

Fundamentals of Biomechanics and Qualitative Analysis

In Chapter 1 we found that biomechanics provides tools that are needed to analyze human motion, improve performance, and reduce the risk of injury. In order to facilitate the use of these biomechanical tools, this text will emphasize the qualitative understanding of mechanical concepts. Many chapters, however, will include some quantitative examples using the algebraic definitions of the mechanical variables being discussed. Mathematical formulas are a precise language and are most helpful in showing the importance, interactions, and relationships between biomechanical variables. While more rigorous calculus forms of these equations provide the most accurate answers commonly used by scientists (Beer & Johnson, 1984; Hamill & Knutzen, 1995; Zatsiorsky, 1998, 2002), the majority of kinesiology majors will benefit most from a qualitative understanding of these mechanical concepts. So this chapter begins with key mechanical variables and terminology essential for introducing other biomechanical concepts. This chapter will emphasize the conceptual understanding of these mechanical variables and leave more detailed development and quantitative examples for later in the text. Next, nine general principles of biomechanics are introduced that will be developed throughout the rest of the text. These principles use less technical language and are the tools for applying biomechanical knowledge in the qualitative analysis of human movement. The chapter concludes by summarizing a model of qualitative analysis that is used in the application section of the book.

KEY MECHANICAL CONCEPTS

Mechanics

Before we can begin to understand how humans move, there are several mechanical terms and concepts that must be clarified. **Mechanics** is the branch of physics that studies the motion of objects and the forces that cause that motion. The science of mechanics is divided into many areas, but the three main areas most relevant to biomechanics are: **rigid-body**, **deformable-body**, and **fluids**.

In **rigid-body mechanics**, the object being analyzed is assumed to be rigid and the deformations in its shape so small they can be ignored. While this almost never happens in any material, this assumption is quite reasonable for most biomechanical studies of the major segments of the body. The rigid-body assumption in studies saves considerable mathematical and modeling work without great loss of accuracy. Some biomechanists, however, use deformable-body mechanics to study how biological materials respond to external forces that are applied to them. **Deformable-body mechanics** studies how forces are distributed within a material, and can be focused at many levels (cellular to tissues/organs/system) to examine how forces stimulate growth or cause damage. **Fluid mechanics** is concerned with the forces in fluids (liquids and gasses). A *biomechanist* would use fluid mechanics to study heart valves, swimming, or adapting sports equipment to minimize air resistance.

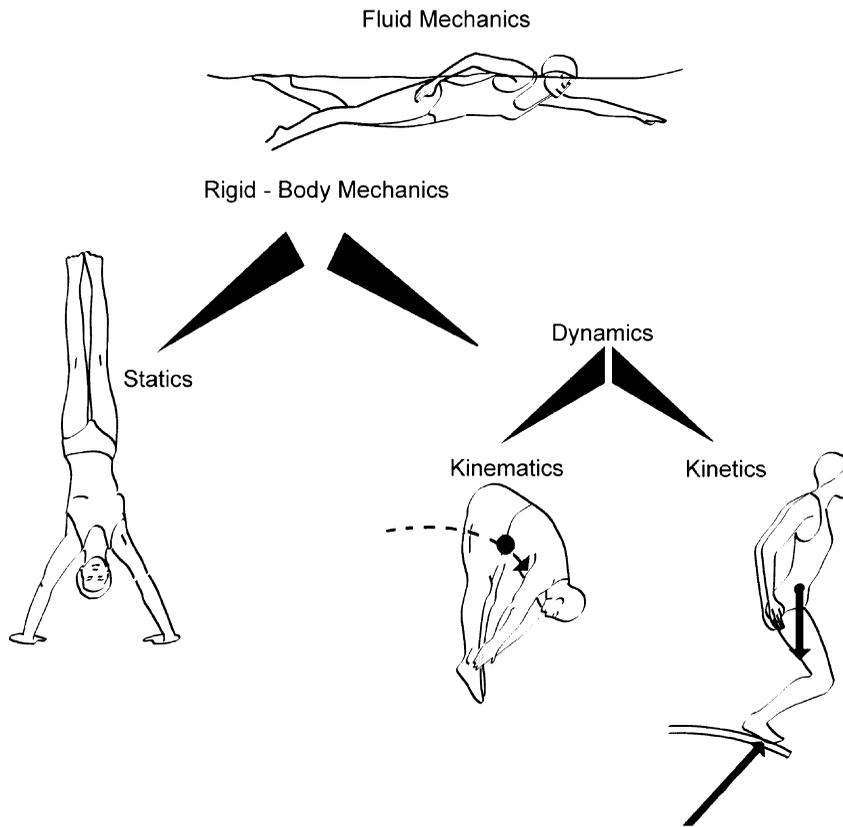


Figure 2.1. The major branches of mechanics used in most biomechanical studies.

Most sports biomechanics studies are based on rigid-body models of the skeletal system. Rigid-body mechanics is divided into **statics** and **dynamics** (Figure 2.1). **Statics** is the study of objects at rest or in uniform (constant) motion. **Dynamics** is the study of objects being accelerated by the actions of forces. Most importantly, dynamics is divided into two branches: **kinematics** and **kinetics**. **Kinematics** is motion description. In kinematics the motions of objects are usually measured in linear (meters, feet, etc.) or angular (radians, degrees, etc.) terms. Examples of the kinematics of running could be the speed of the athlete, the length of the stride, or the angular velocity of hip extension. Most angular mechanical

variables have the adjective “angular” before them. **Kinetics** is concerned with determining the causes of motion. Examples of kinetic variables in running are the forces between the feet and the ground or the forces of air resistance. Understanding these variables gives the track coach knowledge of the causes of running performance. Kinetic information is often more powerful in improving human motion because the causes of poor performance have been identified. For example, knowing that the timing and size of hip extensor action is weak in the takeoff phase for a long jumper may be more useful in improving performance than knowing that the jump was shorter than expected.

Basic Units

The language of science is mathematics. Biomechanics often uses some of the most complex kinds of mathematical calculations, especially in deformable-body mechanics. Fortunately, most of the concepts and laws in classical (Newtonian) rigid-body mechanics can be understood in qualitative terms. A conceptual understanding of biomechanics is the focus of this book, but algebraic definitions of mechanical variables will be presented and will make your understanding of mechanical variables and their relationships deeper and more powerful.

First, let's look at how even concepts seemingly as simple as numbers can differ

in their complexity. **Scalars** are variables that can be completely represented by a number and the units of measurement. The number and units of measurement (10 kg, 100 m) must be reported to completely identify a scalar quantity. It makes no sense for a track athlete to call home and say, "Hey mom, I did 16 and 0"; they need to say, "I made 16 feet with 0 fouls." The number given a scalar quantity represents the magnitude or size of that variable.

Vectors are more complicated quantities, where size, units, and *direction* must be specified. Figure 2.2 shows several scalars and the associated vectors common in biomechanics. For example, **mass** is the scalar quantity that represents the quantity of

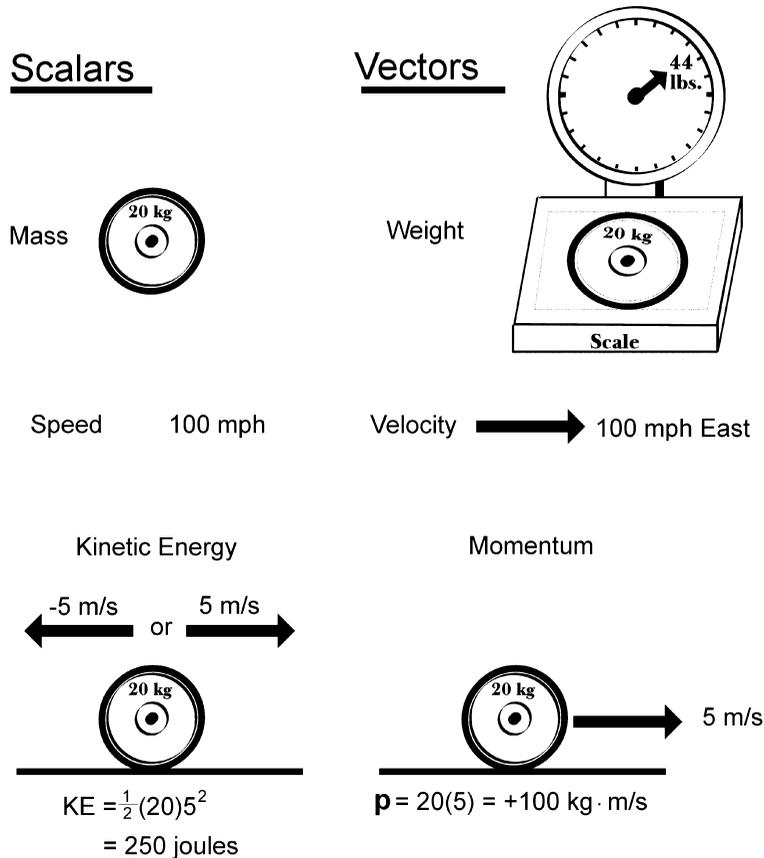


Figure 2.2. Comparison of various scalar and vector quantities in biomechanics. Vector quantities must specify magnitude and direction.

matter for an object. That same object's **weight** is the gravitational force of attraction between the earth and the object. The difference between mass and weight is dramatically illustrated with pictures of astronauts in orbit about the earth. Their masses are essentially unchanged, but their weights are virtually zero because of the microgravity when far from earth.

Biomechanics commonly uses directions at right angles (horizontal/vertical, longitudinal/transverse) to mathematically handle vectors. Calculations of velocity vectors in a two-dimensional (2D) analysis of a long jump are usually done in one direction (e.g., horizontal) and then the other (vertical). The directions chosen depend on the needs of the analysis. Symbols representing vector quantities like velocity (\mathbf{v}) in this text will be identified with **bold letters**. Physics and mechanics books also use underlining or an arrow over the symbol to identify vector quantities. These and other rules for vector calculations will be summarized in chapter 6. These rules are important because when adding vectors, one plus one is often not two because the directions of the vectors were different. When adding scalars with the same units, one plus one is always equal to two. Another important point related to vectors is that the sign (+ or -) corresponds to directions. A -10 lb force is not less than a +10 lb force; they are the same size but in opposite directions. The addition of vectors to determine their net effect is called the **resultant** and requires right-angle trigonometry. In chapter 6 we will also subtract or break apart a vector into right-angle **components**, to take advantage of these trigonometry relationships to solve problems and to "see" other important pushes/pulls of a force.

There are two important vector quantities at the root of kinetics: **force** and **torque**. A **force** is a straight-line push or pull, usually expressed in pounds (lbs) or Newtons

(N). The symbol for force is **F**. Remember that this push or pull is an interactional effect between two bodies. Sometimes this "push" appears obvious as in a ball hitting a bat, while other times the objects are quite distant as with the "pull" of magnetic or gravitational forces. Forces are vectors, and vectors can be physically represented or drawn as arrows (Figure 2.3). The important characteristics of vectors (size and direction) are directly apparent on the figure. The length of the arrow represents the size or magnitude (500 N or 112 lbs) and the orientation in space represents its direction (15 degrees above horizontal).

The corresponding angular variable to force is a **moment of force** or **torque**. A moment is the rotating effect of a force and will be symbolized by an **M** for moment of force or **T** for torque. This book will use the term "torque" synonymously with "moment of force." This is a common English meaning for torque, although there is a more specific mechanics-of-materials meaning (a torsion or twisting moment) that leads some scientists to prefer the term "moment of force." When a force is applied to an object that is not on line with the center of the object, the force will create a torque that tends to rotate the object. In Figure 2.3 the impact force acts below the center of the ball and would create a torque that causes the soccer ball to acquire backspin. We will see later that the units of torque are pound-feet (lb·ft) and Newton-meters (N·m).

Let's look at an example of how kinematic and kinetic variables are used in a typical biomechanical measurement of **isometric** muscular strength. "Isometric" is a muscle research term referring to muscle actions performed in constant (*iso*) length (*metric*) conditions. The example of a spring is important for learning how mathematics and graphs can be used to understand the relationship between variables. This example will also help to understand how muscles, tendons, and ligaments can be said to

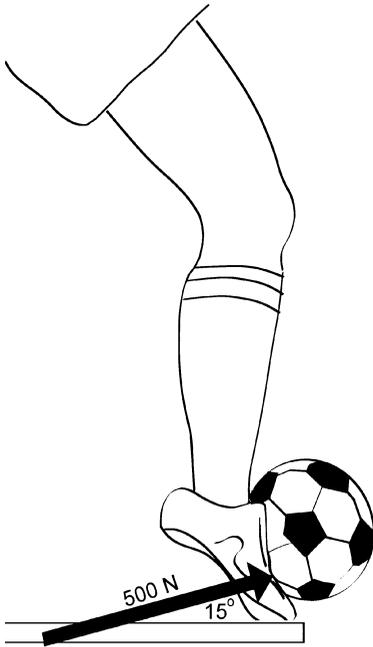


Figure 2.3. Vector representation of the force applied by a foot to a soccer ball. The magnitude and direction properties of a vector are both apparent on the diagram: the length of the arrow represents 500 Newtons of force, while the orientation and tip of the arrow represent the direction (15° above horizontal) of the force.

have spring-like behavior. Figure 2.4 illustrates the force–displacement graph for the spring in a handgrip **dynamometer**. A **dynamometer** is a force-measuring device. As a positive force (F) pulls on the spring, the spring is stretched a positive linear distance (displacement = d). Displacement is a kinematic variable; force is a kinetic variable.

Therapists often measure a person's grip strength in essentially isometric conditions because the springs in hand dynamometers are very stiff and only elongate very small distances. The force–displacement graph in Figure 2.4 shows a very simple (predictable) and linear relationship between the force in the spring (F) and the resulting elongation (d). In other words, there is a uniform increase (constant slope

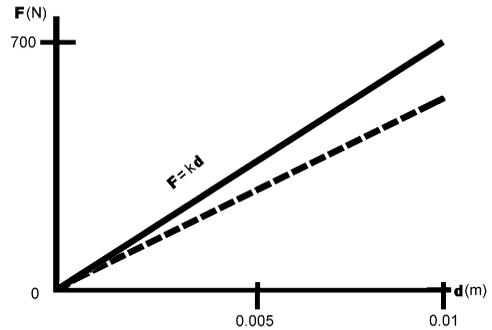


Figure 2.4. A graph (solid line) of the relationship between the force (F) required to stretch a spring a given displacement (d). The elasticity of the spring is the slope of the line. The slope is the constant (k) in Hooke's Law: ($F = k \cdot d$).

of the line) in force with increasing spring stretch. We will see later on in chapter 4 that biological tissues have much more complex (curved) mechanical behaviors when loaded by forces, but there will be linear regions of their load–deformation graphs that are representative of their elastic properties.

Let's extend our example and see how another mechanical variable can be derived from force and displacement. Many simple force measuring devices (e.g., bathroom and fishing scales) take advantage of the elastic behavior of metal springs that are stretched or compressed short distances. This relationship is essentially the mathematical equation ($F = k \cdot d$) of the calibration line illustrated in Figure 2.4, and is called Hooke's Law. Hooke's Law is valid for small deformations of highly elastic materials like springs. The **stiffness** (elasticity) of the spring is symbolized as k , which represents the slope of the line. In chapter 4 we will look at the stiffness of biological tissues as the slope of the linear region of a graph like this. If we plug in the largest force and displacement ($700 = k \cdot 0.01$), we can solve for the stiffness of the spring, and find it to be 70,000 N/m. This

says that the spring force will increase 70,000 Newtons every meter it is stretched. This is about 15,730 pounds of tension if the spring were stretched to about 1.1 yards! Sounds pretty impressive, but remember that the springs are rarely elongated that much, and you might be surprised how stiff muscle-tendon units can get when strongly activated.

Engineers measure the stiffness or elasticity of a material with special machines that simultaneously record the force and deformation of the material. The slope of the load–deformation graph (force/length) in the linear region of loading is used to define stiffness. **Stiffness** is the measure of elasticity of the material, but this definition often conflicts with most people's common understanding of elasticity. People often incorrectly think elasticity means an object that is easily deformed with a low force, which is really compliance (length/force), the opposite of stiffness. An engineer would say that there was less stiffness or greater compliance in the second spring illustrated as a dashed line.

Can you find the stiffness (spring constant, k) that corresponds to the dashed calibration line in Figure 2.4? Remember that the stiffness, k , corresponds to the slope of the line illustrated in the figure and represents the change in force for a given change in length. The slope or rate of change of a variable or graph will be an important concept repeated again and again in biomechanics. Remember that forces and displacements are vectors, so directions are indicated by the sign (+ or –) attached to the number. What do you think the graph would look like if the force were reversed, i.e., to push and compress the spring rather than stretching it? What would happen to the sign of F and d ?

It is also important to know that the previous example could also be measured using angular rather than linear measurements. There are isokinetic dynamometers

Activity: Elasticity

Take a rubber band and loop it between the index fingers of your hands. Slowly stretch the rubber band by moving one hand away from the other. The tension in the rubber band creates a torque that tends to abduct the metacarpophalangeal joints of your index finger. Does the tension your fingers sense resisting the torque from the rubber band uniformly increase as the band is stretched? Does a slightly faster stretch feel different? According to Hooke's Law, elastic materials like springs and rubber bands create forces directly proportional to the deformation of the material, but the timing of the stretch does not significantly affect the resistance. Chapter 4 will deal with the mechanical responses of biological tissues, which are not perfectly elastic, so the rate of stretch affects the mechanical response of the tissue.

that simultaneously measure the torque (T) and rotation (Figure 1.5). These angular measurements have been used to describe the muscular strength of muscle groups at various positions in the range of motion.

There are many other mechanical variables that help us understand how human movement is created. These variables (e.g., impulse, angular momentum, kinetic energy) often have special units of measurement. What all these mechanical variables and units have in common is that they can be expressed as combinations of only four base units. These base units are length, mass, and time. In the International System (SI) these units are the second (s), kilogram (kg), meter (m), and radian (rad). Scientific research commonly uses SI units because they are base 10, are used throughout the world, and move smoothly between traditional sciences. A Joule of mechanical energy is the same as a Joule of chemical energy

stored in food. When this book uses mathematics to teach a conceptual understanding of mechanics in human movement (like in Figure 2.4), the SI system will usually be used along with the corresponding English units for a better intuitive feel for many students. The symbols used are based on the recommendations of the International Society of Biomechanics (ISB, 1987).

These many biomechanical variables are vitally important to the science of biomechanics and the integration of biomechanics with other kinesiological sciences. Application of biomechanics by kinesiology professionals does not have to involve quantitative biomechanical measurements. The next section will outline biomechanical principles based on the science and specialized terminology of biomechanics.

NINE FUNDAMENTALS OF BIOMECHANICS

Biomechanists measure all kinds of linear and angular mechanical variables to document and find the causes of human motion. While these variables and studies are extremely interesting to biomechanists, some kinesiology students and professionals may not find them quite so inherently stimulating. Most kinesiology professionals want to know the basic rules of biomechanics that they can apply in their jobs. This section proposes nine such principles of biomechanics and demonstrates how they relate to scientific laws. These biomechanical tools must be combined with other tools from your kinesiology toolbox to most effectively solve movement problems. Because these principles are the application rules for kinesiology professionals, they have usually been given less-scientific names so that we can communicate effectively with our clients.

Principles and Laws

The nine principles of biomechanics that follow take the form of general principles related to human movement. It is important to realize that principles for application are not the same as scientific laws. **Science** is a systematic method for testing hypotheses with experimental evidence for the purpose of improving our understanding of reality. Science uses a process, known as the scientific method, for testing a theory about a phenomenon with measurements, then reevaluating the theory based on the data. Ultimately, science is interested in finding the truth, facts, or laws of nature that provide the best understanding of reality. When experimentation shows data always consistent with a theory (given certain conditions), then the theory becomes a law. Scientists must always be open to new data and theories that may provide a more accurate description or improved understanding of a phenomenon. True scientific revolutions that throw out long-held and major theories are not as common as most people think. Though news reporters often herald scientific “breakthroughs,” they are usually exaggerating the importance of a small step in what is a very slow process of weighing a great deal of evidence.

Note that science is not defined as a method for making practical applications of knowledge. **Technology** is the term usually used to refer to the tools and methods of applying scientific knowledge to solve problems or perform tasks. Remember that in chapter 1 we noted the belief of some scholars that studying academic disciplines and doing theoretical research are worthy enterprises without any need to show any practical application of knowledge. Even in “applied” fields like kinesiology, there is a long history of a theory-to-practice, or a science-to-profession gap (Harris, 1993). Why does this gap exist? It might exist because some scholars are hesitant to propose appli-

cation based on what is often less-than-conclusive data, or they might be concerned about receiving less recognition for applied scholarship. Practitioners contribute to this gap as well by refusing to recognize the theoretical nature of science, by not reading widely to compile the necessary evidence for practice, and by demanding simple “how-to” rules of human movements when these simple answers often do not exist.

This text is based on the philosophy that the best use of the science of biomechanics is in its translation to principles for improving human movement. These principles are general rules for the application of biomechanics that are useful for most all human movements. Some of the principles are based on major laws of mechanics, many of which are hundreds of years old. For example, Newton's Laws of Motion are still used at NASA because they accurately model the motion of spacecraft, even though there are more recent advancements in theoretical physics that are only an improvement in very extreme conditions (high-energy or near the speed of light). Unfortunately, the human body is a much more complicated system than the space shuttle, and biomechanists have not had hundreds of years to make progress on theories of human movement. For these reasons, these nine principles of application should be viewed as general rules that currently fit what we currently know about the biomechanics of human movement.

Nine Principles for Application of Biomechanics

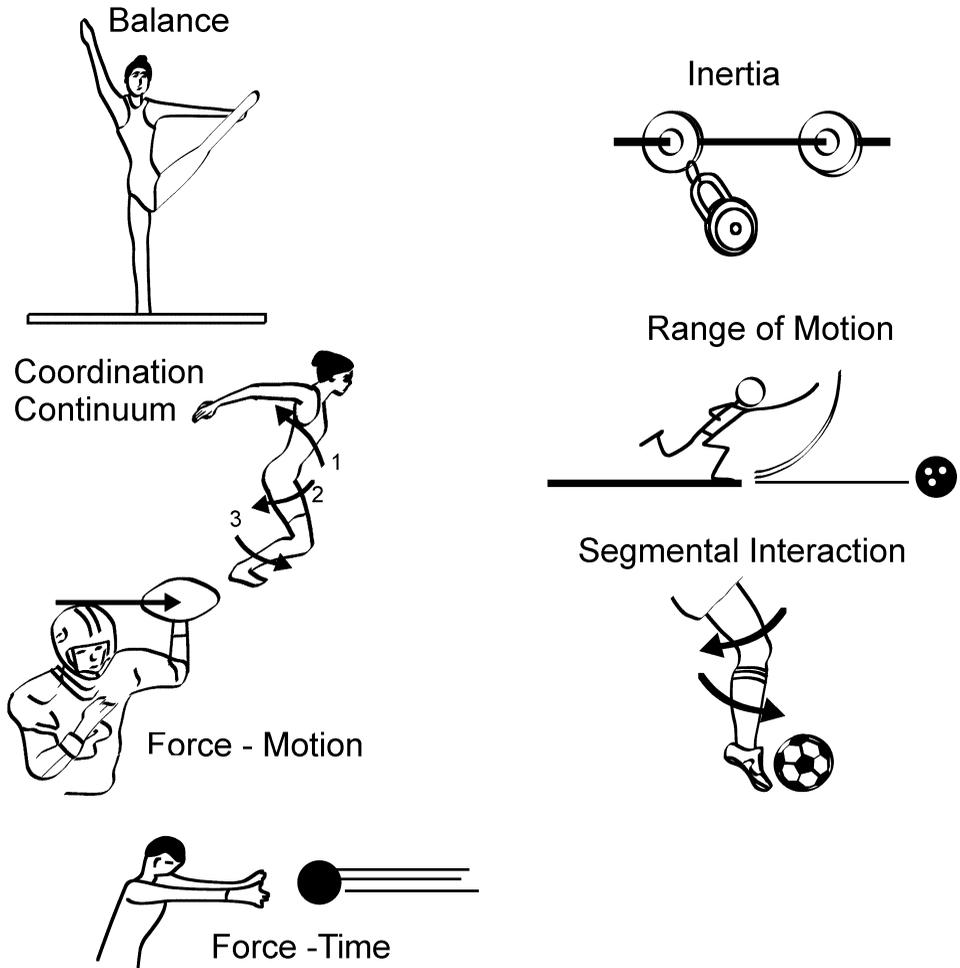
The nine principles of biomechanics proposed in this text were selected because they constitute the minimum number or core principles that can be applied to all human movements and because they provide a simple paradigm or structure to apply biomechanical knowledge. The names of

the principles are put in the common language of application; however, each can be directly linked to the concepts and laws of biomechanics. Special attention has been paid to make application of these principles both friendly and consistent with the specialized terminology of mechanics. As kinesiology professionals you will know the names of the biomechanical laws and theories behind these principles, but you will need to use more applied terminology when communicating with clients. This section will provide a description of each principle, and the application of these principles will be developed throughout the text. The principles can be organized (Figure 2.5) into ones dealing primarily with the creation of movement (process) and ones dealing with the outcome of various projectiles (product).

I want to point out that these principles are based primarily on work of several biomechanists (Norman, 1975; Hudson, 1995) who have developed generic biomechanical principles for all human movements. Many biomechanics books have proposed general principles for all movements (Meinel & Schnabel, 1998); various categories of human movements like throwing, catching, and running (e.g., Broer & Zernicke, 1979; Dyson, 1986; Kreichbaum & Barthels, 1996; Luttgens & Wells, 1982); or specific movements (e.g., Bunn, 1972; Groves & Camaione, 1975). Some biomechanists believe that general principles applicable to all sports are difficult to identify and have limited practical application due to unique goals and environmental contexts of skills (Hochmuth & Marhold, 1978). This book is based on the opposite philosophy. Kinesiology professionals should keep in mind the specific goals and contextual factors affecting a movement, but the nine principles of biomechanics are important tools for improving all human movements.

The first principle in biomechanics is the **Force–Motion principle**. Force–motion

Movement Principles



Projectile Principles

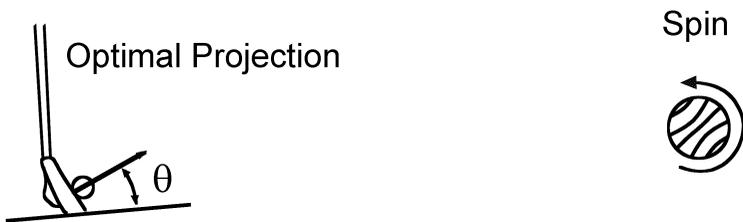


Figure 2.5. The nine principles of biomechanics can be classified into those related to movement of the body or a projectile. The human body can be a projectile, so all nine principles can be applied to the human body.

says that unbalanced forces are acting on our bodies or objects when we either create or modify movement. In quiet standing the force of gravity is balanced by ground reaction forces under our feet (Figure 2.6), so to move from this position a person creates larger horizontal and vertical forces with their legs. This simple illustration of the

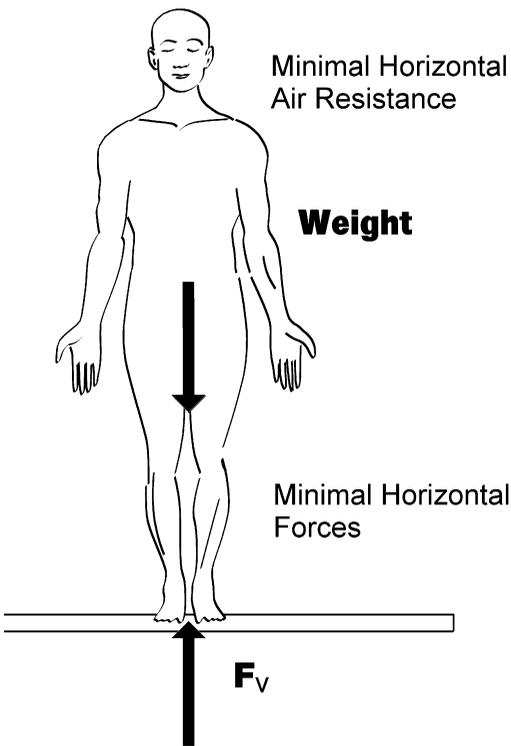


Figure 2.6. A free-body diagram of a person quietly standing. The major vertical forces acting on the person (gravity and ground reaction force) are illustrated, while horizontal forces are small enough to ignore.

body is our first example of what in mechanics is called a **free-body diagram**. A **free-body diagram** is a simplified model of any system or object drawn with the significant forces acting on the object. The complexity and detail of the free-body diagram depends on the purpose of the analysis. In-

spection of Figure 2.6 should make it qualitatively obvious that the addition of the two vertical forces illustrated would cancel each other out, keeping the person essentially motionless in the vertical direction. The Force–Motion principle here correctly predicts no change in motion, since there is no unbalanced force acting on the person. Later on in the text we will use free-body diagrams to actually calculate the effect of forces and torques on the motion of the human body, and we will study the effects of forces acting over time to change the motion of the human body. We will also come to see later that this principle is based on Newton's three laws of motion. The application of the Force–Motion principle in qualitative analysis will be explored throughout the text.

An important thing to notice in this principle is the sequence of events. Forces must act first, before changes in motion can occur. Detailed study of kinematics will illustrate when the motion occurred relative to the acceleration and force causing it. Suppose a person is running on a sidewalk and a small child darts directly in the runner's path to grab a bouncing ball. In order to avoid the child, the runner must change the state of motion. The Force–Motion principle tells the kinesiology professional that the runner's sideward movement (a change in direction and speed) had to be created by large forces applied by the leg to the ground. The force applied by the leg comes first and the sideward motion to avoid the collision was the result.

Substantial changes in motion do not instantly occur but are created over time, which leads us to the next principle of **Force–Time**. It is not only the amount of force that can increase the motion of an object; the amount of time over which force can be applied also affects the resulting motion. A person using a longer approach in bowling has more time to apply forces to increase ball speed. Increasing the time to

apply force is also an important technique in slowing down objects (catching) and landing safely. The impulse–momentum relationship, the original language of Newton's second law, is the mathematical explanation of this important principle.

Another important principle to understand in the modification of motion is **Inertia**. **Inertia** can be defined as the property of all objects to resist changes in their state of motion. Newton's first law of motion outlines the principle of inertia. The Newtonian view of inertia as a fundamental property of motion was a major conceptual leap, rejecting the old Aristotelian view that constant application of force was required for motion. The linear and angular measures of inertia are mass (m) and moment of inertia (I). We will see that inertia can be viewed as a resistance to motion in the traditional sense, but this property can also be used to an advantage when modifying motion or transferring energy from one body segment to another.

The next principle involves the **Range of Motion** the body uses in movement. **Range of Motion** is the overall motion used in a movement and can be specified by linear or angular motion of the body segments. The purpose of some movements might require that some body segments limit range of motion, while others requiring maximum speed or force might require larger ranges of motion. Increasing the range of motion in a movement can be an effective way to increase speed or to gradually slow down from a high speed. A baseball pitcher taking a longer stride (Figure 2.7) is increasing the range of motion of the weight shift. Since moving through a range of motion takes time, this principle is related to the force–time principle.

The next biomechanical principle is **Balance**. **Balance** is a person's ability to control their body position relative to some base of support. Stability and mobility of body postures are inversely related, and

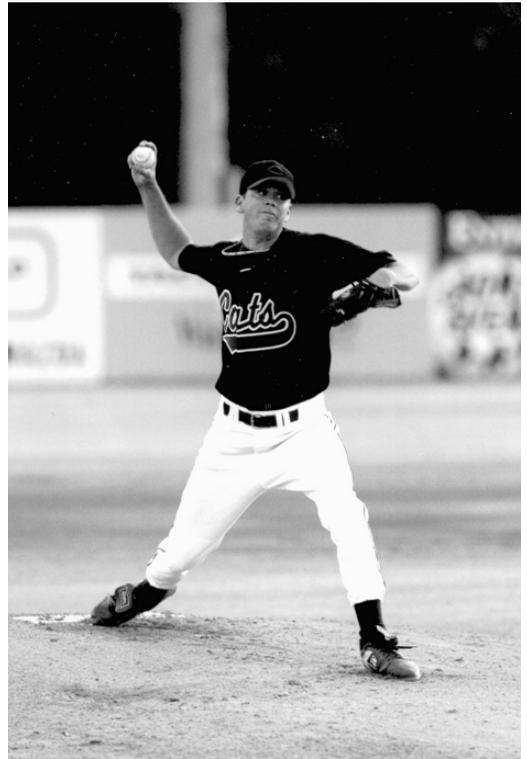


Figure 2.7. The forward stride of a pitcher increases the range of motion used to accelerate the body and eventually the baseball.

several biomechanical factors are involved in manipulating a person's stability and mobility. A handstand is a difficult gymnastic skill not only because of the muscular strength required, but also because of the small base of support in the anterior and posterior directions. Athletes in the starting blocks for sprints choose body postures with less stability in favor of increased mobility in the direction of the race.

How the muscle actions and body segment motions are timed in a human movement is usually referred to as coordination. The **Coordination Continuum** principle says that determining the optimal timing of muscle actions or segmental motions depends on the goal of the movement. If high forces are the goal of the movement,

more simultaneous muscle actions and joints rotations are usually observed, while low-force and high-speed movements tend to have more sequential muscle and joint actions (Hudson, 1995; Kreighbaum & Barthels, 1996). These two strategies (simultaneous/sequential) can be viewed as a continuum, with the coordination of most motor skills falling somewhere between these two strategies.

The principle of **Segmental Interaction** says that the forces acting in a system of linked rigid bodies can be transferred through the links and joints. Muscles normally act in short bursts to produce torques that are precisely coordinated to complement the effects of torques created by forces at the joints. A wide variety of terms have been used to describe this phenomenon (transfer, summation, sequential) because there are many ways to study human movement. This variety of approaches has also created a confusing array of terminology classifying movements as either open or closed (kinematic or kinetic) chains. We will see that the exact mechanism of this principle of biomechanics is not entirely clear, and common classification of movements as open or closed chains is not clear or useful in analyzing movement (Blackard, Jensen, & Ebben, 1999; di Fabio, 1999; Dillman, Murray, & Hintermeister, 1994).

The biomechanical principle of **Optimal Projection** says that for most human movements involving projectiles there is an optimal range of projection angles for a specific goal. Biomechanical research shows that optimal angles of projection provide the right compromise between vertical velocity (determines time of flight) and horizontal velocity (determines range given the time of flight) within the typical conditions encountered in many sports. For example, in throwing most sport projectiles for horizontal distance, the typical air resistance and heights of release combine to make it beneficial for an athlete to use projection

angles below 45 degrees. Chapter 5 will give several examples of how biomechanical studies have determined desirable release angles for various activities. This research makes it easier for coaches to determine if athletes are optimizing their performance.

The last principle involves the **Spin** or rotations imparted to projectiles, and particularly sport balls. Spin is desirable on thrown and struck balls because it stabilizes flight and creates a fluid force called **lift**. This lift force is used to create a curve or to counter gravity, which affects the trajectory and bounce of the ball. A volleyball player performing a jump serve should strike above the center of the ball to impart topspin to the ball. The topspin creates a downward lift force, making the ball dive steeply and making it difficult for the opponent to pass. The spin put on a pass in American football (Figure 2.8) stabilizes the orientation of the ball, which ensures aerodynamically efficient flight. The natural application

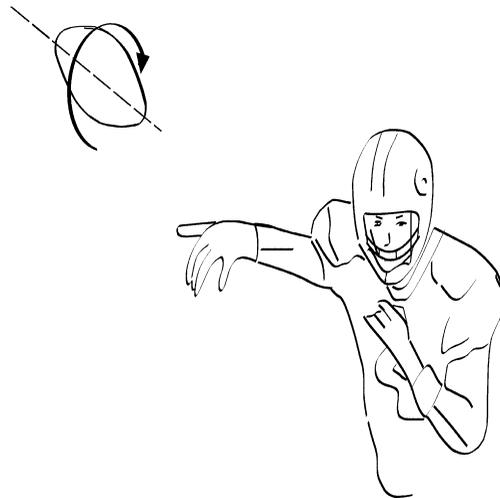


Figure 2.8. The spin imparted to a football during a forward pass serves to stabilize ball flight, to provide aerodynamically efficient flight.

Interdisciplinary Issue: The Vertical Jump

Now that the principles are out of the bag, let's use them to look at a common sport movement, the vertical jump. Imagine an athlete is doing a standing vertical jump test. Which principles of biomechanics would be of most interest to scholars from motor development, motor learning, exercise physiology, or sport psychology studying the vertical jump test? What combinations of the sport sciences are most relevant to the concept of *skill* in vertical jumping? What sports science provides the most relevant information to the physical determinants of jumping ability? How could someone determine if the success of elite jumpers is more strongly related to genetics (nature/physical) than coaching (nurture/training)? How could a strength coach integrate jump training studies with biomechanical studies of jumping techniques?

of these biomechanical principles is in qualitative analysis of human movement.

QUALITATIVE ANALYSIS

The examples that illustrate the application of the principles of biomechanics in the solution of human movement problems in this book will be based on qualitative analyses. Research has shown that general principles of biomechanics provide a useful structure for qualitative analysis of human movement (Johnson, 1990; Matanin, 1993; Nielsen & Beauchamp, 1992; Williams & Tannehill, 1999; Wilkinson, 1996). Quantitative biomechanical analysis can also be used, but most kinesiology professionals will primarily be using qualitative analyses of movement rather than quantitative biomechanical analyses.

There are several models of qualitative analysis of human movement. Traditionally, kinesiology professionals have used a simple error detection and correction approach to qualitative analysis. Here the analyst relies on a mental image of the correct technique to identify “errors” in the performance and provide a correction. This approach has several negative consequences and is too simplistic a model for professional judgments (Knudson & Morrison, 2002). The application of the principles of biomechanics is illustrated in the present book using a more comprehensive vision of qualitative analysis than the simple error detection/correction of the past. This text uses the Knudson and Morrison (2002) model of qualitative analysis (Figure 2.9). This model provides a simple four-task structure: preparation, observation, evaluation/diagnosis, and intervention. This model of qualitative analysis is equally relevant to athletic or clinical applications of biomechanics to improving human movement.

In the preparation task of qualitative analysis the professional gathers relevant kinesiology knowledge about the activity, the performer, and then selects an observational strategy. In the observation task the analyst executes the observational strategy

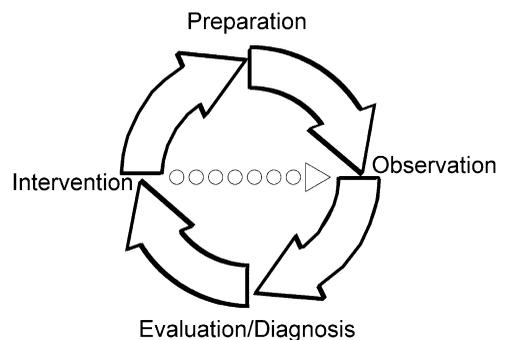


Figure 2.9. The four-task model of qualitative analysis. Adapted from Knudson and Morrison (2002).

to gather all relevant sensory information about the performance of the movement. The third task of qualitative analysis has two difficult components: evaluation and then diagnosis of performance. In evaluation the analyst identifies strengths and weaknesses of performance. Diagnosis involves the prioritizing of the potential interventions to separate causes of poor performance from minor or symptomatic weaknesses. Intervention is the last task of qualitative analysis. In this task the professional executes some action on behalf of the performer. Often in live qualitative analysis, the analyst will return immediately to the observation task to monitor the intervention and the mover's progress.

Application: Quantitative Analysis

An athletic trainer is planning a qualitative analysis of the lower-extremity muscular function of an athlete finishing up an anterior cruciate ligament (ACL) rehabilitation program. The trainer has run the athlete through the rehabilitation program, but wants a more functional evaluation of the athlete's ability and readiness for play. The athlete will be doing several drills, including multiple one-legged hops and squats, shuttle runs, landings, jumps, and lateral cutting movements. For the preparation task of qualitative analysis, give examples of research or biomechanical principles that you think would be relevant to analyzing the athlete's ability to prevent damage to the ACL. Is there a task of qualitative analysis that more heavily relies on biomechanics than other sport sciences?

SUMMARY

Most biomechanical research has been based on rigid-body models of the skeletal

system. Kinematics involves the description of the motion, while kinetics focuses on the forces that created the motion. There are many biomechanical variables and they can be classified as either scalars or vectors. Despite the precision of quantitative biomechanics, most kinesiology professionals apply biomechanics at a qualitative or conceptual level. The nine principles of biomechanics that can be used to apply biomechanics knowledge in professional practice are Force–Motion, Force–Time, Inertia, Range of Motion, Balance, Coordination Continuum, Segmental Interaction, Optimal Projection, and Spin. These nine principles can be applied using a comprehensive model (Knudson & Morrison, 2002) of qualitative analysis.

REVIEW QUESTIONS

1. What are major branches of mechanics, and which are most commonly used in performing biomechanical analyses of human movement?
2. What are the specific foci of kinematic and kinetic analyses, and provide some examples?
3. How are vector variables different from scalar variables?
4. How is a scientific principle different from a law?
5. The nine principles of biomechanics can be classified into which two areas of interest?
6. What are the nine principles of biomechanics?
7. What are some other factors that affect human movement and the application of the principles of biomechanics?
8. List as many reasons as possible for the apparent theory-to-practice gap between scholars and practitioners.

KEY TERMS

components
 deformable body
 dynamics
 dynamometer
 fluid
 free-body diagram
 isometric
 kinematics
 kinetics
 mass
 mechanics
 resultant
 scalar
 science
 strength (muscular)
 stiffness
 technology
 torque/moment of force
 vector
 weight

SUGGESTED READING

- Hudson, J. L. (1995). Core concepts in kinesiology. *JOPERD*, **66**(5), 54–55, 59–60.
- Knudson, D., & Morrison, C. (2002). *Qualitative analysis of human movement* (2nd ed.). Champaign, IL: Human Kinetics.
- Knuttgen, H. G., & Kraemer, W. J. (1987). Terminology and measurement in exercise performance. *Journal of Applied Sport Science Research*, **1**, 1–10.
- Kreighbaum, E., & Bartels, K. M. (1996). *Biomechanics: A qualitative approach to studying human movement*. Boston: Allyn & Bacon.
- Norman, R. (1975). Biomechanics for the community coach. *JOPERD*, **46**(3), 49–52.
- Rogers, M. M., & Cavanagh, P. R. (1984). Glossary of biomechanical terms, concepts, and units. *Physical Therapy*, **64**, 82–98.

WEB LINKS

Physics and Mathematics Review provided by the physics department of the University of Guelph in Canada.

<http://www.physics.uoguelph.ca/tutorials/tutorials.html>

Knudson & Morrison (2002)—A link to the only book on the qualitative analysis of human movement.

<http://www.humankinetics.com/products/showproduct.cfm?isbn=0736034625>