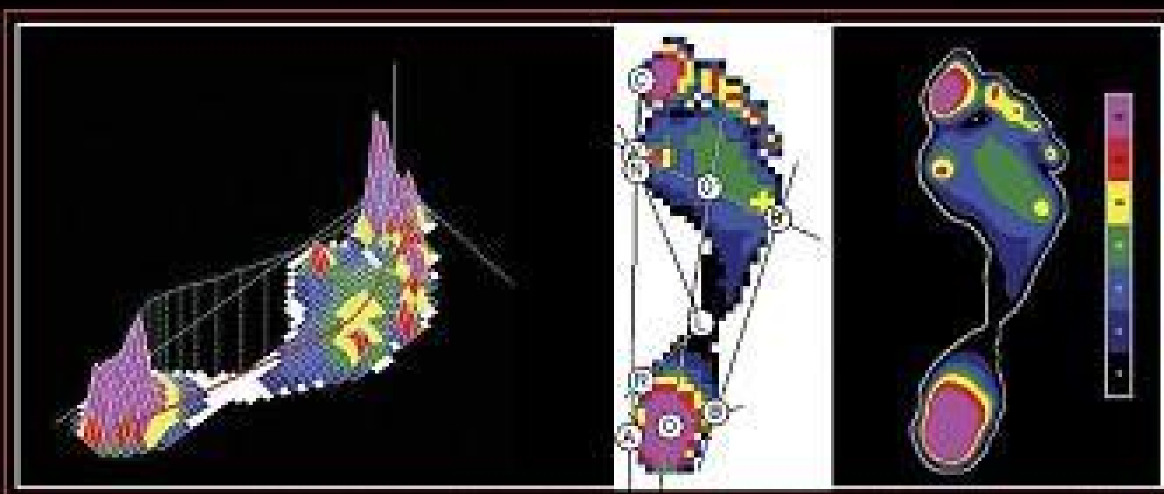

D. Gordon E. Robertson
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Human Kinetics
Web site: www.HumanKinetics.com

United States: Human Kinetics, P.O. Box 5076, Champaign, IL 61825-5076
800-747-4457
e-mail: humank@hkusa.com

Canada: Human Kinetics, 475 Devonshire Road Unit 100, Windsor, ON N8Y 2L5
800-465-7301 (in Canada only)
e-mail: orders@hkcanada.com

Europe: Human Kinetics, 107 Bradford Road, Stanningley, Leeds LS28 6AT, United Kingdom
+44 (0) 113 255 5665
e-mail: hk@hkeurope.com

Australia: Human Kinetics, 57A Price Avenue, Lower Mitcham, South Australia 5062
08 8277 1555
e-mail: liaw@hkaustralia.com

New Zealand: Human Kinetics, Division of Sports Distributors NZ Ltd., P.O. Box 300 226 Albany, North Shore City, Auckland
0064 9 448 1207
e-mail: blairc@hknewz.com

To Dr. James (Jim) G. Hay, 1936-2002,
for his inspiring leadership in sport biomechanics education and research,
and to all our graduate and undergraduate students
who assisted and inspired us.

CONTENTS

PREFACE

This book was developed with biomechanics, biomedical engineering, and kinesiology students and laboratory researchers in mind. The purpose of this book is to outline concisely and extensively the mathematical and technical tools necessary for investigating human and animal motion. In the past, such information had to be gleaned from disparate sources, including the periodical literature, or through hands-on demonstrations by professors or seasoned researchers. Our text provides students and researchers with the tools necessary to collect and analyze the mechanical characteristics of human movements using current biomechanical technologies.

The authors assume that the readers have taken an introductory course in biomechanics or Newtonian or engineering mechanics. Readers should have an understanding of vectors and elementary vector algebra and be familiar with the International System of Units (SI), although these areas are reviewed. Furthermore, readers should know the fundamental laws of mechanics, namely Newton's laws, and basic human musculoskeletal anatomy. The text examines how these laws apply to complex human motions, including the analysis of a human motion segment by segment and combining segments for limb or total body measures. Although knowledge of human anatomy is desirable, it is not essential for in-depth understanding of the analytical tools described.

The text is divided into 11 chapters in three parts. Part I describes the area called *kinematics,* which is concerned with motion description without regard to its causes. This section and part II include chapters specifically concerned with two-dimensional (2-D) and three-dimensional (3-D) analyses. Therefore, the text can be used for both intermediate and advanced courses in biomechanics, ensuring continuity of terminology from year to year. In an intermediate-level course, it is often unnecessary to perform complex 3-D methods to answer particular biomechanical questions. Therefore, suitable methods are outlined using two dimensions alone. If the motion under study is not planar, appropriate 3-D methodologies are included.

Part II pertains to the kinetic analysis of human motion—**kinetics** being the study of causes of motion. In general, this means the quantification of forces and the work, impulse, and power produced by forces. One chapter describes how to obtain various body segment parameters, such as mass, center of gravity, and moment of inertia. Not only are segmental parameters derived, but also methods for determining the total body's center of gravity and moment of inertia. As in part I, part II contains chapters on 2-D and 3-D kinetic analyses. Furthermore, methods for measuring forces and moments of force both directly and indirectly are presented. In biomechanics, it is rarely possible to directly measure forces in muscles and ligaments. These forces are estimated using a process called inverse dynamics. A method to perform inverse dynamics is outlined systematically, with explanations about its limitations and interpretation.

Part III contains four chapters about electromyographic kinesiology, muscle modeling, computer simulation, and signal processing. Electromyography (EMG) is the field of study that records and interprets the electrical signals produced by skeletal muscles when they are recruited to produce force. This discipline offers a direct way of determining the sequence of muscle activities and, therefore, explains how the brain and peripheral nervous system act together to coordinate human movements. Muscle modeling is a method of indirectly estimating the forces produced by individual muscles during a movement sequence. This is important, because it is not possible to measure these forces directly without using surgical intervention. Computer simulation involves the process of forward dynamics, in which a model of the musculoskeletal system predicts the kinematic motion from a set of initial conditions and prescribed kinetic patterns. Simulation allows researchers to explore optimal movement patterns, the effects of possible surgical interventions, and the role of specific muscles to a motion sequence. The final chapter, on signal processing, outlines technologies used when noise is present and needs to be removed. This technological area is of special interest when smoothing displacement signals prior to double differentiation (to obtain acceleration) or to analyze the frequency characteristics of EMG signals from muscle contractions.

The text concludes with a summary of SI units, conversion factors for converting measurements from American to SI units, an outline of basic electronics, outlines of vector and matrix mathematics, derivations and numerical integrations of double pendulum equations, and two computer subroutines for signal analysis. The book's glossary defines biomechanical terminology, and the index provides a quick reference for finding essential biomechanical concepts outlined in the text.