

Contents

Preface	xi
---------------	----

Introduction Biomechanics Analysis Techniques: A Primer 1

Gary Kamen

What Tools Are Needed in Biomechanics?	1
Applications of the Principles of Biomechanics: An Example	1
Numerical Accuracy and Significant Digits.	4
Summary.	5
List of Abbreviations	5

PART I KINEMATICS **7**

Chapter 1 Planar Kinematics 9

D. Gordon E. Robertson and Graham E. Caldwell

Description of Position	9
Degrees of Freedom	11
Kinematic Data Collection	12
Linear Kinematics	18
Angular Kinematics	24
Summary.	32
Suggested Readings	33

Chapter 2 Three-Dimensional Kinematics 35

Joseph Hamill, W. Scott Selbie, and Thomas M. Kepple

Collection of Three-Dimensional Data	35
Coordinate Systems and Assumption of Rigid Segments	36
Transformations Between Coordinate Systems.	37
Defining the Segment LCS for the Lower Extremity	38
Pose Estimation: Tracking the Segment LCS.	45
Joint Angles	50
Joint Angular Velocity and Angular Acceleration of Cardan Joint Angles.	58
Summary.	59
Suggested Readings	59

PART II KINETICS **61**

Chapter 3 Body Segment Parameters **63**

D. Gordon E. Robertson

Methods for Measuring and Estimating Body Segment Parameters	63
Two-Dimensional (Planar) Computational Methods	69
Three-Dimensional (Spatial) Computational Methods	74
Summary	78
Suggested Readings	78

Chapter 4 Forces and Their Measurement **79**

Graham E. Caldwell, D. Gordon E. Robertson, and Saunders N. Whittlesey

Force	79
Newton's Laws	79
Free-Body Diagrams	80
Types of Forces	82
Moment of Force, or Torque	84
Linear Impulse and Momentum	85
Angular Impulse and Momentum	89
Measurement of Force	92
Summary	108
Suggested Readings	108

Chapter 5 Two-Dimensional Inverse Dynamics **109**

Saunders N. Whittlesey and D. Gordon E. Robertson

Planar Motion Analysis	110
Numerical Formulation	115
Human Joint Kinetics	120
Applications	123
Summary	127
Suggested Readings	129

Chapter 6 Energy, Work, and Power **131**

D. Gordon E. Robertson

Energy, Work, and the Laws of Thermodynamics	131
Conservation of Mechanical Energy	133
Ergometry: Direct Methods	135
Ergometry: Indirect Methods	136
Mechanical Efficiency	147
Summary	148
Suggested Readings	149

Chapter 7 Three-Dimensional Kinetics 151

W. Scott Selbie, Joseph Hamill, and Thomas M. Kepple

Segments and Link Models	151
3-D Inverse Dynamics Analysis	152
Presentation of the Net Moment Data	164
Joint Power	168
Interpretation of Net Joint Moments	169
Sources of Error in Three-Dimensional Calculations	175
Summary	175
Suggested Readings	176

PART III MUSCLES, MODELS, AND MOVEMENT 177

Chapter 8 Electromyographic Kinesiology 179

Gary Kamen

Physiological Origin of the Electromyographic Signal	179
Recording and Acquiring the Electromyographic Signal	182
Analyzing and Interpreting the Electromyographic Signal	188
Applications for Electromyographic Techniques	193
Summary	201
Suggested Readings	201

Chapter 9 Muscle Modeling 203

Graham E. Caldwell

The Hill Muscle Model	203
Muscle-Specific Hill Models	216
Beyond the Hill Model	223
Summary	229
Suggested Readings	229

Chapter 10 Computer Simulation of Human Movement 233

Saunders N. Whittlesey and Joseph Hamill

Overview: Modeling as a Process	233
Why Simulate Human Movement?	235
General Procedure for Simulations	236
Control Theory	242
Limitations of Computer Models	243
Summary	245
Suggested Readings	246

Chapter 11 Musculoskeletal Modeling 247*Brian R. Umberger and Graham E. Caldwell*

Musculoskeletal Models	247
Control Models	256
Analysis Techniques	266
Summary	273
Suggested Readings	275

PART IV FURTHER ANALYTICAL PROCEDURES 277**Chapter 12 Signal Processing 279***Timothy R. Derrick*

Characteristics of a Signal	279
Fourier Transform	281
Time-Dependent Fourier Transform	282
Sampling Theorem	282
Ensuring Circular Continuity	285
Smoothing Data	285
Summary	289
Suggested Readings	290

Chapter 13 Dynamical Systems Analysis of Coordination 291*Richard E.A. van Emmerik, Ross H. Miller, and Joseph Hamill*

Movement Coordination	291
Foundations for Coordination Analysis	296
Quantifying Coordination: Relative Phase Methods	298
Quantifying Coordination: Vector Coding	310
Overview of Coordination Analysis Techniques	314
Summary	315
Suggested Readings	315

Chapter 14 Analysis of Biomechanical Waveform Data 317*Kevin J. Deluzio, Andrew J. Harrison, Norma Coffey,
and Graham E. Caldwell*

Biomechanical Waveform Data	317
Principal Component Analysis	319
Functional Data Analysis	327
Comparison of PCA and FDA	336
Summary	336
Suggested Readings	336

Appendix A: International System of Units (Système International, SI)	339
Appendix B: Selected Factors for Converting Between Units of Measure	343
Appendix C: Basic Electronics	345
Appendix D: Vectors and Scalars	355
Appendix E: Matrices and Matrix Operations	361
Appendix F: Numerical Integration of Double Pendulum Equations	365
Appendix G: Derivation of Double Pendulum Equations	369
Appendix H: Discrete Fourier Transform Subroutine	373
Appendix I: Shannon's Reconstruction Subroutine	375
Example Answers	377
Glossary	389
References	395
Index	415
About the Authors	427
Additional Contributors	428