CHAPTER 1

BIOMECHANICS AND RELATED MOVEMENT DISCIPLINES

© technotr/Getty Images

LEARNING OBJECTIVES

1. Understand the discipline of biomechanics.
2. Understand the relationship of biomechanics to related movement disciplines.

1.1 BENEFITS OF A COMPREHENSIVE UNDERSTANDING OF BIOMECHANICS

Have you ever noticed that all of your limbs taper? What if they were not tapered? Does tapering have anything to do with how birds fly? For that matter, how does a boomerang fly? Why does a golf ball rise? Why does a golf ball have all of those dimples? What do those dimples have to do with swimmers? Is bat speed really the most important factor in hitting home runs? Is a "rising" fastball more difficult to hit because it actually rises? Does that fact have any relationship to corner kicks in soccer?

Through a comprehensive understanding of biomechanics, we can actually answer all of these questions. Sometimes we ask ourselves such questions simply because we would like to know, but usually we just dismiss them. The amazing thing is that many of the questions we ask out of curiosity often have some relationship to each other, but we may never make that connection. The ability to make those connections can further our understanding of the movement-related sciences, which in turn makes us more skilled practitioners. Putting practice aside, knowledge of biomechanics aids us in understanding what it is to be a human. Comprehending the connection between a human and the environment with which the human interacts can be deeply fulfilling. But comprehending is the difficult part; the connections are not always obvious. To fully appreciate biomechanics, one must first understand its relationship to other movement-oriented disciplines. One more question: What is biomechanics?

1.2 UNDERSTANDING THE DISCIPLINE OF BIOMECHANICS

Biomechanics is simply the physics (mechanics) of motion exhibited or produced by biological systems. Traditionally, biomechanics is sometimes considered synonymous with the term **kinesiology**, which is the study of human motion. In turn, some disciplines consider kinesiology to be applied or functional anatomy. In our field, kinesiology has been expanded to include all of the movement-related sciences: the anatomical, biomechanical, cultural, motor, pedagogical, physiological, psychological, and sociological aspects of motion. Of these subdisciplines of kinesiology, biomechanics is, of course, the major focus of this textbook. However, biomechanics should never be considered completely independent of any of the movement-related sciences.

More specifically, biomechanics is a highly integrated field of study that examines the forces acting on and within a body as well as those produced by a body (Figure 1.1).

The study of biomechanics also requires that we consider the consequences of the resultant motions produced by forces. Biomechanics is special in that it integrates biological characteristics with traditional **mechanics** (the branch of physics specifically concerned with the effect of forces and energy on the motion of bodies). Within mechanics, one may be concerned with **statics**, the study of systems in a state of equilibrium (at rest or in a constant state of motion); or **dynamics**, the study of systems that are in a state of accelerated or changing motion (Serway & Jewett, 2019). Whether a system is in a state of equilibrium or a state of acceleration, it may be analyzed from two perspectives: **kinetics** and **kinematics**. Kinetics is the study of forces that inhibit, cause, facilitate, or modify motion of a body. Some words in popular language that are actually examples of aspects of kinetics are *friction*, *gravity*, and *pressure*. In contrast, kinematics is the study or description of the **spatial** (direction with respect to the three-dimensional world) and **temporal** (motion with respect to time) characteristics of motion without regard to the causative forces (Serway & Jewett, 2019). Actually, most people are quite familiar with kinematic characteristics

Biomechanics Physics (mechanics) of motion exhibited or produced by biological systems.

Kinesiology Multidisciplinary study of human motion, including the anatomical, biomechanical, cultural, motor, pedagogical, physiological, psychological, and sociological aspects of motion.

Mechanics Branch of physics concerned with the effect of forces and energy on the motion of bodies.

Statics Branch of mechanics concerned with objects in a state of equilibrium (at rest or in a constant state of motion).

Dynamics Branch of mechanics concerned with objects in a state of accelerated or changing motion.

Kinetics Study of forces that inhibit, cause, facilitate, or modify motion of a body.

Kinematics Study or description of the spatial and temporal characteristics of motion without regard to the causative forces.

Spatial Relating to, or with respect to, the three-dimensional world.

Temporal Relating to, or with respect to, time.

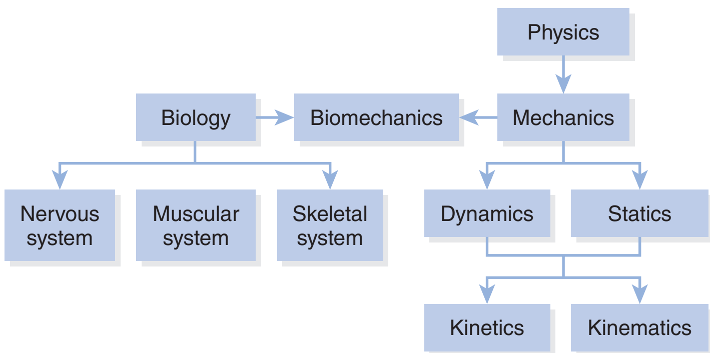

Figure 1.1 **The relationship of biomechanics to biology and physics (mechanics)**

such as displacement (distance traveled in meters or degrees) and velocity (displacement in a given time—for example, meters per second or degrees per second). Biomechanical analysis is applied to a variety of situations, some of which may be surprising. Therefore, we provide a small sampling of these situations.

The term *biomechanics* is sometimes immediately associated with the realm of sports. Indeed, biomechanical concepts are quite frequently applied to sports situations, so we begin with a couple of traditional sports examples. The sport of soccer has many areas to which biomechanical analysis can be applied. For example, a soccer player may injure a knee while trying to outmaneuver an opponent (Figure 1.2).

Figure 1.2 **A soccer player attempting to outmaneuver an opponent.** What elements of the situation are potential sources of injury?

From a *kinematic* perspective, one may be interested in how fast the soccer player was moving at the moment of the injury (was the maneuver performed too quickly?). In *kinetic* terms, we may want to look to the forces involved in the situation. How much force is absorbed by the body when making a quick change in direction? What force makes the change of direction possible? How much force is required to tear an anterior cruciate ligament? Biomechanics can also help us understand whether or not this type of injury is more likely to occur on natural grass or on an artificial playing surface. Still other biomechanists may be interested in whether this injury is more common in females than in males. If so, what are the characteristics of the body that predispose females or males to this particular type of injury? Further, if one attempts to prevent or treat the injury with the use of taping or bracing, how much will this precaution hinder the soccer player's performance? These are just a few of the questions that biomechanical researchers attempt to answer.

In the sport of swimming many questions can also be answered through the use of biomechanical knowledge. We are definitely interested in how fast swimmers can swim and how quickly they can execute a flip turn (*kinematics*) (Figure 1.3), but we are also interested in the forces that act on a swimmer because the environment is a liquid (*kinetics*). Biomechanists study various strategies

Figure 1.3 **A swimmer performing a flip-turn.** In what ways has this swimmer likely attempted to enhance performance?

Figure 1.4 **The ollie skateboarding technique.** What causes the skateboard to rise?

used by swimmers to move easily though the water. For example, does shaving the body actually help? We now know that full body swimsuits provided such an advantage that they were banned after the Beijing Olympics in 2008. The use of use of advanced materials and design were considered "technical doping." One may also be interested in whether or not swimming close to another swimmer (*drafting*) is helpful. A biomechanist may also study a particular swimming stroke to determine if it is likely to result in a repetitive stress disorder. Still other researchers may be interested in the body type that is most suitable for swimming success.

In recent years, some nontraditional sports have become extremely popular (rock climbing, skateboarding, and snowboarding, for example). In the sport of skateboarding, many different maneuvers are performed that are fascinating from a biomechanical perspective. One extremely common skateboard maneuver is the "ollie," a technique used by skaters to hop over objects and onto or down from elevated surfaces (Figure 1.4).

Figure 1.5 **An infant walking.** Notice that the arms are held high and the feet are in a wide stance. In what situations would you adopt this same position?

Although the maneuver is common, it is not simple. It must be coordinated precisely because the skater and the board must travel similar aerial paths without being tethered together. Kinematic studies of the ollie would examine such parameters as the height of the hop or how fast the skater was moving at the time of the ollie. Kinetic examination of the maneuver would reveal such information as to how the skater causes the board to bounce into the air. One could also use kinetic analysis to examine the forces absorbed by the skater when landing from an ollie. And one obvious kinetic issue associated with skateboarding is the numerous falls and injuries that occur.

Outside of the world of sport, biomechanists also examine more common human motions such as walking. Notice the characteristics of a walking infant (Figure 1.5). A biomechanist could examine the pattern for kinematic values such as the length of the infant's strides, the distance between the feet, the height at which the arms are held, and the speed of the infant's progress as a result of these factors. Kinetic analysis would be used in this situation to figure out why the infant walks in that particular manner.

Why are the feet so far apart and the toes pointed outward? What benefit is derived from carrying the arms so high? Why take such short strides? And by the way, haven't I noticed the same characteristics when observing a chimpanzee walk on two legs? Why would they share the same walking pattern?

In addition to developmental walking patterns, some biomechanists study movement in people who may have amputations or congenital abnormalities of the body. Designing prostheses, for example, requires close attention to biomechanical factors. If the kinetic parameters of one side of the body are not the same as those of the opposite side, then abnormalities in kinematic patterns emerge. These abnormalities not only cause self-consciousness in the user of the prosthetic but may also lead to further injury. But one should think beyond prosthetics being used to simply restore normal motion. Biomechanical principles have also been used to design prosthetic devices that aid in sports performance (Figure 1.6).

Common to all of these examples (maybe with the exception of the infant) are the numerous pieces of equipment used to train athletes and, in rehabilitation settings, to gain or regain muscular strength and endurance (Figure 1.7). Through the use of biomechanical principles, each piece of training equipment is designed to produce optimal results while minimizing the risk of injury to the user.

Figure 1.6 **An amputee running with prosthetics.** What do you think are the important aspects of prosthetic design for athletes?

Figure 1.7 **Exercise and therapy equipment.** Notice the design elements of the various pieces of equipment. Why are there so many structural differences?

These are just a few of the numerous situations in which biomechanical analysis can be used to gain insight. As these examples show, many values labeled as *kinematic* or *kinetic* are actually familiar to most people in some way. Biomechanists simply study the parameters in greater detail. Even though many kinetic and kinematic values in biomechanics are somewhat familiar, the field of biomechanics is often misperceived as being isolated from the other movement-related subdisciplines. Therefore, a major goal of this textbook is to make the necessary connections between biomechanics and other disciplines. We begin with some explanation of related fields of study that are referred to throughout the textbook. We will also refer back to the previous examples to demonstrate the perspectives from which other disciplines might approach the same situation.

1.3 RELATIONSHIP OF BIOMECHANICS TO OTHER MOVEMENT DISCIPLINES

One inherent difficulty with the study of biomechanics is that connections to content in other courses may not be as readily apparent as in some other disciplines. In fact, a more integrated discipline is difficult to imagine (Figure 1.8).

At the most superficial level, biomechanics is about movement. Movement is caused by the contraction of skeletal muscle. To understand skeletal muscle contraction, one has to consider issues such as muscle fiber type and metabolism, topics that are traditionally studied in the discipline of **exercise physiology** (the study of physiology under conditions in which physical work has caused disrupted homeostasis). The student of biomechanics must also be concerned with the mechanisms used by the nervous system to control and coordinate the many intricate movements of the musculoskeletal system, which are specifically the interest of the field of **motor control**.

Exercise physiology The study of physiology under conditions in which physical work has caused disrupted homeostasis.

Motor control Mechanisms used by the nervous system to control and coordinate the movements of the musculoskeletal system.

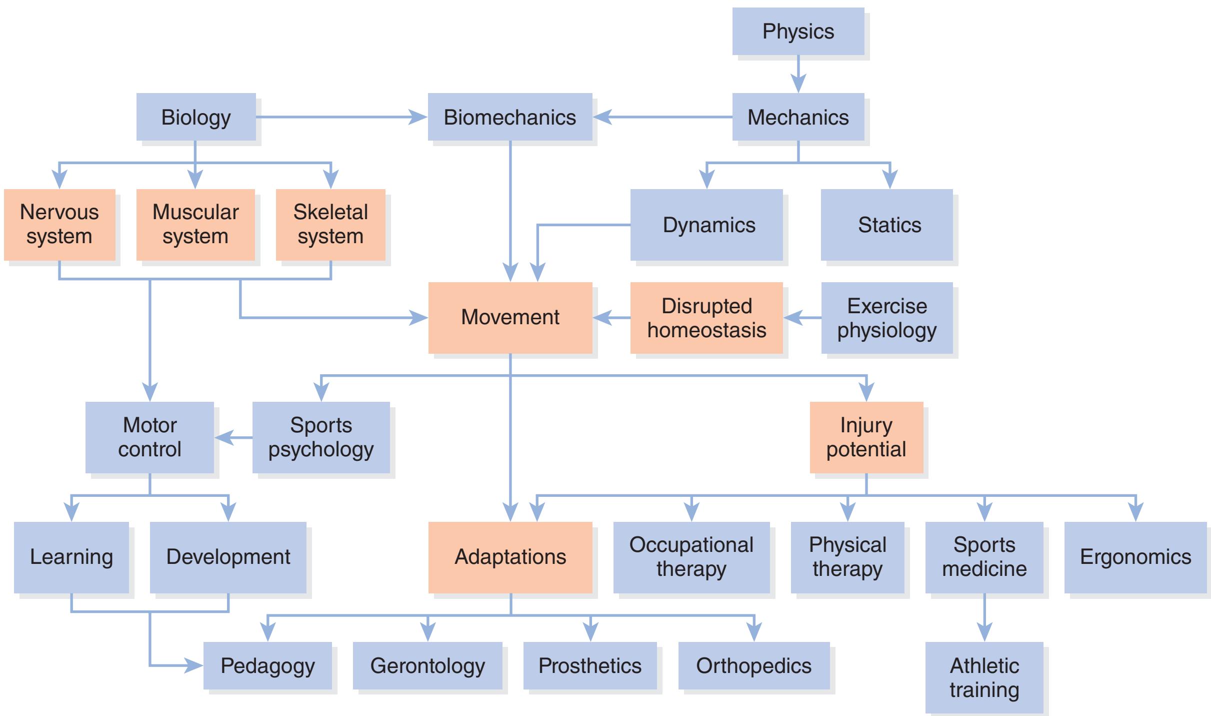

Figure 1.8 **Connections among movement-related disciplines**

Motor control progresses throughout the life span (**motor development**) and can undergo relatively permanent change to become more proficient through experience, practice, or both (**motor learning**). The changes in motor control are accompanied by changes in biomechanical movement patterns. Some movement fields are concerned with human motion as it applies to the work environment. **Ergonomics**, for example, is a discipline that examines human–machine interaction. Ergonomists use many biomechanical techniques in analyzing the work environment. Other related disciplines are primarily concerned with prevention, immediate treatment, and rehabilitation from both acute and chronic injuries that result from human motion. **Physical therapy** and **occupational therapy** are the fields dedicated to evaluating and treating movement abnormalities. Disordered movement may be caused by injury, lack of coordination, muscular imbalance, or congenital conditions. Physical and occupational therapists must be familiar with biomechanical principles to properly diagnose movement disorders and design the most appropriate intervention. In the field of **sports medicine**, practitioners such as athletic trainers focus on preventing and immediately treating injuries that occur during sports. Preventing injury may require such methods as bracing and taping, both of which can affect normal human motion. Movement patterns may be unusual because of temporary or permanent changes to the body that occur congenitally or because of injury or disease. If such changes are present, the biomechanist must be concerned with variation from and compensation in expected movement patterns; these alterations can collectively be called **adapted movement**. Of course, intertwined with all of these fields are the disciplines of **pedagogy** (the study of teaching) and **coaching**. Teachers and coaches work with people at different ages throughout the life span and must try to modify or improve movement behaviors while considering the various abilities of the population with whom they work. The variations in ability with which teachers and coaches contend arise from the interactions of all of these anatomical, biomechanical, motor-related, and physiological factors that are unique to each person at any given time. In common to all of the movement-related disciplines is an understanding of **functional anatomy**. No matter the movement-related discipline, the practitioner must always have an in-depth knowledge of the human body. One must know how the body moves when it is healthy to know when it is injured. Understanding the interrelationships among various body systems is also important to know how damage to one area may cause abnormalities in a seemingly unrelated area.

This section has covered some basic terminology of the disciplines associated with biomechanics. It has also presented some superficial connections to other fields of study. However, to fully comprehend the relationships between biomechanics and other movement-related sciences, a slightly more in-depth overview of some of these related disciplines is needed. The following fields are not the only ones to which biomechanics is related; they are simply the most directly related and are therefore the ones that will be discussed most often throughout the textbook.

Motor development Progression of motor control throughout the life span because of maturation.

Motor learning Relatively permanent changes in proficiency of motor control through experience and/or practice.

Ergonomics Discipline concerned with human–machine interaction.

Physical therapy Field dedicated to evaluating and treating movement abnormalities.

Occupational therapy Field focused on helping people to improve their ability to carry out activities of daily living and self-care tasks (i.e., "occupations") after an injury, disability, or other health condition.

Sports medicine Field dedicated to the prevention, immediate treatment, and rehabilitation of injuries that occur during sports participation.

Adapted movement Movement patterns that emerge because of compensation for changes to the physical body.

Pedagogy Study of principles and methods of instruction.

Coaching Study of principles and methods of instructing athletes.

Functional anatomy Study of the specific functions of individual structures that make up an organism.

Exercise Physiology

The beauty of the human body can best be appreciated when its systems are challenged, for example, during