

Preface

This book is designed to be a first course in human biomechanics. Although it was written with an undergraduate kinesiology student audience in mind, I believe it is equally well suited for students in a graduate-level clinical curriculum, such as athletic training, physical therapy, and chiropractic medicine. This is more of an “ideas” book than a “methods” book, and it is written under the assumption that students have a rudimentary knowledge of anatomy and algebra. Trigonometry and geometry are used throughout the book, but “refreshers” appear at the appropriate places. I do not make use of calculus.

Personally, I think many students have a hard time with biomechanics because it is taught in an intimidating manner, with an emphasis on getting the “right numbers” without an understanding of what the numbers actually mean. I have chosen to take a different approach in this book. First, I have used a conversational writing style because I believe that information presented this way is easier to understand without sacrificing rigor. Second, I have tried to make the material less daunting and more meaningful by presenting a Section Question before each major section. Tying new concepts to everyday experience and highlighting research to show how information obtained in the lab can be applied in practice allows the student to better relate to the content. Third, I have placed an emphasis on concepts over computation and expressing these concepts physically, mathematically, and graphically. My hope is that students get an intuitive feel for which way the data should “go” before ever attempting to calculate a number. It might seem that my extensive use of equations contradicts this goal, but I wanted to introduce the symbolic logic behind the equations, and then draw a link between the concepts and the equations. Graph interpretation allows students to visualize this link.

Each lesson opens with a set of Learning Objectives. Marginal Key Terms, Tables, Figures, Boxes, and Important Point boxed features are used throughout the text. Competency Checks are found after every major section and follow the first three areas of Bloom’s taxonomy: remember, understand, and apply. An alphabetized Glossary has been placed at the end of the book for optimum review and study. My goal in organizing the content in such a fashion is to lead students to better comprehension and optimal retention.

As for the material itself, I have organized the book into 17 lessons that cover the three levels of biomechanical analysis: whole body, joint, and tissue (bone, cartilage, ligament, tendon, and muscle). I chose not to move sequentially from one level to the next but to use a “whole-part-whole” organization. I begin with elucidating mechanical principles using the whole body level (point-mass, center of mass, and rigid body models) and then discuss the basic material mechanics of biological tissues and unique properties of the muscle-tendon complex. Throughout my career, I have been influenced by a systems science perspective, which states that you cannot get a complete understanding of a system by examining the parts in isolation. For this reason, the muscle-tendon complex is then put into a joint system. After reviewing some mechanical properties of the individual joints of the musculoskeletal system, the mechanics of multi-joint systems is then introduced. In Lesson 17, the three levels are integrated in the context of analyzing movement to improve performance and/or reduce the risk of injury.

I hope that this book provides you with an alternative perspective for teaching and learning the science of biomechanics. Comments and criticisms are welcomed and appreciated.

PEDAGOGICAL FEATURES

Biomechanics: A Case-Based Approach incorporates a number of engaging pedagogical features to aid the student's understanding and retention of the material.

Each lesson starts with Learning Objectives, which highlight the critical points of each lesson.

LEARNING OBJECTIVES

After finishing this lesson, you should be able to:

- Define the following terms: abscissa, absolute value, acceleration, average value, axis, body, cadence, direction, displacement, distance, frame of reference, gait, instantaneous value, kinematics, net value, ordinate, orientation, origin, point, position, relative speed, sense, scalar, slope, speed, step, stride, system, vector, and velocity.
- Explain the difference between speed and velocity.
- Write equations for the following concepts: distance, displacement, speed, velocity, and acceleration.
- Identify speed on a position–time curve.
- Identify velocity on a position–time curve.
- Identify acceleration on a velocity–time curve.
- Explain the difference between instantaneous and average kinematic measures.
- Describe situations in which velocity is more important than acceleration.
- Describe situations in which acceleration is more important than velocity.
- List the determinants of gait velocity.

Important Point! boxes clarify essential math concepts relevant to the content within the specific section.

Important Point! A net acceleration causes a change in velocity, and a change in velocity causes a displacement.

Section Questions present salient questions to address the point of focus for each section.

Section Question

According to the Disability Statistics Center at the University of California, San Francisco,¹ 1.6 million Americans use wheelchairs (Figure 4.1). Understanding the motion of the wheel is essential in understanding the mobility of wheelchair users. Is the motion of the wheel the same as the motion of a body previously explored?

Section Question Answers provide contextual responses to the each section question.

Section Question Answer

Angular motion is similar to linear motion in that there are positions, displacements, velocities, and accelerations. The relation between position, velocity, and acceleration are also the same. The main difference is that you are replacing a linear term with its angular equivalent.

Using the first three levels of Bloom's taxonomy, Competency Checks ask students conceptual and quantitative questions to assist in gauging their understanding of the material.

COMPETENCY CHECK

Remember:

1. Define the following terms: work, positive work, negative work, and mechanical energy expenditure.
2. List the assumptions associated with mechanical energy expenditure.

Understand:

1. How much work is required to do the following? Is the energy entering or leaving the system?
 - a. Raise a 10 kilogram mass 0.5 meters.
 - b. Lower a 5 kilogram mass 0.1 meters.
 - c. Raise a 15 kilogram mass by 0.5 meters, and then lower it back to its original starting position.
2. How much mechanical energy expenditure is required to do the following?
 - a. Raise a 10 kilogram mass 0.5 meters.
 - b. Lower a 5 kilogram mass 0.1 meters.
 - c. Raise a 15 kilogram mass by 0.5 meters, and then lower it back to its original starting position.

Apply:

1. List several activities where:
 - a. Work would be an appropriate measure for analysis.
 - b. Mechanical energy expenditure would be an appropriate measure for analysis.
 - c. Neither work nor MEE would provide useful insights.

Equations are numbered throughout the lesson for easy referral.

frictional (or other external) forces, and the time of impact is extremely small. Because the change in momentum of the system is zero in each case, you know:

$$\Delta L = L' - L = 0 \quad (9.2)$$

where the prime sign will indicate the time immediately after impact, and the momentum without the prime sign is the momentum immediately before impact. You know that momentum is the product of mass and velocity:

$$L = mv \quad (9.3)$$

It is also important to note that the momentum of any system is the sum of the momentum of each body in a system:

$$L = \sum (m_i \times v_i) \quad (9.4)$$

where the symbol i represents the number of bodies in the system. If there are two bodies (a and b) in your system, then:

$$L = m_a v_a + m_b v_b \quad (9.5)$$

If you substitute Equation 9.5 into Equation 9.4, you get:

$$\Delta L = (m'_a v'_a + m'_b v'_b) - (m_a v_a + m_b v_b) = 0 \quad (9.6)$$

Essential Math boxed features provide a review of mathematical material crucial to the understanding of biomechanics.

Box 2.1 Essential Math: Ratios and Rates

A **ratio** is simply one number divided by another number:

$$\text{ratio} = \frac{\text{one quantity}}{\text{another quantity}}$$

A **rate** is a ratio between the change in one quantity and the change in time:

$$\text{rate} = \frac{\Delta \text{one quantity}}{\Delta \text{time}}$$

The delta symbol (Δ) is shorthand for "change in." Think of the dividing line as "per," so we can think of a rate as a change in one quantity (position, velocity, force, work) per a change in a unit of time (seconds, minutes, hours). Rates are going to be very important in biomechanics. From algebra, you should be able to recognize that the rate will be larger if the change in the quantity is increased and/or the change in time is decreased.

$$\frac{\Delta \text{one quantity}}{\Delta \text{time}} \begin{matrix} \nearrow \text{Increase this} \\ \searrow \text{Decrease this} \end{matrix} \quad \text{or} \quad = \text{Larger ratio}$$

Applied Research boxed features provide examples that are helpful in illustrating biomechanical concepts and present evidence of the practical value of biomechanics.

Box 9.1

Applied Research: Effective Mass and Head Injuries in American Football

Head injuries in American football are a serious problem, particularly those resulting from helmet-to-helmet contact. In many cases, the injury to the offensive player receiving the impact is greater than the injury sustained by the striking, defensive player. In this investigation, the researchers provide an explanation for why this is the case. Reconstructing actual, recorded game-time head injuries using instrumented dummies in the laboratory, they found that the striking player aligned their head, neck, and torso (called spearing), increasing the effective mass of the striking player to 1.67 times that of the player being hit. In a follow-up investigation, they compared these impacts to punches to the head delivered by Olympic-caliber boxers. They found these impacts did not transfer as much linear momentum as the football head strikes due to the lower effective mass of the fist.

Data from: Viano DC, Pellman EJ. Concussion in professional football: biomechanics of the striking player—Part 8. *Neurosurgery*. Feb 2005;56(2):266–278.

Viano DC, Casson IR, Pellman EJ, Bir CA, Zhang LY, Boitano MA. Concussion in professional football: comparison with boxing head impacts—Part 10. *Neurosurgery*. Dec 2005;57(6):1154–1170.

Key Terms are highlighted and defined in the margins throughout the lesson and compiled into a Glossary at the end of the book.

Plastic deformation A deformation in which the object does not return to its original dimensions after the deformation.

original shape. With a plastic deformation, the object has been "stretched out of shape" and will not ever return to its original dimensions. Think of the

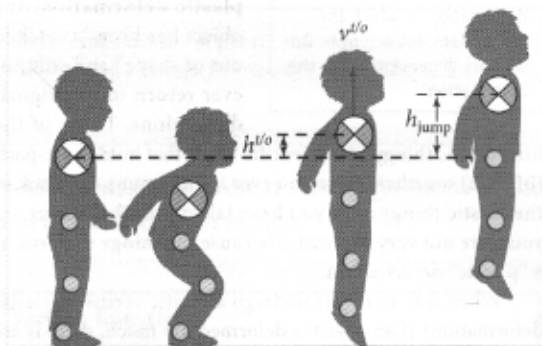
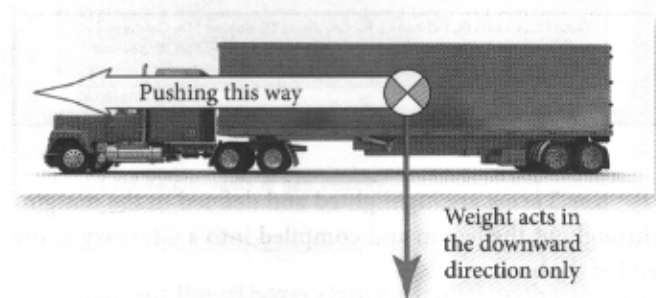
little plastic thingy (the scientific term) that holds a six-pack (of soda) together. Have you ever tried to put a can back in the plastic thingy after you have taken it out? Chances are you were not very successful because the thingy underwent a "plastic" deformation.

When will an object undergo a plastic versus an elastic deformation? If an object is deformed too much, there is actually a microtearing of the

Yield point The amount of deformation that marks the transition from elastic to plastic deformations, and deformation beyond this point results in a permanent deformation.

material. The point where it is deformed too much is called the yield point: Any deformations beyond the yield point result in permanent (plastic) deformations.

A comprehensive and instructional art package includes photographs and illustrations throughout the book to encourage learning with a unique visual appeal.



At the end of each lesson, a Summary reinforces key ideas and helps students recall and connect the concepts discussed. Key Concepts are presented in table format for review. Review Questions test comprehension of the concepts discussed within the lesson. References used in the lesson are also listed.

Table 8.1 Key Concepts

- Energy
- Work
- Mechanical energy expenditure
- Efficiency
- Power

SUMMARY

In this lesson, you learned about an alternative to Newton's laws for analyzing human movement. This method involved the concepts of work, energy, and power (Table 8.1). Because of some issues with using these concepts with biological systems, mechanical energy expenditure was introduced. The first law of thermodynamics was compared to the center of mass equation, and efficiency and economy were introduced. Impulse-momentum and work-energy methods provide complementary information and a more complete analysis of movement for several different tasks.

REVIEW QUESTIONS

1. Define the following terms: energy, kinetic energy, potential energy, gravitational potential energy, strain potential energy, work, mechanical energy expenditure, efficiency, economy, and power.
2. State the conservation of energy and the first law of thermodynamics.
3. What is meant by the term *negative* work or power?

REFERENCES

1. Feynman RP. *Six Easy Pieces*. New York: Basic Books, 1995.
2. Watson D. Energy Definition. 2011. Internet Communication.
3. Zatsiorsky VM. *Kinetics of Human Motion*. Champaign, IL: Human Kinetics, 2002.
4. Aleshinsky SY. An energy-sources and fractions approach to the mechanical energy-expenditure problem. 1. Basic concepts, description of the model, analysis of a one-link system movement. *J Biomech*. 1986;19:287-293.

Instructor Resources available for download to adopters of the book include PowerPoint Lecture Presentations, Image and Table Bank, Test Bank, and Instructor's Manual. For access, contact your Representative at www.jblearning.com.

The Companion Website for *Biomechanics: A Case-Based Approach*, go.jblearning.com/biomechanics, offers students and instructors an unprecedented degree of integration

between their text and the online world through many useful study tools, activities, and supplementary information. Study tools include Student Practice Problems, Weblinks, Flashcards, an Interactive Glossary, and Crossword Puzzles. This interactive and informative website is accessible to students through the redeemable access code provided in every new text.

