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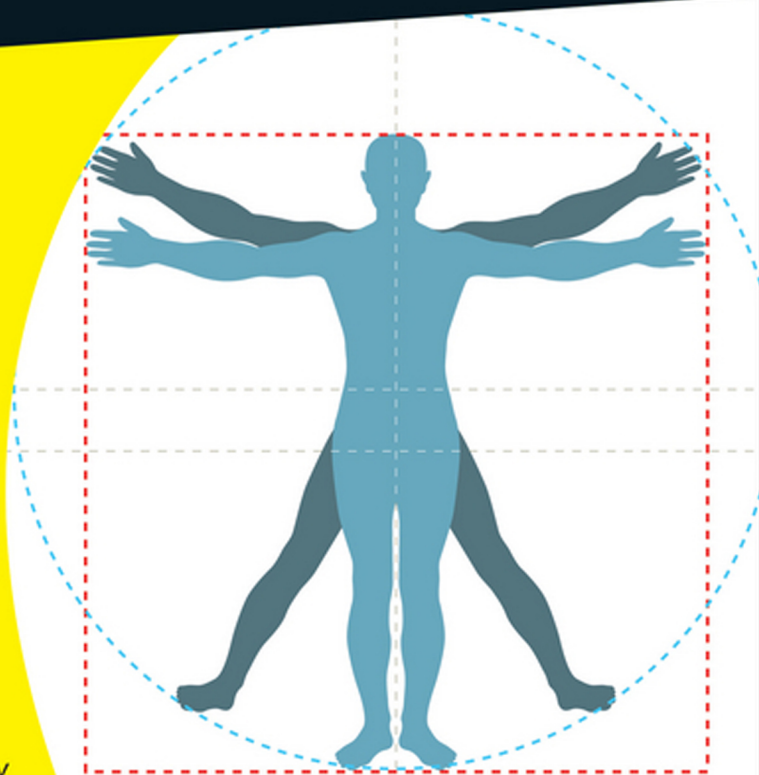
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- Navigate the intersection of the biological and mechanical worlds
- Score your highest in your biomechanics course

Steve McCaw, PhD

Professor of Biomechanics, Illinois State University



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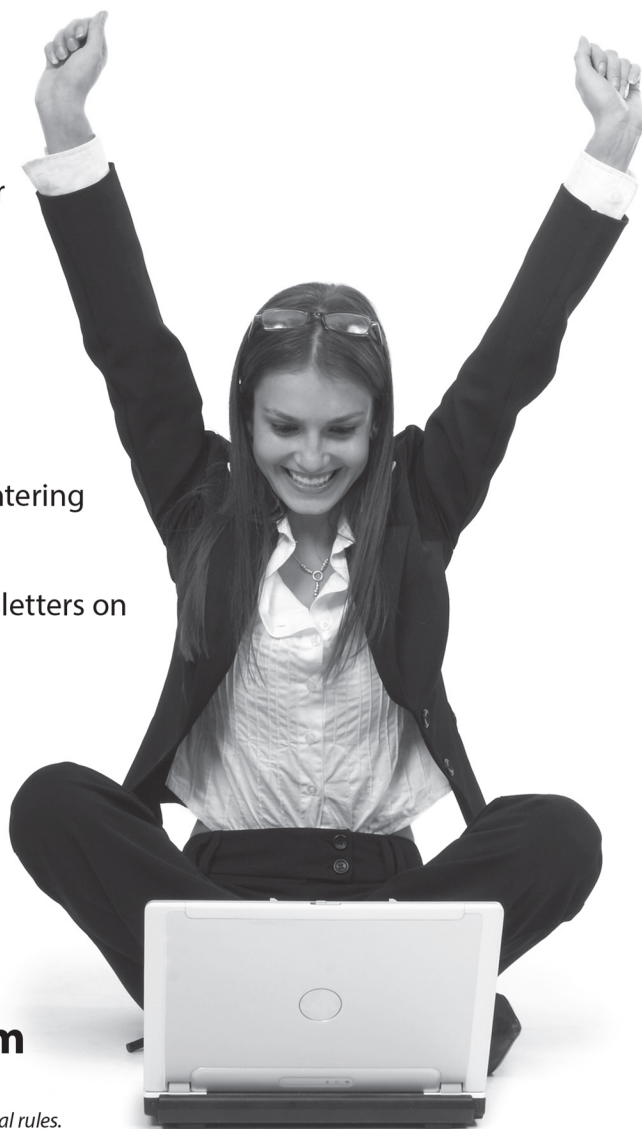
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by Steven T. McCaw, PhD

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Biomechanics For Dummies®

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Introduction

Students enrolled in a biomechanics class usually find themselves looking at movement in a whole new way. After years of participation in organized or recreational sports, dance, and fitness, they've become pretty good “movers” in at least one activity. And because they like to, they just get out and move. For many, the enjoyment of moving has piqued an interest in pursuing a career as a teacher, coach, fitness specialist, or clinical therapist to help others become better movers.

Biomechanics is often your first exposure to the science of explaining how and why things move. Mechanics is the science concerned with forces acting on objects, and mechanics by itself is a demanding topic. Biomechanics goes a step further by applying the principles of mechanics to a living body. And the human body is the most complex thing around.

Fortunately, all movement and injury share the same basic principles. The overriding principle of biomechanics is that force causes all movements and underlies all injury or training that occurs. Knowing the effect of force — in fact, just knowing more about force as the source of all movement — provides a solid foundation for knowing more about movement and injury. And that's what biomechanics is all about.

About This Book

No biomechanics book can show you how to apply biomechanics to every possible form of human movement — there are just too many ways the human body can move. But what a biomechanics book can show you is that biomechanics applies to every possible form of human movement.

Biomechanics For Dummies is a reference book on the “what” and “how” of biomechanics. The “what” relates to the explanation of the terminology and principles of biomechanics, and the “how” relates to solving all the pesky equations that pop up in any science.

I try to be as informal as possible in a book that explores the science of something as complex as movement of the human body. I also try to make it clear why you need to know the concepts and equations of mechanics. I stay logical and factually precise, while simplifying some extremely challenging ideas.

In the examples, I demonstrate and reinforce a step-by-step format to problem solving. A systematic approach to equation and problem solving is important for anyone working at any level in biomechanics, maybe even more so at the beginning.

Anything marked by a Technical Stuff icon provides a more in-depth discussion of whatever material is being explained where the icon appears. This is useful but not necessary information. Also, the text in sidebars (shaded gray boxes) provides more details about a topic. It's interesting information (or I wouldn't have included it), but you won't miss any explanation about a topic by skipping right over a sidebar.

Finally, within this book, you may note that some web addresses break across two lines of text. If you're reading this book in print and want to visit one of these web pages, simply key in the web address exactly as it's noted in the text, pretending as though the line break doesn't exist. If you're reading this as an e-book, you've got it easy — just click the web address to be taken directly to the web page.

Foolish Assumptions

While writing this book, I made the following assumptions about who would read it:

- ✔ You may be an undergraduate college student taking an introductory biomechanics course. Most likely, you're enrolled in a program in kinesiology, exercise science, physical education, or athletic training. You've probably heard that biomechanics is a tough course, with a lot of math and physics, and you're pretty nervous about how well you'll do in the class.
- ✔ You may be a parent or coach in a youth league, and you've heard people talking about "the biomechanics of <insert the activity of your choice here>." You want to know more about the topic because it seems interesting and useful.
- ✔ Your basic math skills are still in your head somewhere, but you don't necessarily like to use them all that much unless you have to. You consider trigonometry something best avoided, although you may remember the Pythagorean theorem and what a hypotenuse is.
- ✔ You may or may not have had a previous course in anatomy and physiology. And if you did, you learned the names, origins, and insertions of a lot of muscles. But you don't recall a lot of details about exactly how we use our muscles to move.

Basically, except for the second item in this list, I'm assuming you're me back when I took an introductory biomechanics class.

Icons Used in This Book



Icons are the little pictures you see sprinkled throughout the margins of this book. They draw your attention to key types of information:

The Tip icon highlights a quick summary of an idea, application, or definition, or gives you insight on using a shortcut step with an equation.



The Remember icon jogs your memory to facts and ideas touched on earlier in the chapter or book that are relevant to the section you're reading.



The Warning icon tells you're in a misstep zone — a theory or equation where I've commonly seen (or made) bad moves. Take extra care.



The Technical Stuff icon marks some additional information on the topic that's too good not to include, but not essential to understanding the concept, equation, or idea.

Beyond the Book

In addition to the material in the print or e-book you're reading right now, this product also comes with some access-anywhere goodies on the web. Check out the free Cheat Sheet at www.dummies.com/cheatsheet/biomechanics for information on how running shoes work, what causes low-back pain, and more.

In addition, I've written several articles on topics ranging from how to turn around in outer space to composing a resultant force vector from multiple vectors. They're available at www.dummies.com/extras/biomechanics.

Where to Go from Here

You can use *Biomechanics For Dummies* as a supplement to a course you're taking or on its own as a text to understand the basic principles of biomechanics. I've written each chapter to stand on its own, so you don't need to move through the book in order, beginning with Chapter 1.

As you read the book, you'll notice that the principles of biomechanics are intertwined. The material in some chapters builds off topics explained in depth in other chapters. For example, the explanation of force, covered in Chapter 4, is useful to understanding torque, explained in Chapter 8. As a convenience, I include cross-references in each chapter to guide you to more in-depth discussions.

If you're new to the subject of biomechanics, beginning with Chapter 1 is a good idea. If you're taking an introductory course in biomechanics, your instructor and/or your textbook may present the material in a different order than I use here. If so, you can jump around, supplementing your instructor's lectures and your textbook by reading the chapters of this book that are relevant to the material being covered in your course.

Part I

Getting Started with Biomechanics



For Dummies can help you get started with lots of subjects. Visit www.dummies.com to learn more and do more with *For Dummies*.

In this part...

- ✓ Identify the “bio” and the “mechanics” parts of biomechanics.
- ✓ Get a refresher on the basic math and geometry skills you need to solve biomechanics problems.
- ✓ Discover a systematic approach to resolving or composing vectors using SOH CAH TOA.
- ✓ Understand the fundamental terms and concepts of biomechanics.

Chapter 1

Jumping Into Biomechanics

In This Chapter

- ▶ Defining biomechanics
 - ▶ Introducing linear and angular mechanics
 - ▶ Using biomechanics to analyze movement
-

Kinesiology is the science focused on the study of motion. It's the core area of many majors at colleges and universities for students interested in exercise or movement science, athletic training, and physical education teacher education. A degree in kinesiology can lead to a career in itself in teaching, exercise prescription, sports medicine, and coaching. In addition, many students study kinesiology at the undergraduate level because its focus on the human body provides a strong foundation for graduate study in physical therapy and medicine.

Biomechanics is one of the core courses in kinesiology. Along with the foundation knowledge from other core courses (including anatomy and physiology, psychology of sport and exercise, exercise physiology, and motor learning), biomechanics contributes to a basic understanding of human movement possibilities.

In this chapter, I introduce you to the subject of this book — think of this as the book in a nutshell — with plenty of cross-references so you know where to turn to find more information.

Analyzing Movement with Biomechanics

Biomechanics uses three branches of mechanics, along with the structure and function of the living body, to explain how and why bodies move as they do (see Figure 1-1). The different branches of mechanics are used to study movement in specific situations, and the systems of the living body determine what it's capable of doing and how it responds during movement.

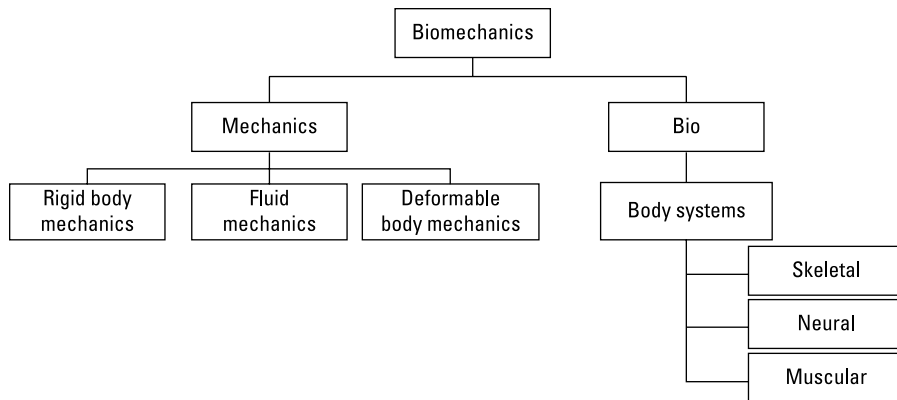


Figure 1-1:
The
branches
of bio-
mechanics.

In this section, I give you a brief overview of the three branches of mechanics, along with the structure and function of the living body.

Mechanics

Mechanics is a long-established field of study in the area of physics. It focuses on the effect of forces acting on a body. A *force* is basically a push or a pull applied to a body that wants to make it move (see Chapter 4). Mechanics looks at how a body is affected by forces applied by muscle, gravity, and contact with other bodies.



I use the term *body* to refer to the focus of attention during an analysis. For someone walking, the body could be the person as a whole entity. But the body could also be an individual segment, like the walker's thigh, lower leg, or foot, or, going even further, an individual bone in a segment. For more on defining the body under analysis, turn to Chapter 4.

Rigid body mechanics

An applied force affects the motion of a body — meaning, it tries to make the body speed up or slow down. The motion can be large and involve a lot of body segments, like walking, or it can be small and involve only a couple of segments, like bending a finger. Both of these movements, and all other movements involving body segments, can be analyzed using rigid body mechanics.

Rigid body mechanics simplifies a body by *modeling* (representing) it as a single, rigid bar. A rigid bar can be used to represent the entire body (quite a simplification) or just the individual segments of the body. The modeled segments can be combined as rigid, non-deforming links joined at hinges (the joints) to represent any part of the body.

Consider your arm, made up of the complex anatomical structures of the upper arm, forearm, and hand. If you hold your arm out in front of you and bend and straighten your wrist and elbow, you'll notice that your skin shifts and folds and soft areas bulge as muscles change shape under the skin. Place a finger over the front of your upper arm, and feel the changing stiffness of the muscle when your arm bends and straightens. If you poke your skin with a finger, it sinks in a little bit. In rigid body mechanics, these changes in, or deformations of, the individual segments are ignored. The upper arm, forearm, and hand are considered to be separate, simple rigid links or sticks that move at the joints where they meet. The rigid link model of the human body is more fully explained in Chapter 8.

Fluid mechanics

Fluid mechanics is the branch of mechanics focused on the forces applied to a body moving in air or water. These fluids produce forces called *lift* and *drag*, which affect the motion of a body when a fluid moves over it, or as the body moves through a fluid.

Fluid mechanics is obviously applicable to swimming and water sports, but it's also useful when explaining how to make a soccer ball, tennis ball, or baseball curve through the air. For more on fluid mechanics, float on over to Chapter 11.

Deformable body mechanics

Deformable body mechanics focuses on the changes in the shape of the body that are ignored in rigid body mechanics. An applied force causes a *deformation* (change in shape) of the body by loading the particles of material making up the body. Deformable body mechanics involves looking at the loading and the motion of the material within the body itself.

The loading applied to a body is called a *stress*. The size and the direction of the stress cause deformations of the material within the body, called *strain*. The relationship between the applied stress and the resulting strain is useful to understand injury to and training of tissues within the body. Chapter 12 provides more detail on deformable body mechanics.

Bio

Bio is Greek for “life,” making biomechanics the science applying the principles of mechanics to a living body. Biomechanics is used to study and explain how and why living things move as they do, including the flight of a bumblebee, the swaying of a stalk of corn, and, more important for most of us, the movements of human beings.

Part IV of this book covers the “bio” of biomechanics, explaining aspects of the following systems important to the mechanics of movement:

- ✔ **Skeletal system:** The skeletal system, including bones, ligaments, and joints, provides the physical structure of the body and allows for movement. (See Chapter 13.)
- ✔ **Neural system:** The neural system, also known as the nervous system, including different types of nerve cells, serves as the communication system to control and respond to movement. (See Chapter 14.)
- ✔ **Muscular system:** The muscular system, including muscle and the tendon attaching muscle to bone, provides the motors we control to make our segments, and our bodies, move. (See Chapter 15.)

Later in this book, I give you an overview of the anatomy and function of the components of each of these systems and explain how each system influences movement.

Expanding on Mechanics

In mechanics, we look at how an applied force affects the motion of a body. Each branch of mechanics includes two subdivisions, one focused on describing the motion (kinematics) and the other focused on the forces that cause motion (kinetics). Figure 1-2 gives you a handy diagram of these subdivisions of mechanics, which I describe in more detail in this section.

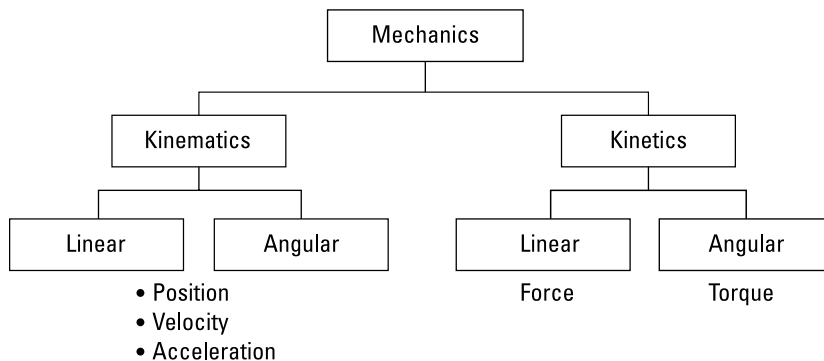


Figure 1-2:
The subdivisions of mechanics.

Describing motion with kinematics

Kinematics is the subdivision of mechanics focused on the description of motion. Kinematics is what we see happen to the body. When you watch a body, and describe its position, how far it travels, how fast it travels, and whether it's speeding up or slowing down, you're conducting a kinematic analysis.

Human movement is complex, even with simple moves. Try this: Use the tip of your index finger to draw a straight line across this page or screen. Can you do it if just your index finger moves? No, you get a short curved line. If just your hand moves at the wrist? No, you get a long, but still curved, line. If just your forearm moves at the elbow? No, you get a longer curved line. To make the tip of your finger move in a straight line across the page, you must coordinate the movement of at least two joints: the shoulder and elbow joints.

Coordinating multiple segments at multiple joints to create linear motion of one part of the body is called *general motion*. Most human movement is general motion, and most of it is more complex than just tracing a straight line with a finger. Because it's complex, it's useful to look separately at the linear and angular motions that make up general motion.

Linear kinematics

Linear kinematics describes *linear motion*, or motion along a line (also called *translation*). There are two forms of linear motion:

- ✔ **Rectilinear motion:** Translation in a straight line. Your fingertip exhibited rectilinear motion as you successfully traced a line across the page or screen.
- ✔ **Curvilinear motion:** Translation along a curved line. Your fingertip exhibited curvilinear motion when you tried to move it across the page using only a single joint.

Curvilinear motion also describes the path followed by an object moving through the air without support, like a thrown ball or a jumping child. This airborne body, whether it's a ball or a child, is called a *projectile*, and the curvilinear path it follows is called a *parabola* (an inverted U-shaped path).

Common descriptors of linear motion include how far the body moves, how fast the body moves, and the periods of slowing down or speeding up as it moves. Some familiar terms are used to describe linear motion, but in mechanics they have precise definitions:

- ✓ *Distance* and *displacement* are often used interchangeably to describe how far a body moves, but in mechanics *distance* simply means how far and *displacement* means how far in a specified direction.
- ✓ *Speed* and *velocity* both describe how fast a body moves, but in mechanics *speed* is simply how fast a body moves, while *velocity* refers to how fast the body moves in a specific direction.
- ✓ *Acceleration* is a tricky, but important, idea describing a change in velocity of a body. In everyday language, *acceleration* is often used to mean “speeding up” and *deceleration* is often used to mean “slowing down.” In mechanics, *acceleration* is used to describe both speeding up and slowing down. The term is used both ways because acceleration provides a link between the description of motion, kinematics, and the force causing the motion, *kinetics*. For example, the force of gravity creates a downward acceleration on a body; when you jump into the air, the downward acceleration of gravity slows down your upward motion when you’re going up, but speeds up your downward motion when you’re coming down.

For more on all things related to linear kinematics, including projectiles and parabolic motion, jump right over to Chapter 5.

Angular kinematics

Angular kinematics describes *angular motion*, or motion involving rotations like swings, spins, and twists. Angular kinematics are used to describe the rotation of the whole body, like when a diver or gymnast performs a spin in the air, or the rotation of individual body segments, like when you bend or straighten your forearm at the elbow.

The common descriptors of angular motion include how far the body rotates, how fast the body rotates, and the periods of slowing down or speeding up while it rotates. The terms used to describe angular motion are similar to those used for linear kinematics, but they refer, as you might expect, to measures of angles.

- ✓ *Angular distance* and *angular displacement* describe how far a body rotates. Similar to linear kinematics, *angular distance* means how far the body rotates, while *angular displacement* means how far it rotates in a specified direction.

- ✓ *Angular speed* and *angular velocity* describe how fast a body rotates. *Angular speed* is just how fast the body rotates, but *angular velocity* refers to how fast it rotates in a specific direction.
- ✓ *Angular acceleration* is used to describe a change in the angular velocity of a body and can be used to describe both “speeding up” and “slowing down” the rate of rotation.

For more on all things related to angular kinematics, spin right over to Chapter 9.

Causing motion with kinetics

Kinetics is the subdivision of mechanics focused on the forces that act on a body to cause motion. Basically, a *force* is a push or a pull exerted by one body on another body. But a force, whether it’s a push or a pull, can’t be seen — we can see only the *effect* of a force on a body. An applied force wants to change the motion of the body — to speed it up or slow it down in the direction the force is applied. As I describe earlier, the speeding up or slowing down of a body is called *acceleration*.

Sir Isaac Newton formulated a set of three laws, appropriately called Newton’s laws, describing the cause–effect relationship between the force applied and the changing motion, or acceleration, of a body. These three laws are the foundation for using kinetics to analyze both linear and angular motion. For more on Newton’s laws, turn to Chapter 6.

Linear kinetics

Linear kinetics investigates how forces affect the linear motion, or *translation*, of a body. The characteristics of a force include its size, direction, point of application, and line of action. Each characteristic influences the force’s effect on the body, and identifying the characteristics of each force applied to a body is an important step in kinetics. In Chapter 4, I show you how to describe the characteristics of a force and explain what makes gravity pull and friction push.

A body, especially the human body during movement, is usually acted on by several different external forces. The acceleration of the body is determined by the net force created by all the different forces acting at the same time. In Chapter 6, I show you the process of determining if the net force created by multiple forces represents an unbalanced, or unopposed, force; then I explain what Newton had to say about unbalanced force and why what he said is still important more than 300 years later.

From this basic understanding of unbalanced force and its effect on a body, you can use the impulse–momentum relationship to determine how an unbalanced force applied for a period of time speeds up or slows down the body.

Angular kinetics

Angular kinetics investigates the causes of angular motion, or *rotation*. The turning effect of a force applied to a body is called *torque*. Torque is produced when a force is applied to a body at some distance from an axis of rotation. I introduce the basic concept of torque in Chapter 8 and explain how the turning effect of a force is affected by manipulating the size of the force or by applying the force farther from the axis.

From this basic understanding of torque, I explain how muscle acts as a torque generator on the linked segments of the human body. The torque created by muscle interacts with the torque created by other external loads to cause, control, and stop the movement of segments.



Newton's laws make it possible to explain and predict the motion of all things. Using a Newtonian approach to analyze movement means to utilize the cause–effect relationship between the forces that act on a body and the motion of the body. Always.

Putting Biomechanics to Work

When you have the basic tools of kinematics and kinetics, along with a basic understanding of how the neuromusculoskeletal system controls movement, you can use them to analyze movement. In Part V, I show some common applications of using biomechanics to conduct an analysis:

- ✓ **Qualitative analysis:** This type of analysis is most frequently done in teaching, coaching, or clinical situations. You can apply the principles of biomechanics to visually evaluate the quality of a performance and provide feedback based on an accurate and specific troubleshooting of the cause of the level of performance.
- ✓ **Quantitative analysis:** This type of analysis measures kinematic and kinetic parameters of performance, usually using sophisticated laboratory equipment. It provides a more detailed description of a performance and is most typically used in a research study (or often in a laboratory experience in a biomechanics class).
- ✓ **Forensic analysis:** Biomechanics is one of the tools used to resolve criminal and civil legal questions. The principles of biomechanics are combined with evidence gathered by other investigators to answer the question of “whodunit.”