# Biomechanical Basis of Human Movement

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# Preface

Biomechanics is a quantitative field of study within the discipline of Exercise Science. This book is intended as an introductory textbook but will stress this quantitative rather than qualitative nature of biomechanics. It is hoped that while stressing the quantification of human movement the book will also acknowledge those with a limited background in mathematics. The quantitative examples are presented in a detailed, logical manner that highlight topics of interest. The goal of this book, therefore, is to provide an introductory text in biomechanics that integrates basic anatomy, physics, calculus, and physiology for the study of human movement. We decided to use this approach because numerical examples are meaningful and easily clear up misconceptions concerning the mechanics of human movement.

Several features of this text serve as effective means for students to comprehend biomechanics as a field of study. This book is organized into three major sections: Part I—Foundations of Human Movement; Part II—Functional Anatomy; and Part III—Mechanical Analysis of Human Motion. The chapters are ordered to provide a logical progression of material essential toward the understanding of biomechanics and the study of human movement.

Part I, Foundations of Human Movement, includes Chapters 1 through 4. Chapter 1 "Basic Movement Terminology," presents the terminology and nomenclature generally used in biomechanics. Chapter 2, "Skeletal Considerations for Movement," covers the skeletal system with particular emphasis on joint articulation. Chapter 3, "Muscular Considerations for Movement," discusses the organization of the muscular system. Finally, in Chapter 4, "Neurological Considerations For Movement," the control and activation systems for human movement are presented.

Part II, Functional Anatomy, includes Chapters 5 through 7, deals with specific regions of the body: the upper extremity, lower extremity, and trunk, respectively. Each chapter integrates the general information presented in Part I relative to each region.

Part III, Mechanical Analysis of Human Motion includes Chapters 8 through 12, in which quantitative mechanical techniques for the analyses of human movement are presented. Chapter 8 and 9 present the concepts of linear and angular kinematics. Included in these two chapters are the equations used to describe the motion of projectiles. Conventions for the study of angular motion in the analysis of human movement are also detailed. A portion of each chapter is devoted to a review of the research literature on human locomotion, which is used throughout the section to illustrate the quantitative techniques presented.

Chapters 10 and 11 present the concepts of linear and angular kinetics, including discussions on the forces and torques that act on the human body during daily activities. Included here is a discussion of the inertial characteristics of the segments of the body.

Chapter 12, "Types of Mechanical Analysis," is the culminating chapter in the mechanics section, in which three methods of analyzing human movement are presented with computations and examples of each method.

Although the book follows a progressive order, the major sections are generally self-contained. Therefore, instructors may delete or de-emphasize certain sections. Parts I and II, Foundations of Human Movement and Functional Anatomy, for example, could be used in a traditional kinesiology course, while Part III—Mechanical Analysis of Human Motion, could be used for a biomechanics course.

A second feature of the book is the means used to reinforce the principles presented. Each chapter contains a list of chapter objectives to enable the student to focus on key points in the material. Each concept is accompanied by problems, which are solved to highlight the concept. A chapter summary then outlines the major concepts presented. A glossary is presented at each chapter's end defining terms found in each chapter, as a source of reenforcement and reference. Both an up-to-date reference list of the research literature cited in the chapter and a list of additional readings for students who wish to study the material in more depth are included.

Each chapter contains a series of problems to challenge students and to help them digest and integrate the material presented. Finally, four appendices present information on bony landmarks, ligaments, muscles, units of measurement, and a review of trigonometric functions.

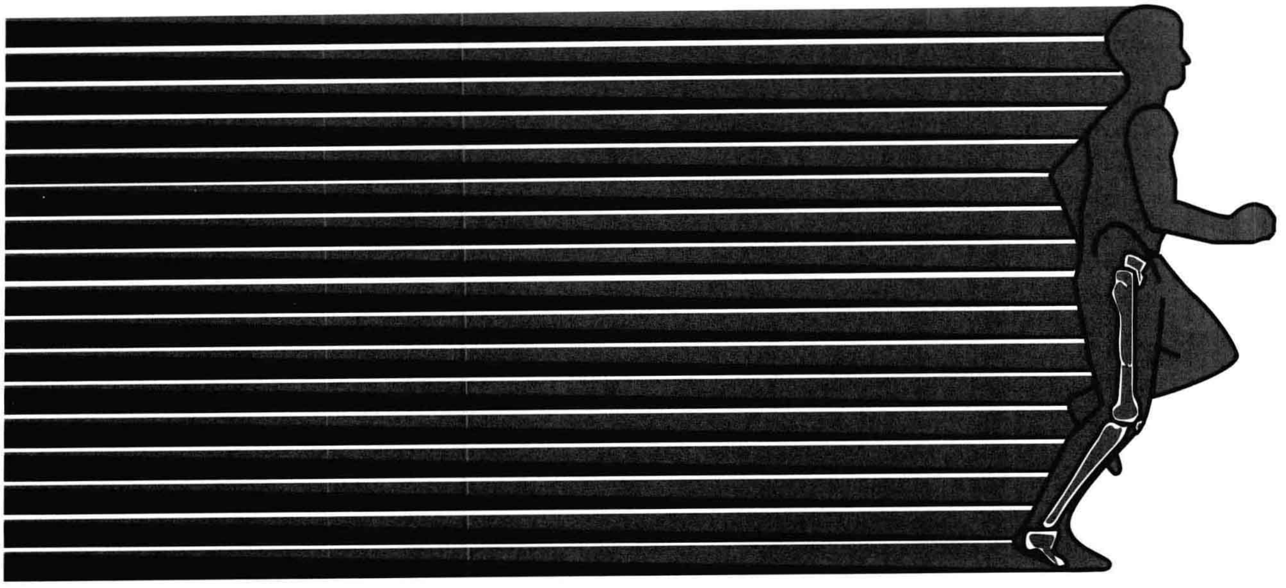
A third feature of this book is the examples of human movement presented. While illustrations of the principles of human movement are easily seen in most sports examples, applications from ergonomics, orthopedics, and exercise are presented as well, with references from the current biomechanics literature. In doing so, the full continuum of human movement potential is considered in examples.

# Contents

PART 1

# Foundations of Human Movement





Chapter 1

# Basic Movement Terminology

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*II. Core Areas of Study*

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## Student Objectives

After reading this chapter, the student will be able to:

1. Define mechanics, biomechanics, and kinesiology and differentiate between their uses in the analysis of human movement.
2. Define and provide examples of linear and angular motion.
3. Define kinematics and kinetics.
4. Explain the difference between a relative and absolute reference system.
5. Define sagittal, frontal, and transverse planes along with corresponding frontal, sagittal, and longitudinal axes. Provide examples of human movements that occur in each plane.
6. Explain "degree of freedom" and provide examples of degrees of freedom associated with numerous joints in the body.
7. Describe the location of segments or landmarks using correct anatomical terms such as medial, lateral, proximal, and distal.
8. Identify segments by their correct name, define all of segmental movement descriptors, and provide specific examples in the body.
9. Describe the segmental movements occurring in a multijoint activity or sport skill.

### Introduction

To begin or renew the study of kinesiology and biomechanics using this textbook requires a fresh mind. Remember that human movement is the theme and the focus of study in both biomechanics and kinesiology. A thorough understanding of various aspects of human movement may facilitate better teaching, successful coaching, more observant therapy, knowledgeable exercise prescription, or new research ideas. Movement is used to interact with the environment, whether it be simply to take a walk in a park, to strengthen muscles in a bench press, to compete in the high jump at a collegiate track meet, or to stretch or rehabilitate a joint that has been injured. Movement, or motion, involves a change in place, position, or posture relative to some point in the environment.

This textbook focuses on developing knowledge in the area of human movement in order to feel comfortable observing human movement and solving movement problems. There are many different approaches to the study of movement, such as observing movement using only the human eye, or collecting data on movement parameters using laboratory equipment. Different observers of activities also have different concerns: a coach may be interested in the final outcome of a tennis serve, while a therapist may be interested in identifying where in the serve the athlete is placing the stress on the medial elbow that has a tendinitis condition. Some applications of biomechanics and kinesiology will only require a cursory view of a movement, such as visual inspection of the forearm position in the jump shot. Other applications, such as evaluating the forces applied by the hand on the basketball during the shot will require some advanced knowledge and the use of sophisticated equipment and techniques.

Elaborate equipment is not needed to apply the material in this text, but it will be necessary to understand and interpret numerical examples collected using such intricate instrumentation. There will be qualitative examples in this text where movement characteristics will be described. A qualitative analysis is a non-numeric evaluation of the motion based on direct observation. These examples can be applied directly to a particular movement situation using visual observation or video.

There will also be quantitative information presented in this text. A quantitative analysis is a numerical evaluation of the motion based on data collected during the performance. For example, movement characteristics can be presented to describe the forces, or the temporal and spatial components of the activity. The application of this material to a practical setting such as teaching a sport skill is more difficult, since it is more abstract and often cannot be visually observed. However, the quantitative information is very important since it substantiates what is seen visually in a qualitative analysis. It also directs the instructional technique because a quantitative analysis will identify the source of a movement. For example, a front handspring can be qualitatively evaluated through visual observation by focusing on such things as whether the legs are together and straight, the back arched, the landing solid, and whether it was too fast or slow. But it is through the quantitative analysis that the source of the movement, the magnitude of the torque generated about the ground and the center of gravity, can be identified. Torque cannot be observed qualitatively, but knowing it is the source of the movement will help to qualitatively assess the effects of the torque, the success of the handspring.

This chapter will introduce terminology that will be used numerous times throughout the text. The chapter will begin by defining and introducing the various areas of study for movement analysis. This will be the first exposure to the areas that will be presented in much greater depth later in the text. Next, this chapter will establish a working vocabulary for movement description by presenting reference systems, anatomical descriptors, segment names, and names for all of the major movements of the body. By the end of this chapter, you should be able to describe a movement or skill using correct anatomical terminology and references. Numerous examples are provided to assist you with this.

For example, a common locomotor activity such as walking can be studied using different approaches. In exercise prescription, it may be important to know what muscles are used in walking and when in the walking cycle the muscles are used. It may also be important to understand the changes in muscular usage occurring when an individual walks up or down a hill or walks with weights on the ankles. To teach physical education, it may be important to understand the sequence of joint motions that comprise the walking pattern so that the pattern can be emphasized for students with developmental impairments. Also, a race-walking unit may be included in the curriculum, in which case a thorough understanding of the joint sequences would be helpful. In addition, understanding basic force concepts as they relate to walking substantiates the benefit of using walking, rather than running, as a fitness activity, since walking reduces by half the forces that may cause an injury. A completely different aspect of walking, concentrating on one injured joint, may be the focus of a physical therapist. For example, the hip joint may be creating an abnormal walking pattern such as a limp. Knowing this, the focus may be shifted to developing strength and flexibility surrounding the hip joint so that the individual can resume a normal walking pattern. Lastly, a researcher may be interested in measuring walking to evaluate forces at the feet, forces in the joints, muscle forces involved in the movement patterns of walking, and measuring the speeds of the body and the limbs. These research measurements may serve purposes such as designing a new walking shoe, evaluating an artificial limb, or describing the efficiency of various walking patterns. This textbook will explore the tools that can be used to conduct and understand any of these movement evaluations.

## *Core Areas of Study*

### *Biomechanics vs Kinesiology*

Among people who study human movement, there is often disagreement over the use of the terms "kinesiology" and "biomechanics". The word "kinesiology" can be used in two ways. First, kinesiology is the scientific study of human movement, and can be an umbrella term used to describe any form of anatomical, physiological, psychological, or mechanical human movement evaluation. A second use of the term kinesiology is to describe the content of a class where human movement is evaluated by examining its source and characteristics. Consequently, kinesiology has been used by several disciplines to describe many different content areas. Some departments of physical education have gone so far as to adopt kinesiology as the department name. A class in kinesiology may consist primarily of functional anatomy at one university and strictly biomechanics at another.

Historically, a kinesiology course has been part of college curricula as long as there have been physical education programs. The course originally focused on the musculoskeletal system, movement efficiency from the anatomical standpoint, and joint and muscular actions during simple and complex movements. A typical student activity in the kinesiology course was to identify discrete phases in an activity, describe the segmental movements occurring in each phase, and then identify the major muscular contributors to each joint movement. Thus, if one were completing a kinesiologic analysis of the movement of rising from a chair, the movements would be hip extension, knee extension, and plantar flexion via the hamstrings, quadriceps femoris, and triceps surae muscle groups, respectively. Most kinesiological analyses are considered qualitative because they involve observing a movement and providing a breakdown of the skills and identification of the muscular contributions to the movement.

The content from the study of kinesiology is currently incorporated into many biomechanics courses, and is used as a precursor to the introduction of the more quantitative biomechanical content. In this text, biomechanics will be used as an umbrella term to describe that content previously covered in courses in kinesiology, as well as content developed as a result of growth of the area of biomechanics (FIGURE 1–1).

In the 1960s and 1970s, biomechanics was being developed as an area of study within the undergraduate and graduate curricula across North America. The content of biomechanics was extracted from an area of physics, mechanics, the study of motion and the effect of forces on an object. Mechanics is used by engineers to design and build structures such as bridges, or machines such as airplanes, since it provides the tools for analyzing the strength of structures and ways of predicting and measuring the movement of a machine. It was a natural transition to take the tools of mechanics and apply them to living organisms. Thus, biomechanics, the study of the application of mechanics to biological systems, evolved.

Biomechanics evaluates the motion of a living organism and the effect of force–either a push or pull–on a living organism. The biomechanical approach to movement analysis can be qualitative, with movement observed and described, or quantitative, meaning that some measurement of the movement will be performed. The use of the term "biomechanics" in this text will incorporate qualitative components as well as a more specific, quantitative approach in which the motion characteristics of a human or an object will be described using such parameters as speed and direction, how the motion is created through application of forces both inside and outside the body, and the optimal body positions and actions for efficient, effective human or object motion. To evaluate biomechanically the motion of rising from a chair, for example, one would attempt to measure and identify joint forces acting at the hip, knee, and ankle, as well as the force between the foot and the floor, all of which act together to produce the movement up out of the chair. The components of a biomechanical and kinesiologic movement analysis are presented in FIGURE 1–1. Let's examine some of these components individually. A glossary of movement analysis terms is provided at the end of this chapter.

### *Anatomy vs Functional Anatomy*

Anatomy, the science of the structure of the body, is the base of the pyramid from which expertise about human movement will be developed. It is very helpful to develop a strong understanding of regional gross anatomy so that for a specific region such as the shoulder, the bones, location of muscles, nerve innervation of those muscles, blood supply to those muscles, and other significant structures such as ligaments can be identified. A knowledge of anatomy can be put to good use if, for

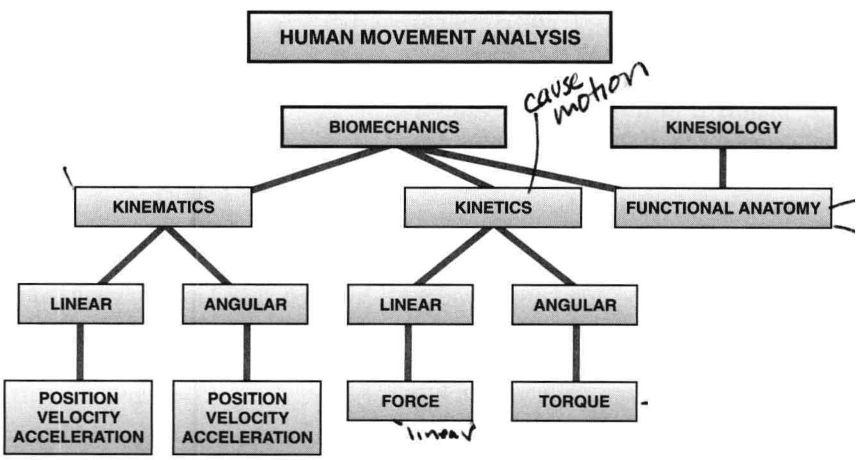


*FIGURE 1–1.* Types of movement analysis. Movement can be analyzed by assessing the anatomical contributions to the movement (functional anatomy), describing the motion characteristics (kinematics), or determining the cause of the motion (kinetics).

example, one is trying to assess an injury. Let's say that a patient has a pain on the inside of her elbow. Using a knowledge of anatomy, the medial epicondyle of the humerus would be recognized as the prominent bony structure of the medial elbow. It would also be known that the muscles that pull the hand and fingers toward the forearm into flexion attach on this epicondyle. Thus, familiarity with anatomy might lead to a diagnosis of medial epicondylitis, possibly caused by overuse of the hand flexor muscles.

Functional anatomy is the study of the body components needed to achieve or perform a human movement or function. Using functional anatomy to analyze a dumbbell lateral raise of the arm, the deltoid, trapezius, levator scapulae, rhomboid, and supraspinatus muscles would be identified as contributors to upward rotation and elevation of the shoulder girdle as well as the abduction of the arm. Knowledge of functional anatomy will be useful in a variety of situations to set up an exercise or weight-training program, assess the injury potential in a movement or sport activity, or when training techniques and drills for athletes are established. The prime consideration of a functional anatomy perspective is not the muscle's location, but rather the movement produced by the muscle or muscle group.

### *Linear vs Angular Motion*

When looking at a human movement or an object being propelled by a human, two different types of motion are present. First is linear motion, often termed translation or translational motion, which is movement along a straight or curved pathway. Examples focusing only on the linear motion in the activity are the examination of the speed of a sprinter, the path of a baseball, the bar movement in a bench press, or the movement of the foot during a football punt. The focus in these activities is on the direction, path, and speed of the movement of the body or object. FIGURE 1–2 illustrates two different focal points for a linear movement analysis.

The center of mass of the body, segment, or object is usually the point monitored in a linear analysis (see FIGURE 1–2). The center of mass is the point about which the mass of the object is balanced, and it represents the point where the total effect of gravity acts on the object. However, any point can be selected and evaluated for linear motion characteristics. In skill analysis, for example, it is often very helpful to monitor the motion of the top of the head to gain an indication of certain trunk motions. An examination of the head in running is a prime example. Does the head move up and down? Side to side? If so, it is an indication that the central mass of the body is moving in those directions as well. The path of the hand or racket is very important in throwing or racket sports, so visually monitoring the linear movement of the hand or racket throughout the execution of the skill is benefi-

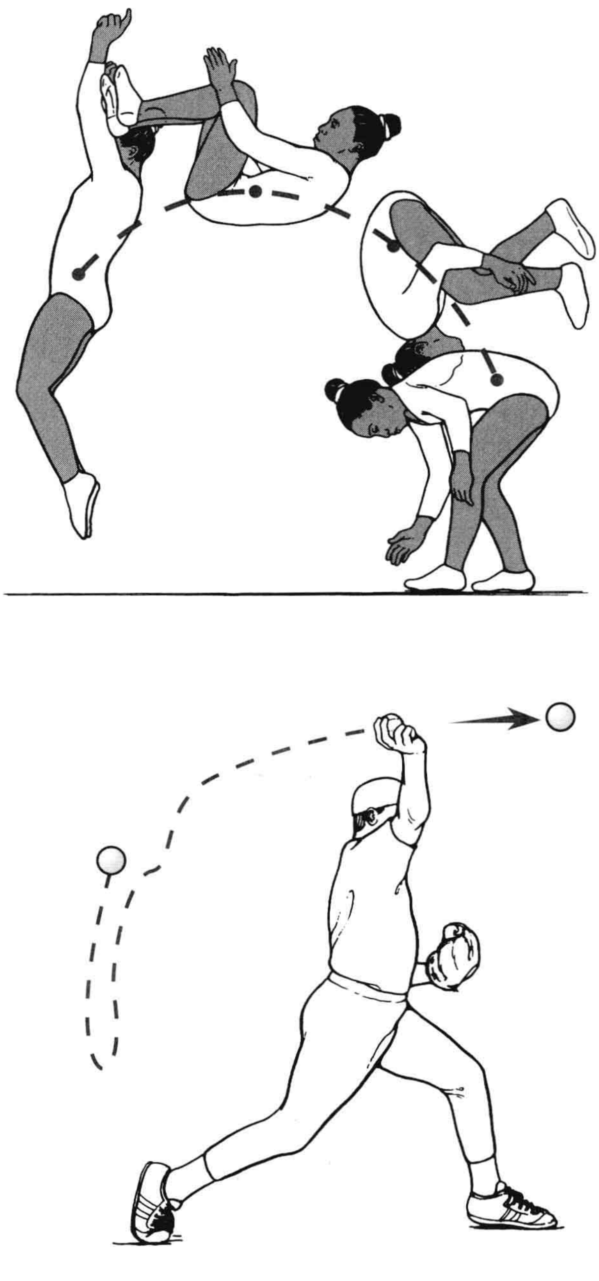

*FIGURE 1–2.* Linear motion examples. Examining the motion of the center of gravity or the path of a projected object are examples of how linear motion analyses are applied.

cial. In an activity such as sprinting, the linear movement of the whole body is the most important component to analyze since the object of the sprint is to move the body quickly from one point to another.

The second type of motion is angular motion, which is motion around some point where different regions of the same body segment or object do not move through the same distance. As illustrated in FIGURE 1–3, swinging around a high bar is an angular motion because the whole body rotates around the contact point with the bar. To make one full revolution around the bar, the feet travel through a much greater distance than the arms because they are farther away from the point of turning. It is typical in biomechanics to examine the linear motion characteristics of an activity and then follow up with a closer look at the angular motions that create and contribute to the linear motion.

All linear movements of the human, or objects propelled by humans, occur as a consequence of angular contributions. The only exceptions to this rule are movements such as skydiving or free falling where the body is held in a position to let gravity create the movement lin-

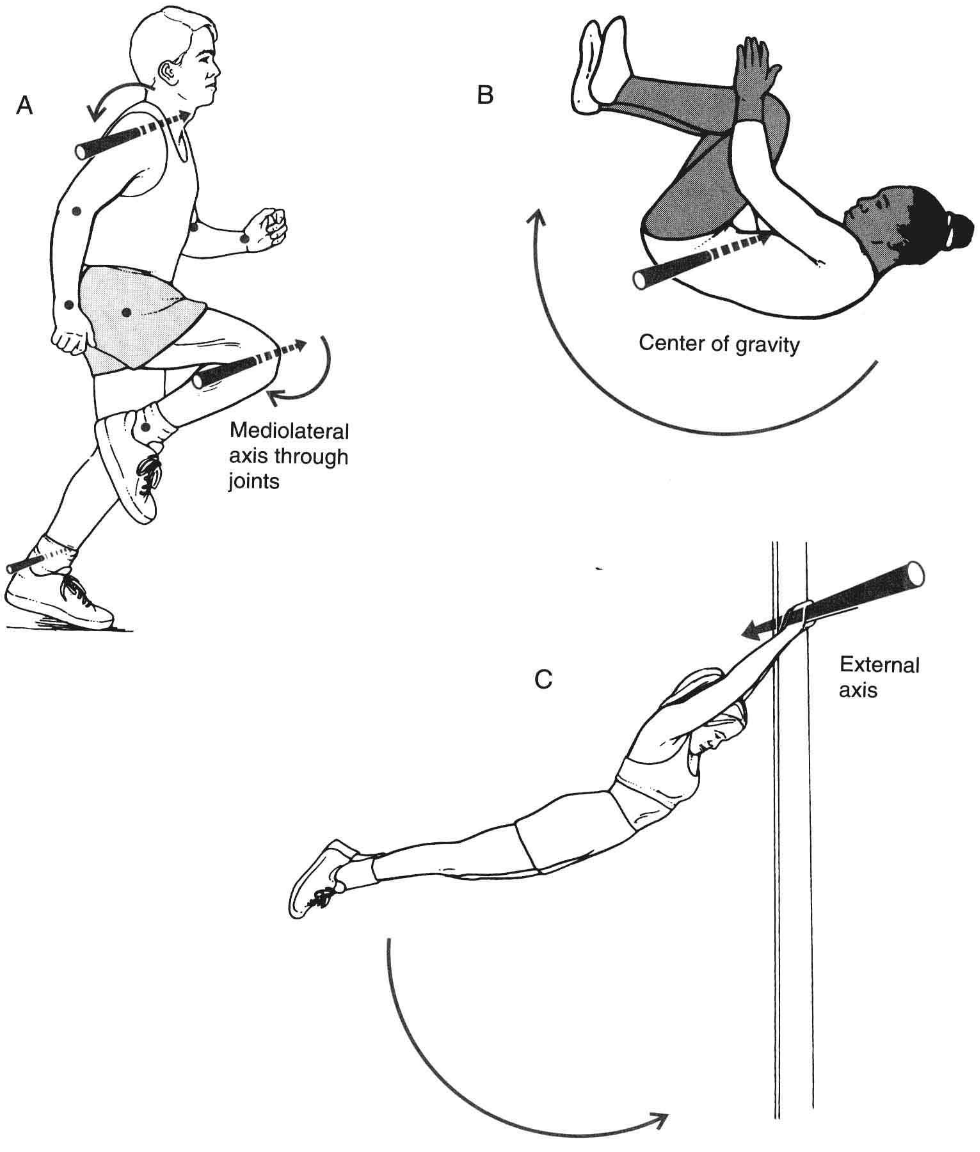


*FIGURE 1–3.* Angular motion examples. Angular motion of the body, an object, or segment can take place around an axis running through a joint (A), through the center of gravity (B), or about an external axis (C).

early downward, or cases where an external pull or push moves the body or an object. It is important to identify the angular motions and the sequence of angular motions that make up a skill or human movement, because the angular motions will determine the success or failure of the linear movement.

Angular motions occur around an imaginary line called the axis of rotation. Angular motion of a segment, such as the arm, occurs about an axis running through the joint. Thus, lowering the body into a deep squat entails angular motion of the thigh around the hip joint, angular motion of the leg around the knee joint, and angular motion of the foot around the ankle joint. Angular motion can also occur around an axis through the center of mass. Examples of this type of angular motion are performing a somersault in the air, and spinning vertically when figure skating. Finally, angular motion can occur around a fixed external axis, such as swinging around a high bar, rotating over the foot in a run or walk, or swinging on the end of the pole in the pole vault.

To be proficient in human movement analysis, the identification of angular motion contributions to the linear motion of the body or an object is important. This is apparent in a simple activity such as kicking a ball for maximum distance. The intent of the kick is to make solid contact between a foot travelling at a high linear speed and moving in the proper direction and a ball to send the ball in the desired linear direction. The linear motion of interest is the actual path and movement of the ball after it leaves the foot. To create the high speeds and the right path, the angular motions in the kicking leg are sequential and draw speed from each other so that the velocity of the foot is determined by the summation of the individual velocities of the connecting segments. The kicking leg moves into a preparatory phase and draws back through angular motions of the thigh, leg, and foot. The leg whips back underneath the thigh very quickly as the thigh starts to move forward to initiate the kick. In the power phase of the kick, the thigh moves vigorously forward, and rapidly extends the leg and foot forward at very fast angular speeds. As contact is made with the ball, the foot is moving very fast because the velocities of the thigh and leg have been transferred to the foot. Through a skilled observation of human movement, the relationship between angular and linear motion, shown in this kicking example, will serve as a foundation for techniques used to correct or facilitate a movement pattern or skill.

### *Kinematics vs Kinetics*

Biomechanical analysis can be conducted from one of two perspectives. The first, kinematics, is concerned with motion characteristics, and examines motion from a spatial and temporal perspective without reference to the forces causing motion. A kinematic analysis involves the description of movement to determine how fast an object is moving, how high it goes, or how far it travels. Thus, position, velocity, and acceleration are the components of interest in a kinematic analysis. Examples of linear kinematic analysis are the examination of the projectile characteristics of a high jumper and a study of the performance of elite swimmers. Examples of angular kinematic analysis are an observation of the joint movement sequence for a tennis serve, and an examination of the segmental velocities and accelerations in a vertical jump. FIGURE 1–4 presents both an angular and linear example of the kinematics of the golf swing. By examining an angular or linear movement kinematically, we can identify segments of a movement needing improvement, obtain ideas and technique enhancements from elite performers, break a skill down into identifiable parts, and further our understanding of human movement.

Pushing on a table may or may not move the table, depending upon the direction and strength of the push. A push or pull between two objects that may or may not result in motion is termed a force. Kinetics is the area of study that examines the forces acting on a system such as the human body or any object. A kinetic movement analysis area attempts to define the forces causing a movement. A kinetic movement analysis is more difficult than a kinematic analysis to both comprehend and evaluate, since forces cannot be seen (FIGURE 1–5). Only the effects of forces can be observed!

Watch someone lift a 200 pound barbell in a squat. How much force has been applied? Since the force cannot be seen, there is no way of accurately evaluating the force unless it can be measured using recording instruments. A likely estimate of the force would be at least 200 pounds since that is the weight of the bar. The estimate may be off by a significant amount if the weight of the body lifted and the speed of the bar is not considered. The forces produced are very important since they are responsible for creating all of our movements and for maintaining positions or postures having no movement. The assessment of these forces represents the greatest technical challenge in this field since it requires equipment and expertise. Thus, for the novice movement analyst, concepts relating to maximizing or minimizing force production in the body will be more important than evaluating the actual forces themselves.

A kinetic analysis can provide the teacher, therapist, coach, or researcher with valuable information about how the movement is produced or how a position is

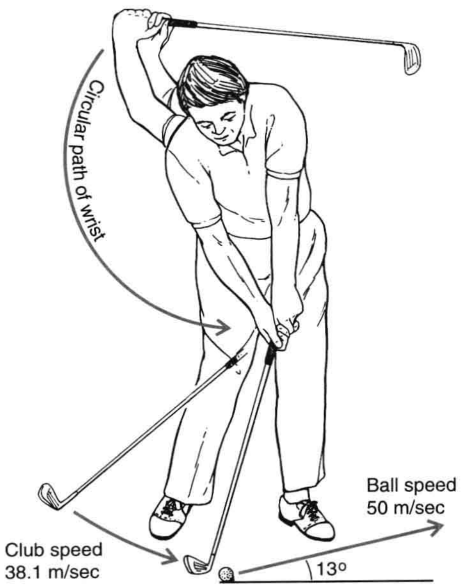


*FIGURE 1–4.* Examples of kinematic movement analysis. A kinematic analysis is one which focuses on the amount and type of movement, the direction of the movement, and the speed or change in speed of the body or an object. The golf example above is presented from two of these perspectives: the angular components of the golf swing (top) and the linear direction and speed of the club and ball (bottom).

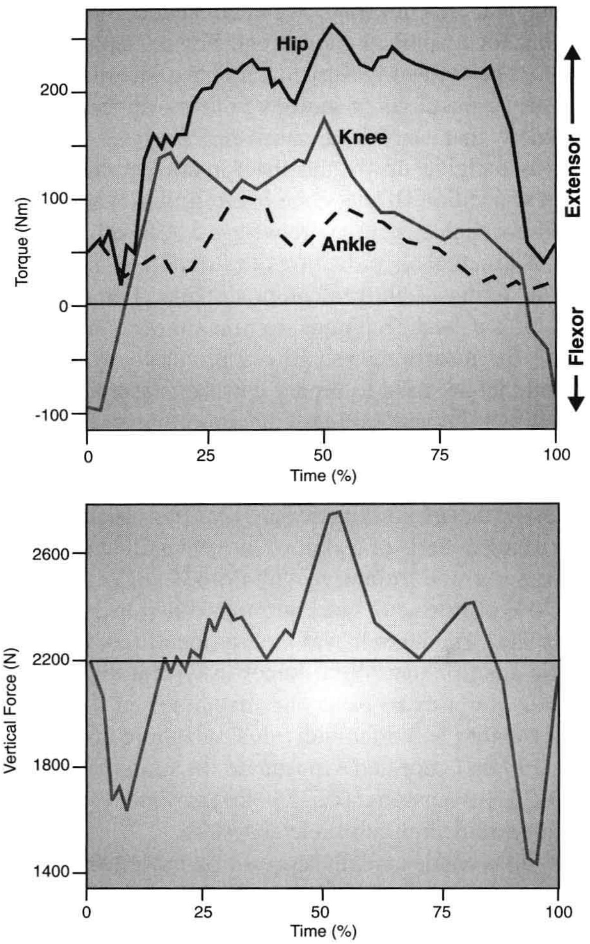


*FIGURE 1–5.* Examples of kinetic movement analysis. A kinetic analysis is one which focuses on the cause of movement. The lifting example above demonstrates how lifting can be analyzed by looking at the vertical forces on the ground that produce the lift (linear) and the torques produced at the three lower extremity joints which generate the muscular force required for the lift (Redrawn from Lander, 1984).

maintained. This information can direct conditioning and training for a sport or movement. For example, kinetic analyses performed by researchers have identified weak and strong positions in various joint movements. Thus, we know that starting an arm curl exercise with the weights hanging down and the forearm straight is the weakest position. If the same exercise was started with the elbow slightly bent, more weight could be lifted. The area of kinetics also identifies the important parts of a skill in terms of movement production. For example, what is the best technique for maximizing a vertical jump? By measuring the forces produced against the ground that are used to propel upward, researchers have agreed that the vertical jump incorporating a very quick drop, stop, and pop action upward produces more effective forces at the ground than the slow, deep, gather jump.

Lastly, the area of kinetics has played a crucial role in identifying aspects of a skill or movement that make the performer prone to injury. Why do 43% of participants and 76% of instructors of high-impact aerobics incur an injury (1)? The answer was clearly identified through a kinetic analysis that found forces in typical high impact aerobic exercises to be in the magnitude of 4–5 times body weight (2). For an individual weighing 667.5 newtons (150 lbs), repeated exposure to forces in the range of 2670–3337.5 newtons (600–750 lbs) partially contributes to injury of the musculoskeletal system.

To fully understand all aspects of a movement, examination of both the kinematic and kinetic components must be performed. It is also important to study the kinematic and kinetic relationships since any acceleration of a limb, object, or human body is a result of a force applied at some point, at a particular time, of a given magnitude, and for a particular duration. While it is of some use to merely describe the motion characteristics kinematically, one must also explore the kinetic sources before a thorough comprehension of a movement or skill is possible.

### Statics vs Dynamics

Examine the posture used to sit at a desk and work at a computer. Are there forces present? Yes, even though there is no movement, there are forces present between the back and the chair, the foot and the ground, as well as muscular forces acting in the neck to counteract gravity in order to keep the head up and looking at the screen. Forces are present without motion and are being produced continuously to maintain positions and postures that do not involve movement. Principles from the area of *statics* are used to evaluate the sitting posture. Statics is the examination of systems that are not moving, or are moving at a constant speed such that they are considered to be in equilibrium. Equilibrium is a balanced state in which there is no acceleration because the forces causing a person, or object, to begin moving, speed up, or slow down are neutralized by opposite forces that cancel them out.

Statics is also very useful for determining stresses on anatomical structures in the body, identifying the magnitude of muscular forces, and identifying the magnitude of force that would result in the loss of equilibrium and create movement in the system. How much force from the deltoid would be required to hold the arm out to the side? Why is it easier to hold an arm at the side if you lower or raise the arm so that it is no longer perpendicular to the body? What is the effect of an increased curvature, or swayback, on forces coming through the lumbar vertebrae? These are the types of questions one might answer using a static analysis. Since the static case involves no change in the kinematics of the system, a static analysis is usually performed using kinetic techniques to identify the forces and the site of the force applications responsible for maintaining a posture, position, or constant speed in an object. However, kinematic analyses can be applied in statics to substantiate whether there is equilibrium through the absence of acceleration.

To leave the computer work station and get up out of the chair, forces must be produced in the lower extremity and on the ground to produce the rising motion. *Dynamics* is the area of mechanics used to evaluate this movement since it examines systems in accelerated motion using both the kinematic and kinetic approach to movement analysis. A dynamic analysis of an activity such as running would incorporate a kinematic analysis in which the linear motion of the total body and the angular motion of the segments would be described and related to the kinetic analysis, which would then describe forces applied to the ground and across the joints in order to produce the running actions. Since this textbook will deal with numerous examples involving motion of the human or a human-propelled object, the area of dynamics will be addressed in detail later in specific chapters on linear and angular kinematics and kinetics.

## Anatomical Movement Descriptors

### Segment Names

To flex the arm, would a lift be performed at the elbow with weights in the hand or would the whole arm be raised in front of you? Whatever interpretation is placed on the segment name "arm" will determine the type of movement performed. It is important to correctly identify segment names and use them consistently when analyzing movement. The correct interpretation of flexing the arm would be to raise the whole arm, since the arm refers to the humerus, not the radius and the ulna. A review of segment names is worthwhile in preparation for more extensive use of them in the study of biomechanics.

The head, neck, and trunk are segments composing the main part of the body and the axial portion of the skeleton. This portion of the body is large, accounting for more than 50% of a person's weight, and it usually moves much more slowly than the other parts of the body. Because of its large size and slow speed, the trunk is a good segment to visually observe when one is learning to analyze movement or if one wants to follow the total body activity.

The upper and lower extremities are termed the appendicular portion of the skeleton. Generally speaking, as one moves away from the trunk, the segments become smaller, move faster, and are more difficult to observe due to their size and speed. In the upper extremity, the humerus is termed the arm, the radius and the ulna constitute the forearm, and the carpals, metacarpals, and phalanges are termed the hand. Thus, in the example above, the movement of arm flexion would be a movement of raising the upper extremity in front, while forearm flexion would describe a movement at the elbow joint. The movements of the arm will typically be described as they occur in the shoulder joint, the forearm movements will be described in relation to either elbow or radioulnar joint activity, and the hand movements will be described relative to the wrist joint activity. See FIGURE 1–6 for a graphical representation of the segments.

In the lower extremity, the segment name thigh describes the femur, leg describes the tibia and fibula segment, and foot describes the tarsals, metatarsals, and phalanges. Additionally, the movement of the thigh will typically be described as it occurs at the hip joint, the leg movement as described by actions at the knee joint, and the foot movements as determined by ankle joint activity.

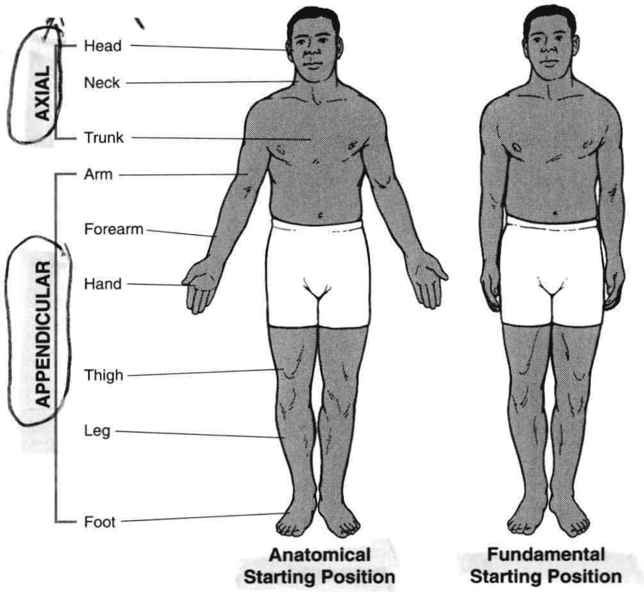


*FIGURE 1–6.* Anatomical vs fundamental starting position. The anatomical and fundamental starting positions serve as a reference point for the description of joint movements.

### *Anatomical Terms*

The description of a segmental position or joint movement is typically expressed relative to a designated starting position. The anatomical starting position has been a standardized reference used for many years by anatomists, biomechanists, and the medical profession. In this position, the body is in an erect stance with the head facing forward, arms at the side of the trunk with palms facing forward, and the legs together with the feet pointing forward. Some biomechanists prefer to use the fundamental starting position that is similar to the anatomical position except that the arms are in a more relaxed posture at the sides with the palms facing in toward the trunk. Whatever starting position used, all segmental movement descriptions are made relative to this starting position. Both of these starting positions are illustrated in FIGURE 1–6.

The starting position is also called the zero position, or origin, for description of most joint movements. For example, when standing, there is zero movement at the hip joint. If the thigh is lifted or rotated in or out, the amount of movement is described relative to the fundamental or anatomical starting position. Most zero positions appear to be quite obvious since there is usually a straight line between the two segments so that no relative angle is formed between them. A relative angle is the included angle between the two segments. Zero position in the trunk occurs when the trunk is vertical and lined up with the lower extremity. The zero position at the knee is found in the standing posture when there is no angle between the thigh and the leg. One not so obvious zero position is at the ankle joint, and is the position assumed in stance with the foot at a right angle to the leg.

Movement description or anatomical location can best be presented using terminology universally accepted and understood. Movement terms should become a part of a working vocabulary, regardless of the level of application