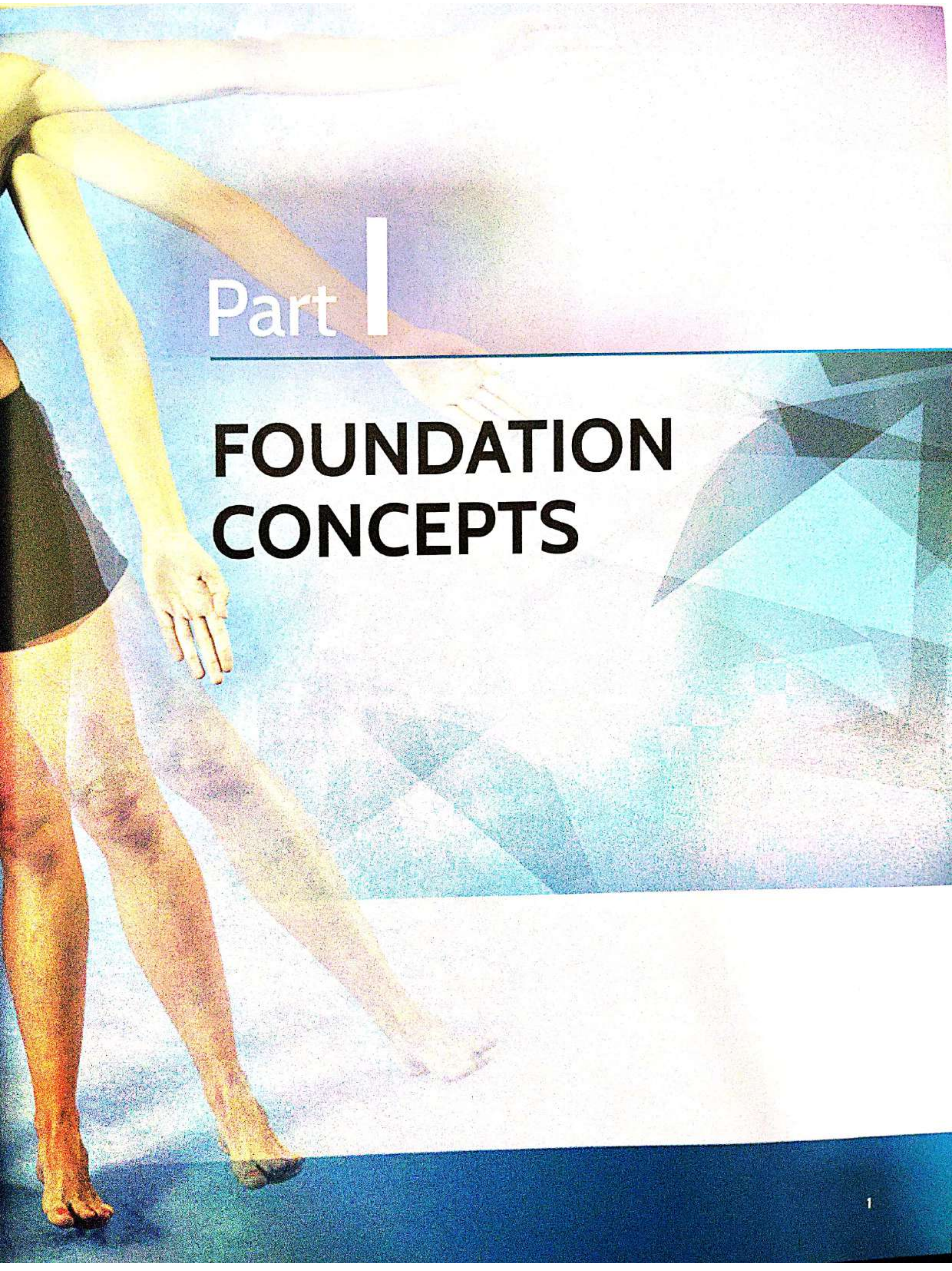


Part I

FOUNDATION CONCEPTS

1

Principles of Kinesiology and Biomechanics

Key Concepts

DIRECTIONAL TERMS
OSTEOKINEMATICS
Planes of Motion
- Sagittal Plane
- Frontal Plane
- Horizontal Plane

Axis of Rotation
Osteokinematic Movement Terminology
Degrees of Freedom
KINEMATICS
Linear Motion
- Straight Line Motion
- Curved Line Motion

Rotary Motion
General Motion
Kinematic Chains of Motion
Open Kinematic Chain Movement
Closed Kinematic Chain Movement

FORCES
Internal Forces
External Forces
Types of Forces
Influence of Forces
- Center of Mass
- Base of Support

Vectors
- Composition of Vector Forces
- Resolution of Vector Forces

Torques
- Joint Position and Forces

Force Couples

Learning Outcomes

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

1.1 Identify the directional location of sites using universal descriptors.
1.2 Demonstrate movement in the three cardinal planes, and identify the axes around which the movement occurs.

(Continued)

Learning Outcomes–cont'd

1.3 Describe movement directions and explain the concept of degrees of freedom of movement.
1.4 Discern the differences between linear, angular, and general motion.
1.5 Illustrate the concepts of open and closed kinematic chain movement and identify examples of these types of movement that occur in daily activities.
1.6 Discuss types of forces and understand how internal and external forces can work to provide movement, stability, or dysfunction.
1.7 Explain the concepts of vector forces in terms of their magnitude and direction.
1.8 Outline the components of torques and understand the relationship between forces, moment arms, and the torques they produce.
1.9 Define the concept of force couples in human motion.

From the beginning of life, humans develop, refine, and perfect various movements to perform functional tasks for daily life, work, and recreational activities, and to play sports. To enhance the development of movement or assist with the return to function after injury, one must first understand typical human movement. The term **kinesiology**, from the Greek word *kinein*, meaning "to move," and the addition of the English suffix *-logy*, meaning "to study," is the scientific study of movement and performance. Several branches of science, particularly anatomy, physiology, physics, and biomechanics, contribute to the science of kinesiology. Human anatomy lays the foundation by providing information about the structures of the body, and physiology outlines the interactions between these structures and various body systems. Physics describes the concepts of force and mass and their relationship in movement through the understanding of mechanics. **Biomechanics** applies the concepts of mechanics to human movement. The study of human kinesiology includes examination of human structures, study of the individual and collective functions of the joints, and understanding concepts related to forces that produce or prevent movement. Once these concepts are understood, studies related to how injury, disorders, disease, and aging affect human movement and function and how the human body is capable of adapting to these challenges can be explored.

To begin the study of human movement, this text first discusses universal terms to describe various types of movement and the directions and planes in which they occur. Motion can occur in linear paths and angular arcs, both of which are necessary for the accomplishment of daily tasks, recreation, and sports. The way body segments move in relationship to each other determines their function and how tasks are accomplished. The legs function in two entirely different ways depending on whether the feet are on the floor when moving from sitting to standing or free from a surface when kicking a ball. Arms can be free to throw a ball, or stationary to push up from the arms of a chair when moving from sitting to standing. For movement to occur, external forces such as those from gravitational forces and friction must be overcome by internal forces generated by the musculoskeletal system. Insight into how alignment and forces can either foster healing and increase function or cause injury and produce dysfunction provides a foundation on which to build rehabilitation concepts and principles.

DIRECTIONAL TERMS

To describe and discuss anatomical structures and movement in a consistent manner, there is a universal reference or starting point: the **anatomical position.** This fundamental reference depicts the human body in a standing position facing forward, arms at the side of the body, and the palms of the hands facing forward (Fig. 1.1). This position is the reference for describing anatomical structures, planes of movement, and axes of rotation.

In the anatomical position, structures and their relationship to each other are described in standard directional terms. **Medial** and **lateral** are terms used to describe the relationship of a point to the midline of either the entire body or a body segment. A point closer to the midline is described as medial to other sites, whereas a site farther from the midline is described as lateral. The ulna bone in the forearm is medial to the radius. The sternum in the thorax is medial to the ribs. **Anterior** and **posterior** reference the relationship between a location and the front (anterior) or back (posterior) of the body. The patella is anterior to the femur. The spine is posterior to the sternum. When discussing the relationship between a site and the trunk, the terms **proximal** and **distal** are used. A site closer to the trunk than another site is considered proximal; for example, the hip is proximal to the knee. The knee is proximal to the ankle. Sites distal are farther from the trunk. The foot is located distal to the knee. The knee is distal to the hip. **Superior** and **inferior** describe structures in terms of being above or below another structure. The terms used to describe directions and examples using the terms are outlined in Table 1.1 and depicted in Figures 1.2 and 1.3.

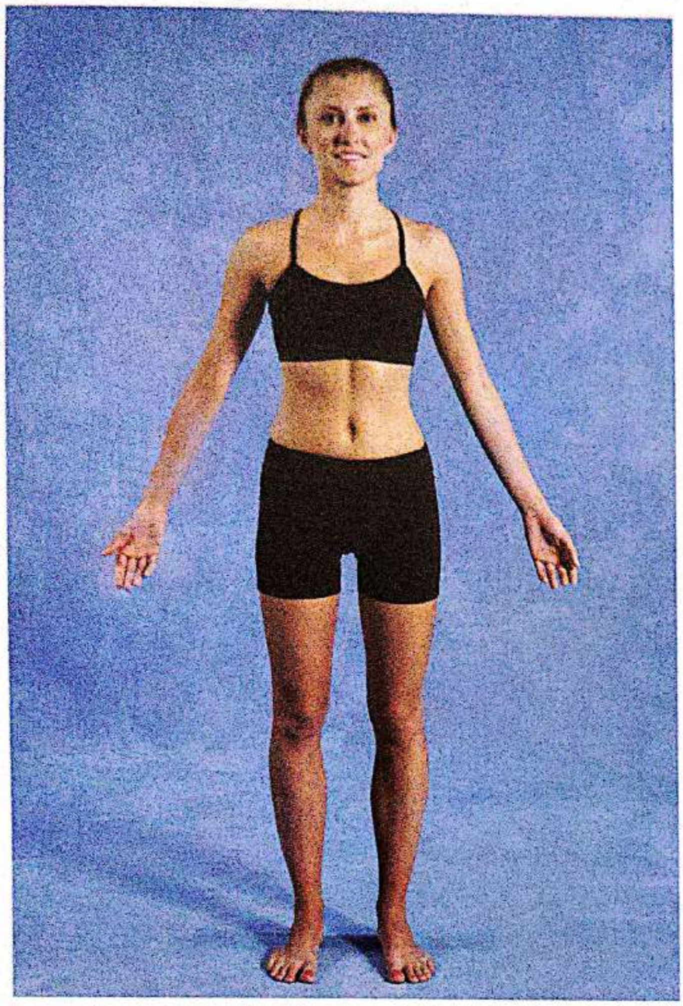


Figure 1.1 In the anatomical position, arms at the side, palms facing forward.

The terms **cephalic** and **cranial** can be used to describe positions closer to the head; **caudal** relates to positions closer to the feet. **Superficial** describes structures or areas that are closer to the surface, whereas **deep** refers to structures that are farther from the surface. The skin is superficial to muscle tissue in the body.

OSTEOKINEMATICS

PLANES OF MOTION

The skeletal system moves through three-dimensional space as the body performs daily activities, such as rising to stand from a chair or reaching overhead for an object. This same three-dimensional movement produces complex movements when performing higher-intensity work during exercise and various recreational and sport activities. Three **cardinal** (principal) **planes** of motion correspond to the dimensions of space: sagittal, frontal, and horizontal (transverse). **Osteokinematics** describes the movement of the skeletal system through these planes of motion using a body standing in the anatomical position as the reference. If the motion occurs in only one plane, it is considered a straight plane or uniplanar movement. Most of the motion that occurs during human movement takes place through more than one plane and is considered multiplanar. As a person rolls over in bed, moves to a sitting position, and then stands, the various sections of the body move through all the cardinal planes of motion. An athlete throwing a ball moves the arm and body through a combination of planes of motion to produce ball flight.

TABLE 1.1 Anatomical Direction Terms

Term	Definition	Example
Medial	Closer to the midline of the body	The ulna is medial to the radius.
Lateral	Farther away from the midline of the body	The radius is lateral to the ulna.
Anterior	Closer to the front of the body	The sternum is anterior to the spine.
Posterior	Closer to the back of the body	The femur is posterior to the patella.
Proximal	Closer to the trunk	The hip is proximal to the knee.
Distal	Farther from the trunk	The knee is distal to the hip.
Superior	Describes a structure above another	The sternum is superior to the pelvis.
Inferior	Describes a structure below another	The pelvis is inferior to the sternum.

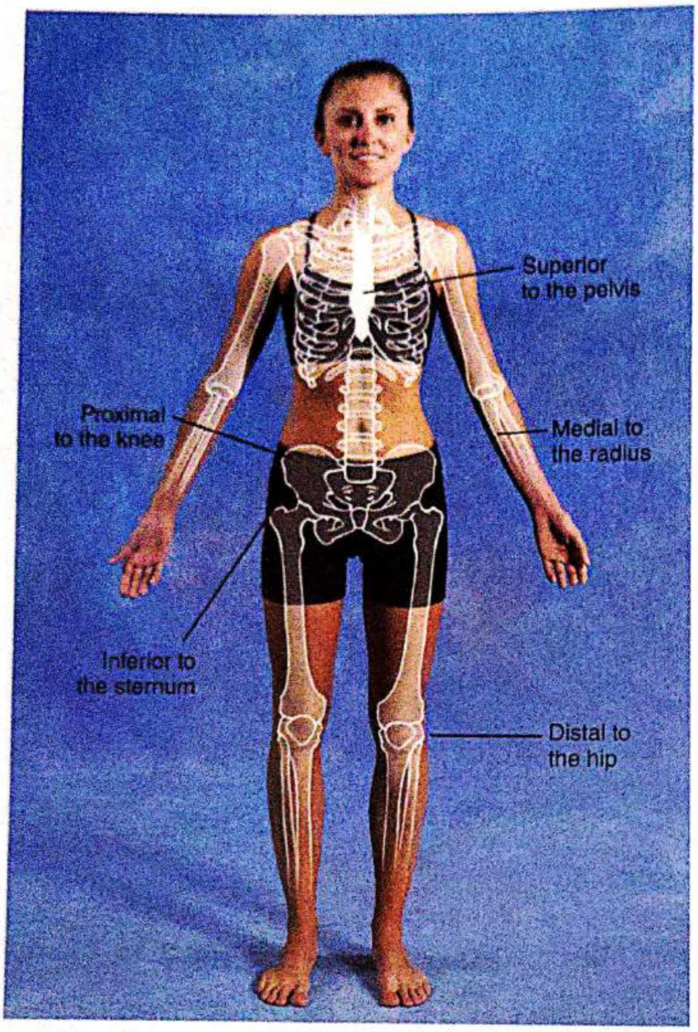


Figure 1.2 The ulna is medial to the radius, and the radius is lateral to the ulna. The hip is proximal to the knee, and the knee is distal to the hip. The sternum is located superior to the pelvis, and the pelvis is inferior to the sternum.

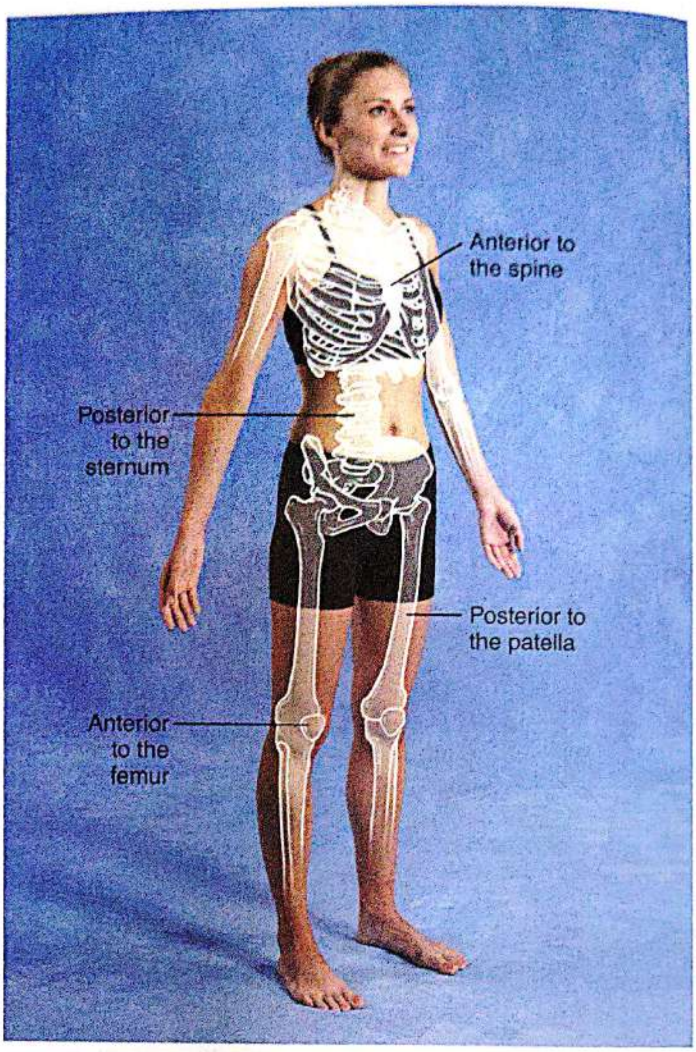


Figure 1.3 The sternum is anterior to the spine, and the spine is posterior to the sternum. The femur is posterior to the patella, and the patella is anterior to the femur.

Sagittal Plane

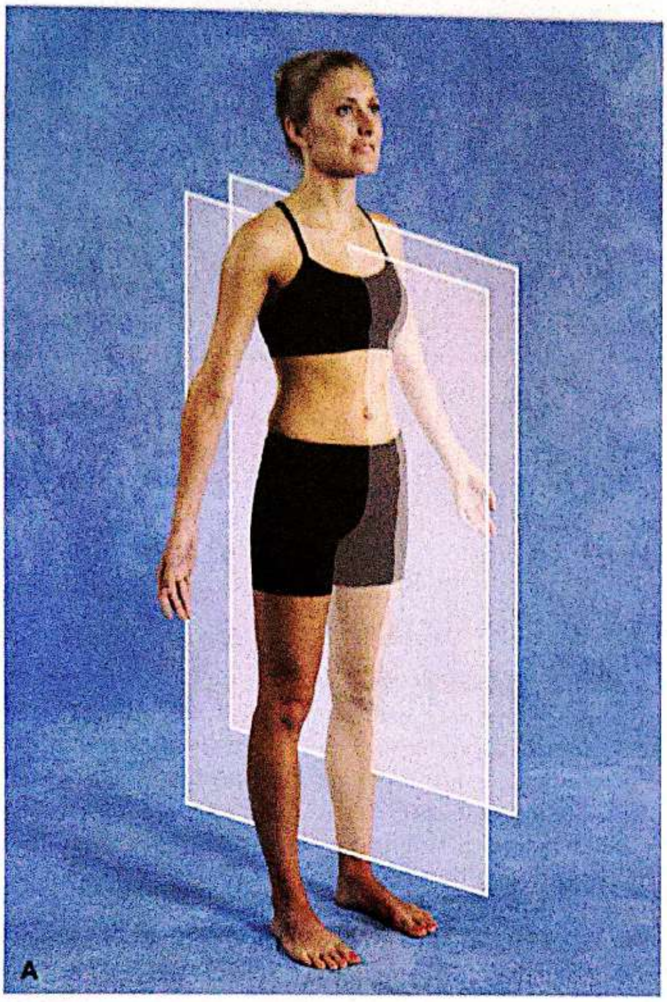
The **sagittal plane** is oriented vertically and divides the body and segments of the body into right and left sections. Movement such as flexion and extension that occurs anterior (front) to posterior (back) or posterior to anterior occurs in the sagittal plane. As the arm reaches forward and up to retrieve an object, it is moving in the sagittal plane. Flexing and extending the elbow occur in the sagittal plane. Figure 1.4 depicts the body divided in the sagittal plane and various body segments moving in the sagittal plane.

Frontal Plane

The **frontal (coronal) plane** is also positioned vertically and dissects the body and its segments into front and back portions. Moving the arm or leg out to the side, moving it away from the body, and laterally bending the neck or trunk sideways are examples of movement in the frontal plane. The frontal plane is the plane of motion for sideways motion such as abduction and adduction, as shown in Figure 1.5.

Horizontal Plane

Rotational movement that occurs parallel to the ground takes place in the **horizontal (transverse) plane.** This plane is oriented in the horizontal position and divides the body and its segments into upper and lower parts. Examples of movement occurring in the horizontal plane are rotating the hip or shoulder medially (inward) toward the body or laterally (outward) away from the body. Turning the forearm so that the palm is facing upward (supination) or downward (pronation) and rotating the trunk are movements that occur in the horizontal plane. Figure 1.6 illustrates examples of movement occurring in the horizontal plane.



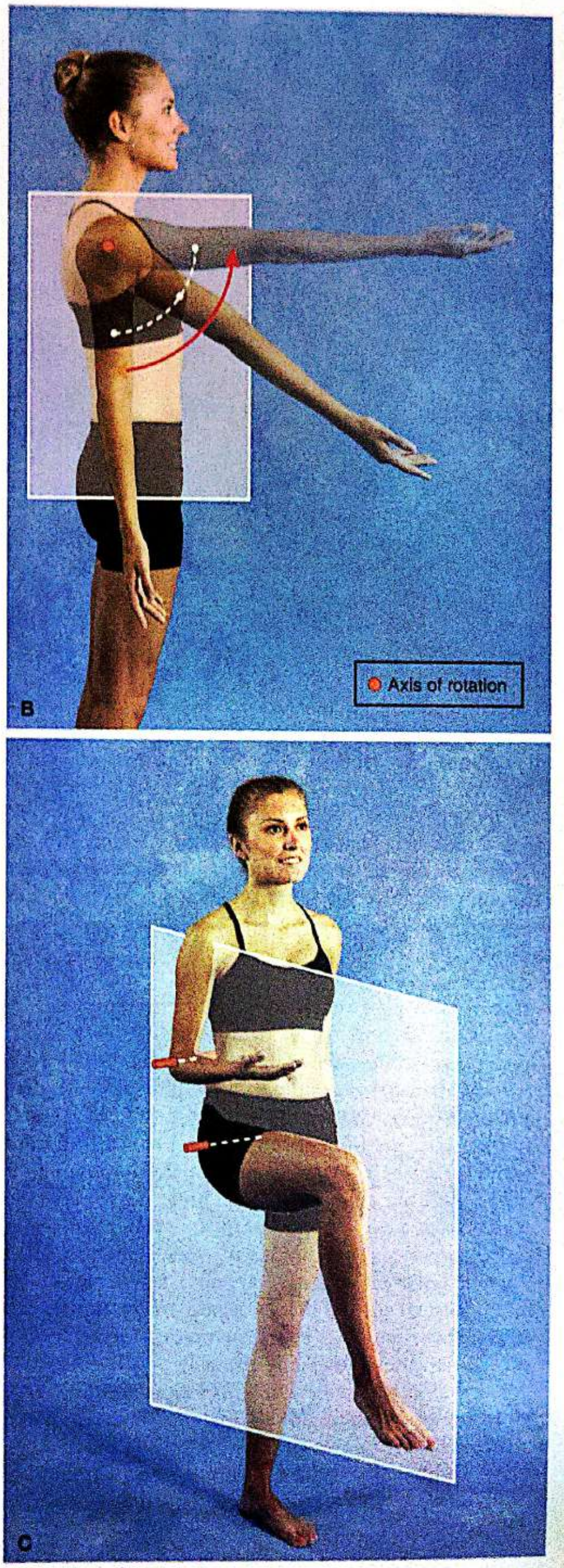


Figure 1.4 **(A)** In the sagittal plane, the body and body segments are divided into right and left sections. **(B)** During shoulder flexion and extension, the arm moves in the sagittal plane around an axis that is oriented in the frontal plane. **(C)** The elbow and hip are flexing in the sagittal plane around a frontal axis.

AXIS OF ROTATION

As a body part moves in one of the three-dimensional planes, it revolves around a pivot point, or an axis of rotation. This axis around which the movement occurs is always perpendicular to the plane of motion. A **sagittal axis** runs in an anterior-posterior orientation (in the sagittal plane), and movement occurs in the frontal plane. Abduction and adduction of the extremities as they move in a sideways direction away from and toward the body occur in the frontal plane around a sagittal axis. Figure 1.5 illustrates a sagittal axis during shoulder and hip abduction. Conversely, a **frontal axis** lies in the frontal plane, as depicted in Figure 1.4, and is oriented medial-lateral (side to side); with flexion and extension movements occurring around its axis. As the arm flexes forward in the sagittal plane, it is rotating around a frontal axis. Rotational movement of a body segment occurs in the horizontal plane around a **vertical (longitudinal) axis** (see Fig. 1.6). As the head rotates from side to side, it is moving around a vertical axis.

Although this discussion seems to describe an axis as a completely stationary point, in reality the axis moves slightly as the segment moves through the motion. The small shift in the location of the axis is due to the lack of complete symmetry resulting from changes in the curvature of the joint surfaces. Figure 1.7 depicts an example of this slight shift in a joint axis, called the **instantaneous axis of rotation.** As the knee moves during flexion and extension, the axis of rotation moves slightly because the distal end of the femur is not a geometrically perfect sphere.

OSTEOKINEMATIC MOVEMENT TERMINOLOGY

Universal terms describe osteokinematic movements as they occur in planes of motion around axes. Table 1.2 provides an overview of common osteokinematic movement terms, the planes and axes that represent the movement, and examples of functional movement related to the terms. (Descriptors specific to each region are presented in the individual chapters related to the joint.) **Flexion** describes the motion that occurs when the angle between two bones decreases, as when the forearm moves closer to the upper arm during elbow flexion. **Extension** movements increase the angle between the two bones that form the joint, as when the elbow straightens and the forearm moves away from the upper arm. In most cases, the muscles that cross the anterior aspect of joints flex the joints, while those located on the posterior aspect extend the joints. In the spine, movements that bring the head and trunk anterior to the vertical axis are flexion movements, whereas posterior movements are described as spinal extension. **Abduction** and **adduction** represent segments moving away from and toward the midline, respectively. Moving the leg away from the body in the frontal plane is abduction of the hip. Moving the leg from this position back toward the trunk is adduction. **Medial rotation** occurs when the anterior surface of a bone rotates toward the midline, and **lateral rotation** occurs when the surface rotates away from the midline. The shoulder and hip rotate in medial and lateral rotation. Muscles located on the lateral aspect of a joint typically abduct the joint and may assist with lateral rotation. Joint adduction and medial rotation are often accomplished by muscles located on the medial aspect of a joint. In the forearm, this rotation is called **pronation** (palm downward) and **supination** (palm upward); in the foot, it is called **eversion** and **inversion. Circumduction** is a term used to describe circular motion of a body segment moving through at least two different planes of movement. Figure 1.8 illustrates typical motions occurring during flexion, extension, abduction, adduction, and medial and lateral rotation.

The examples in Figure 1.8 illustrate the proximal bony segment remaining stationary while the distal segment moves toward or away from it. These same motions can occur as a **reversal of action** when the distal segment remains stationary and the proximal bony segment moves toward or away from the distal bone. In an example of a reversal of action at the elbow, the hand is placed on the arm of a chair holding the forearm relatively still while the upper arm moves away from the forearm as a person pushes with the arms into a standing position. Although the upper arm moves away from the forearm rather than the forearm moving away from the upper arm, the elbow moves into extension as the angle between the two bones increases. In another example of a reversal of action during a chin-up exercise, the hands are fixed on a bar and the upper arm moves toward the forearm as the elbow flexes and decreases the angle between the two bones.

DEGREES OF FREEDOM

Degrees of freedom refer to the number of planes of angular motion that can occur at a specific joint. For example, the shoulder and the hip can move in flexion and extension (sagittal plane), abduction and adduction (frontal plane), and medial and lateral rotation (horizontal plane). Because the joints have the capability for motion in three planes of movement, they are described as having three degrees of angular freedom. In contrast to these joints, the elbow moves only in flexion and extension, having one degree of angular freedom, as the joint moves in only one plane of motion. The metacarpophalangeal joints of the hand have two degrees of freedom, as flexion and extension and abduction and adduction motions can occur at these joints.

Clinical Connection 1.1

Loss of even one degree of freedom in a joint from either paralysis or loss of range of motion can result in dysfunction of the entire extremity. Consider an athlete who is attempting to throw a ball but is experiencing shoulder pain. The athlete may be able to hold the ball with the hand, flex the elbow during a windup, but because of pain with shoulder movement doesn't have the shoulder range of motion needed to throw the ball. Another example of this concept is a person who loses the ability to flex the shoulder but has the ability for the hand to hold a hairbrush and flex the elbow through full range. Due to the shoulder dysfunction, the person may be unable to lift the brush up toward the head to brush the hair.

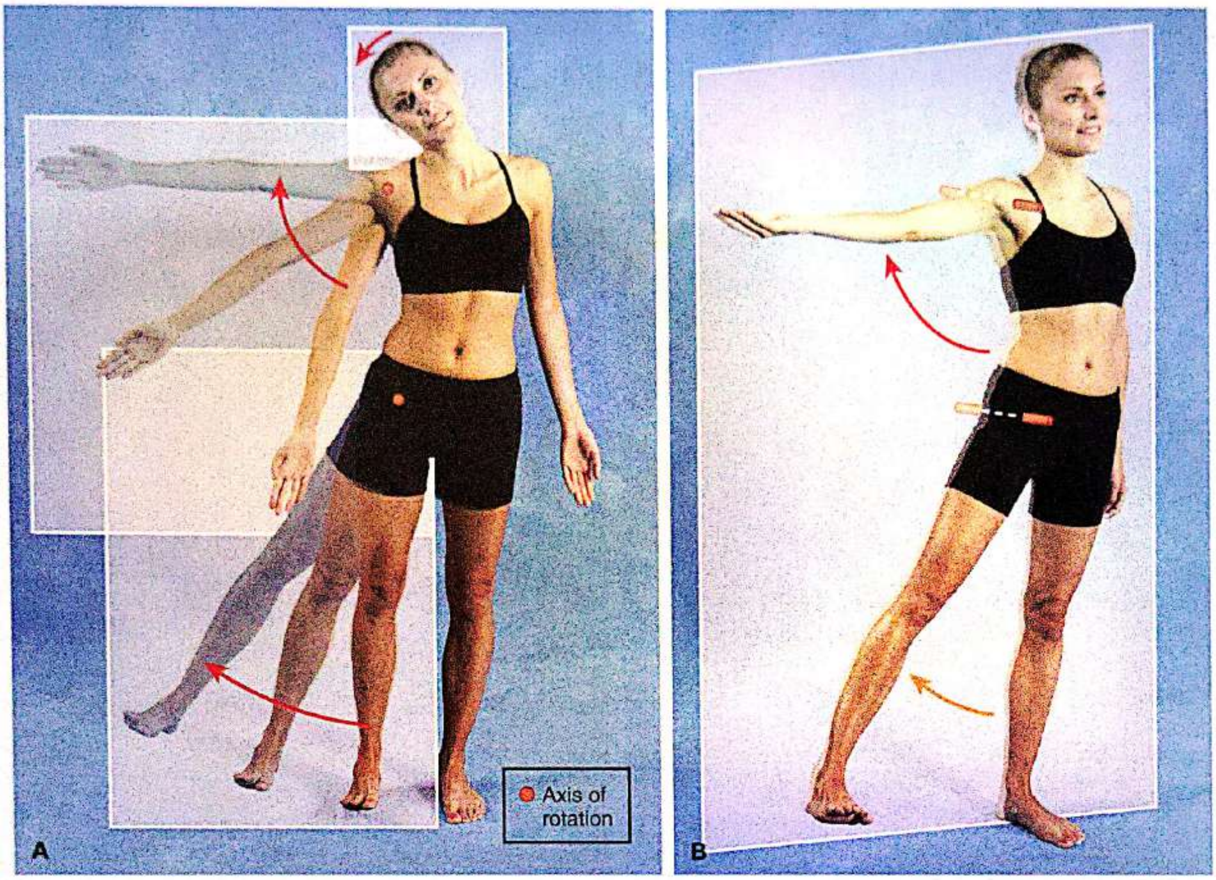


Figure 1.5 (A) The upper and lower extremities are moving in the frontal plane as they abduct away from the midline of the body. The cervical spine is side-bending to the right, also in the frontal plane. (B) The shoulder and hip are moving in the frontal plane around an axis that is oriented in the sagittal plane.

TABLE 1.2 Osteokinematic Movement Terms

Plane	Axis	Terms	Functional Movement Example
Sagittal plane	Frontal axis	Flexion, extension	The forearm brings the hand toward the mouth for eating during elbow flexion. As it returns to its original position, it is moving in extension.
Frontal plane	Sagittal axis	Abduction, adduction	Stepping into a car with one leg first is an example of hip abduction. The hip is moving the lower extremity away from the trunk.
Horizontal plane	Vertical axis	Medial rotation, lateral rotation	Pouring liquid out of a glass requires forearm pronation (medial rotation of the forearm).

KINEMATICS

Human movement is analyzed in terms of position, velocity, and acceleration. The previous sections described the planes and axes around which movement can occur. **Velocity** describes both the speed and direction of movement, while **acceleration** describes the rate at which velocity changes over time. Both these terms are discussed in greater detail in Chapter 2. Movement can occur as linear or angular (rotational) motion or as a combination of the two.

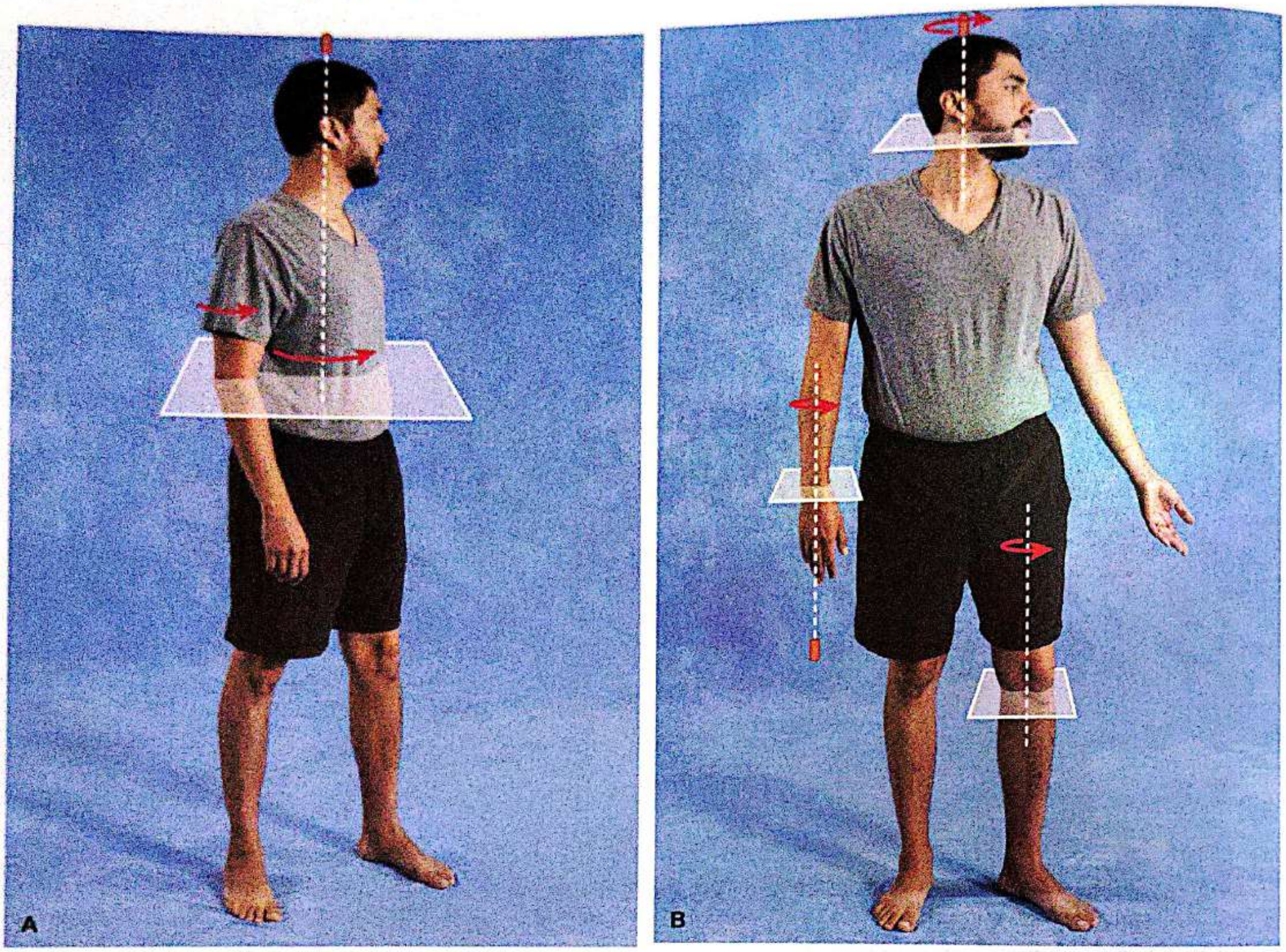


Figure 1.6 (A) The spine is rotating to the left, moving in the horizontal plane around a vertical axis. (B) The right arm is rotating medially in a horizontal plane around a vertical axis. The left leg is rotating laterally.

LINEAR MOTION

Linear motion, in which all parts of the object move in the same direction and parallel to each other, is also known as translation, or translatory motion. Linear motion can be described as movement in either a straight line or a curved line and is measured in units of meters (m) or feet (ft). When describing linear motion of the body as a whole unit, a clinician may document that a person walked 50 ft (15.24 m) on a level surface.

Straight Line Motion

Straight line **linear (rectilinear) motion** depicts point-to-point straight movement. Typically, the movement is in a two-dimensional or three-dimensional system in the planes established by the Cartesian coordinate system (Fig. 1.9). The system describes the position of any point in three-dimensional space. The movement occurs on the x, y, or z ordinance. Linear movement can take place in an anterior/posterior, medial/lateral, or vertical direction. An example of linear movement is the path of an object as it drops vertically from a height. In the body, limb and trunk movements do not typically occur in a purely linear fashion. Gliding linear motions occur between the surfaces of synovial joints as the limb moves in a rotation arc of movement. This passive linear motion is called **accessory movement (joint play)** and describes the amount slight joint motion that occurs between most joint surfaces. This gliding motion of surfaces rarely occurs without some degree of rotation accompanying the gliding. Figure 1.10 illustrates the linear gliding motion between the carpal bones in the wrist. (This gliding motion is addressed in greater detail in the arthrokinematics discussion in Chapter 3 and for each joint specifically in the individual chapters related to specific joints.)

Curved Line Motion

Curved line (curvilinear) motion is movement from one point to another in an arched path. This movement combines translation and rotation of a segment. The

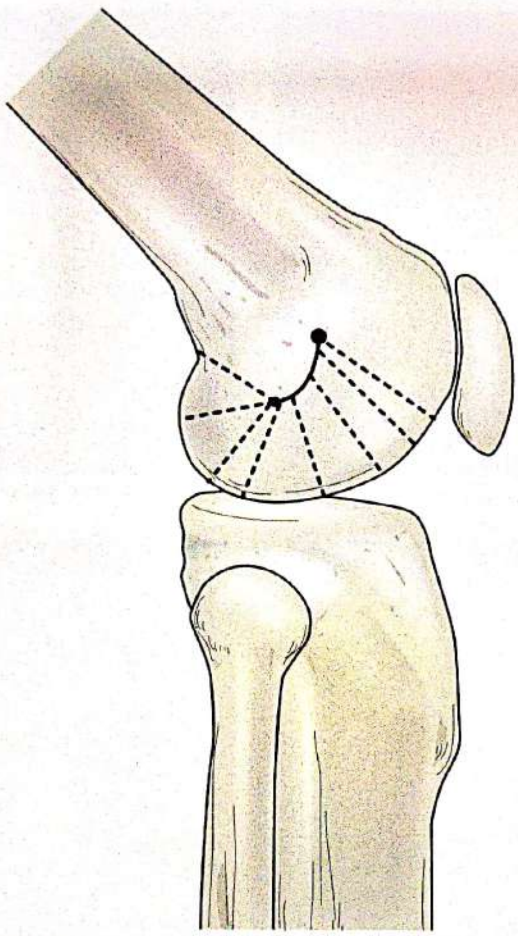


Figure 1.7 A sagittal view of the femur, tibia, and fibula. The axis of motion moves slightly as the knee moves during flexion and extension.

axis around which the movement occurs is not fixed but rather shifts in space. An example of curvilinear motion is the vertical displacement of the center of the body as it moves upward and downward during walking. Curvilinear motion of the center of mass of the body and linear motion of the entire body that occur during walking are shown in Figure 1.11.

ROTARY MOTION

Rotation or **rotary motion** (also called angular motion) describes the arc of motion of a body around an axis. Joints in which the body part moves in a circular path around a pivot point represent this axis of rotation. An example of body segment rotation occurs when the arm rotates medially around a vertical axis during shoulder medial rotation. Rotary motion also occurs in the frontal plane as the arm or leg moves in abduction and adduction in the frontal plane around a sagittal axis. During rotary motion, each point on the limb moves in the same direction, time, and angle but through different distances. The movement is measured using the polar coordinate system, which documents the angle in one dimension between two fixed points and is measured in degrees. In Figure 1.12, the lower leg is rotating around the knee joint axis from 0° to 90° of motion.

GENERAL MOTION

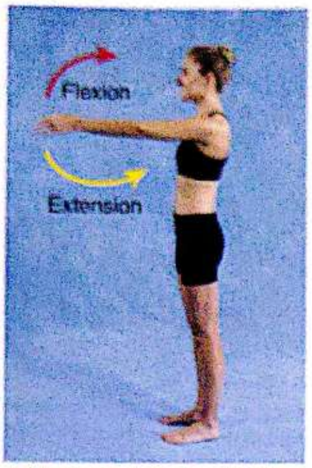
Most of the motion that occurs between joint surfaces and during limb and trunk movement represents a combination of translation and rotation and is known as **general motion.** When a person is running on a flat surface, the body is moving in a straight linear motion, while the lower extremities are rotating at the hip, knee, and the ankle axes to propel the body forward. Lifting an object overhead is an example of linear motion of the object as it moves upward and rotation motion of the upper extremity joints as they rotate around their axes to perform the lift. Whether the movement of body segments or the body as a whole is translatory or rotational, it is classified as either **active** or **passive movement.** Active movements occur when muscles contract and provide the force to move a body segment, such as when hip flexor muscles lift a leg to step up onto a step or when the hand brings food to the mouth. These movements are results of the internal forces produced by muscles and an intact neurological system. Forces besides those produced by muscles produce passive movement, such as a push or pull produced by another person on the body or by the pull of gravity on the mass of an object. A clinician holding a client's leg and moving the leg into flexion is an example of the leg passively being moved.

KINEMATIC CHAINS OF MOTION

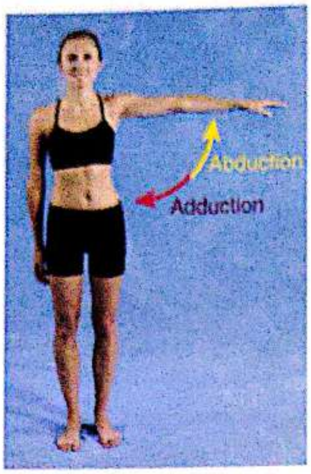
As the body moves throughout daily life, it accomplishes movements and tasks as the various joints work together, forming chains of movement in an extremity. When a person reaches for an object on a high shelf, the trunk must provide a stable static base on which the scapula can upwardly rotate, the shoulder flex, and the elbow and wrist extend so that the fingers and thumb can grasp the object. Each of the joints performs as a link in the chain in the total motion of the extremity. As a person rises to standing from sitting in a chair, the feet provide a stable base, as the knees, hips, and trunk move into extension, each contributing to the achievement of an erect standing position.

Open Kinematic Chain Movement

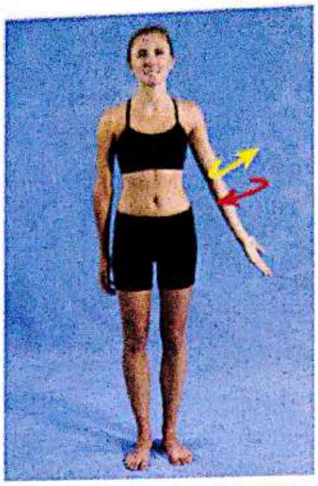
During kinematic chains of motion, the body moves in either **open kinematic chains (OKC)** or **closed kinematic chains (CKC).** Open chain movement occurs when the proximal portion of the limb segment or chain is fixed and not moving, while the distal portion of the limb is moving. Typically, these motions occur in



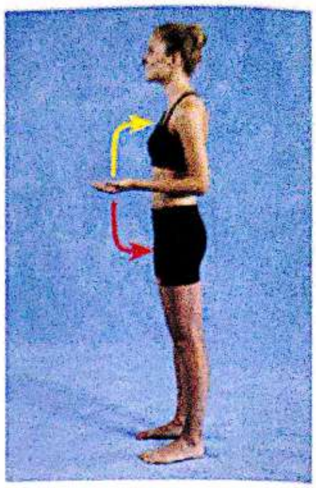
Shoulder flexion and extension



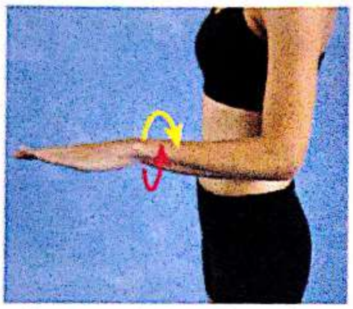
Shoulder abduction and adduction



Shoulder lateral and medial rotation



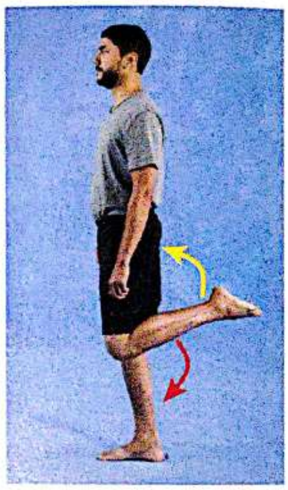
Elbow flexion and extension



Forearm supination and pronation

Hip flexion and extension

Hip abduction and adduction



Knee flexion and extension

Ankle inversion and eversion

Trunk flexion and extension

Trunk and neck sidebending

Trunk and neck rotation

Figure 1.8 Types of joint motion.

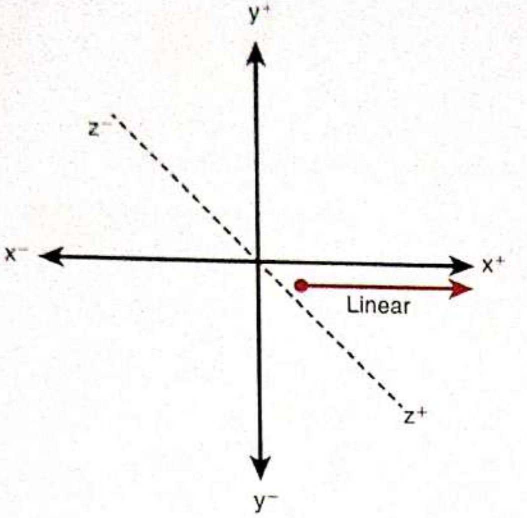


Figure 1.9 Linear movement occurs in a straight line along a coordinate of the Cartesian coordinate system.

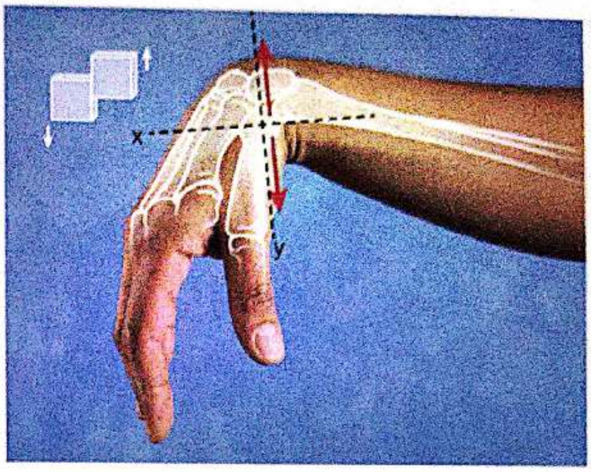


Figure 1.10 A sagittal view of the wrist in flexion. Linear movement (arrows) occurs between carpal bones during wrist movement.

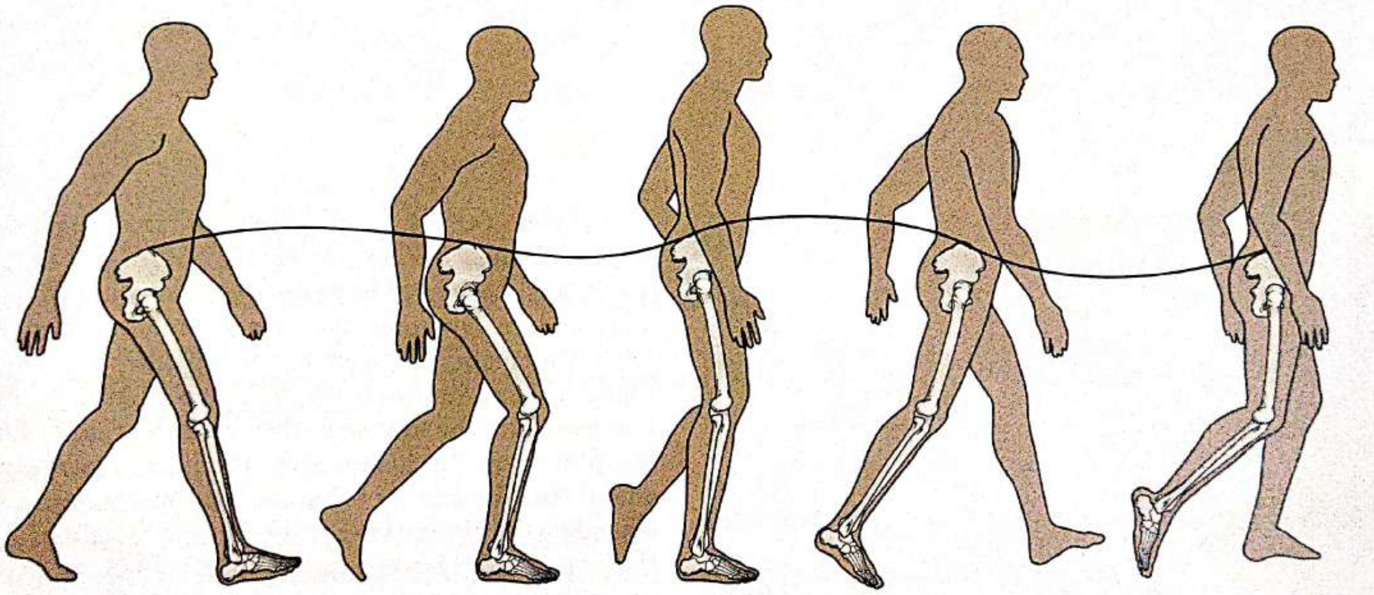


Figure 1.11 During the gait cycle, the entire body moves in a linear motion, whereas the center of gravity (COG) of the body moves in a curvilinear motion. The highest point of the curve occurs during midstance of the limb; the lowest point occurs during heel strike.

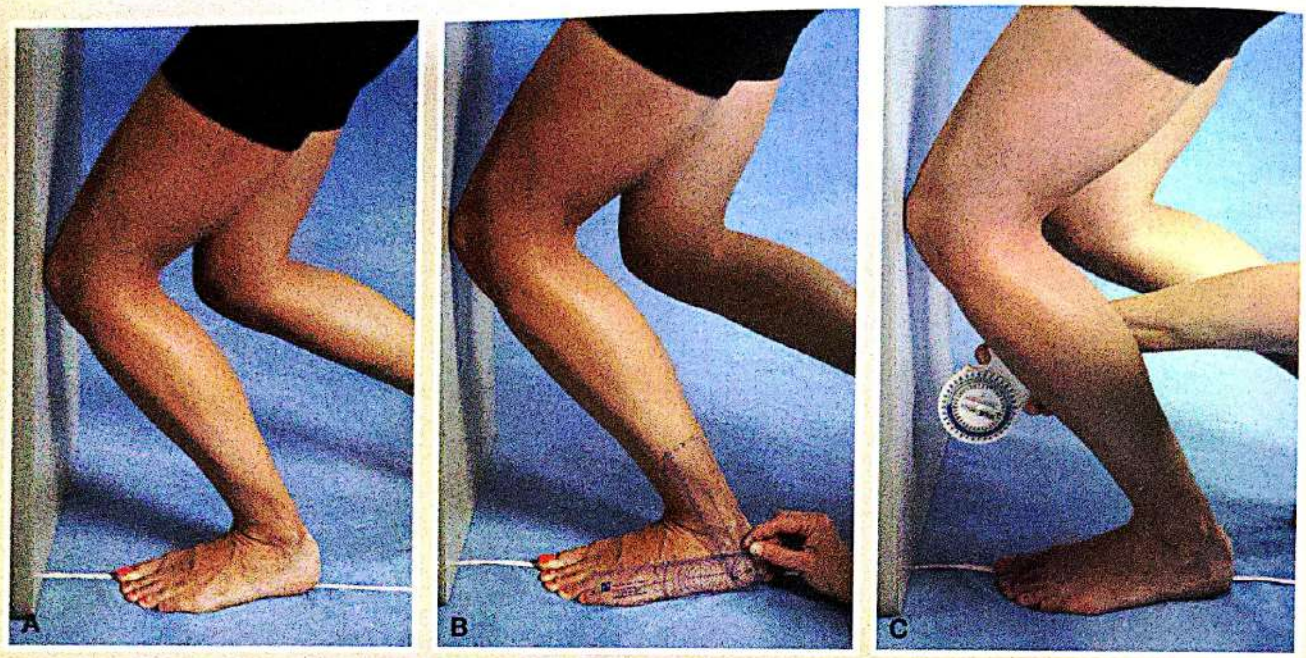
non-weight-bearing positions. In the example of lifting the arm up to a high shelf, the limb is performing an OKC motion. Lifting a dumbbell during a biceps curl is exercising the biceps in an open chain activity. Although the hand is holding the weight in a relatively fixed grasp, the distal segment of the arm chain is moving toward a fixed proximal shoulder joint. The motion at the distal joints is independent of the motions at proximal joints; they can either move in a variety of directions or remain in static positions. The fingers can flex and grasp the dumbbell during the biceps curl or extend and release the weight; the finger movement is independent of the elbow and shoulder movement.

Closed Kinematic Chain Movement

CKC movement occurs when the distal segment of the movement part is fixed and the proximal segments move in relationship to the distal segment. These movements usually occur in weight-bearing positions. Moving from

Clinical Connection 1.2

In the clinical setting, angular or rotary motion is measured with a goniometer or an inclinometer. In the figure, ankle dorsiflexion is being measured with a tape measure (A), a goniometer (B), and an inclinometer (C).



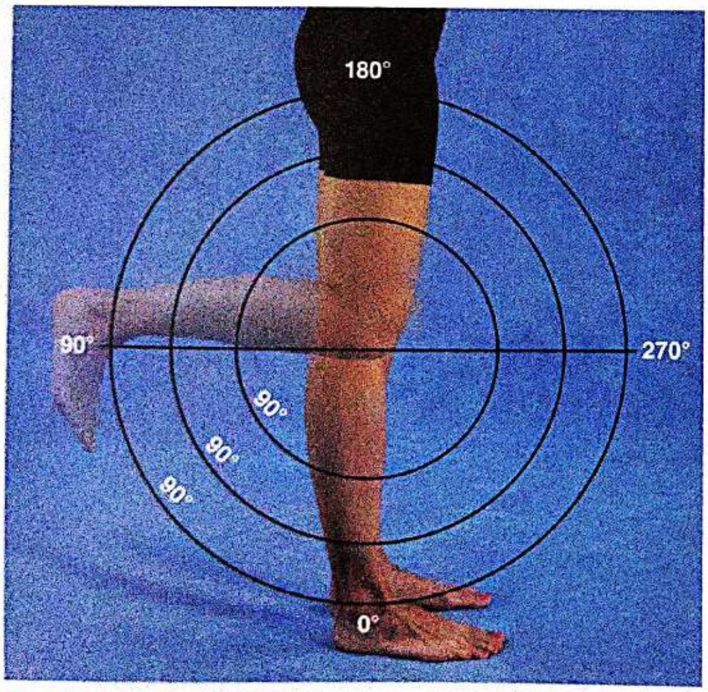


Figure 1.12 The knee is moving from a position of 0° of extension to 90° of flexion. Each point of the lower limb is moving in the same direction, at the same time, and through the same degrees of motion.

a sitting to a standing position is an example of a closed chain activity. The feet are fixed on a surface, while the more proximal knees, hips, and trunk move into extension to achieve the standing position. Placing the hands on the arm of a chair and pushing the elbows into extension is another example of a closed kinetic chain activity. The distal hands are fixed on the chair, while the proximal elbow and shoulder move into extension. Most human activities are a combination of open and closed chain movement. Open chain movement occurs as a person lifts a leg from one step up to the next step when ascending stairs. Once the foot is on the higher step, the person performs a closed chain activity of fixing the foot on the step, while extending the hip and knee to lift the body weight up onto the step (Fig. 1.13). Although the terms OKC and CKC are widely used in the clinic and in the literature, there are some inconsistencies with the terminology. The terms distally fixed to represent CKC and nondistally fixed or joint isolation exercises to describe OKC movements have been suggested as terms that do not consider the factor of weight-bearing during the movement.

FORCES

Understanding the concepts related to external forces and how these forces act on the body and internal forces generated by the body are essential to the study of kinesiology and human movement. **Force**, in simple terms, is defined as a push or a pull of one object with respect to another object. Forces have a point and line of application, magnitude, and direction. An example of an external force is

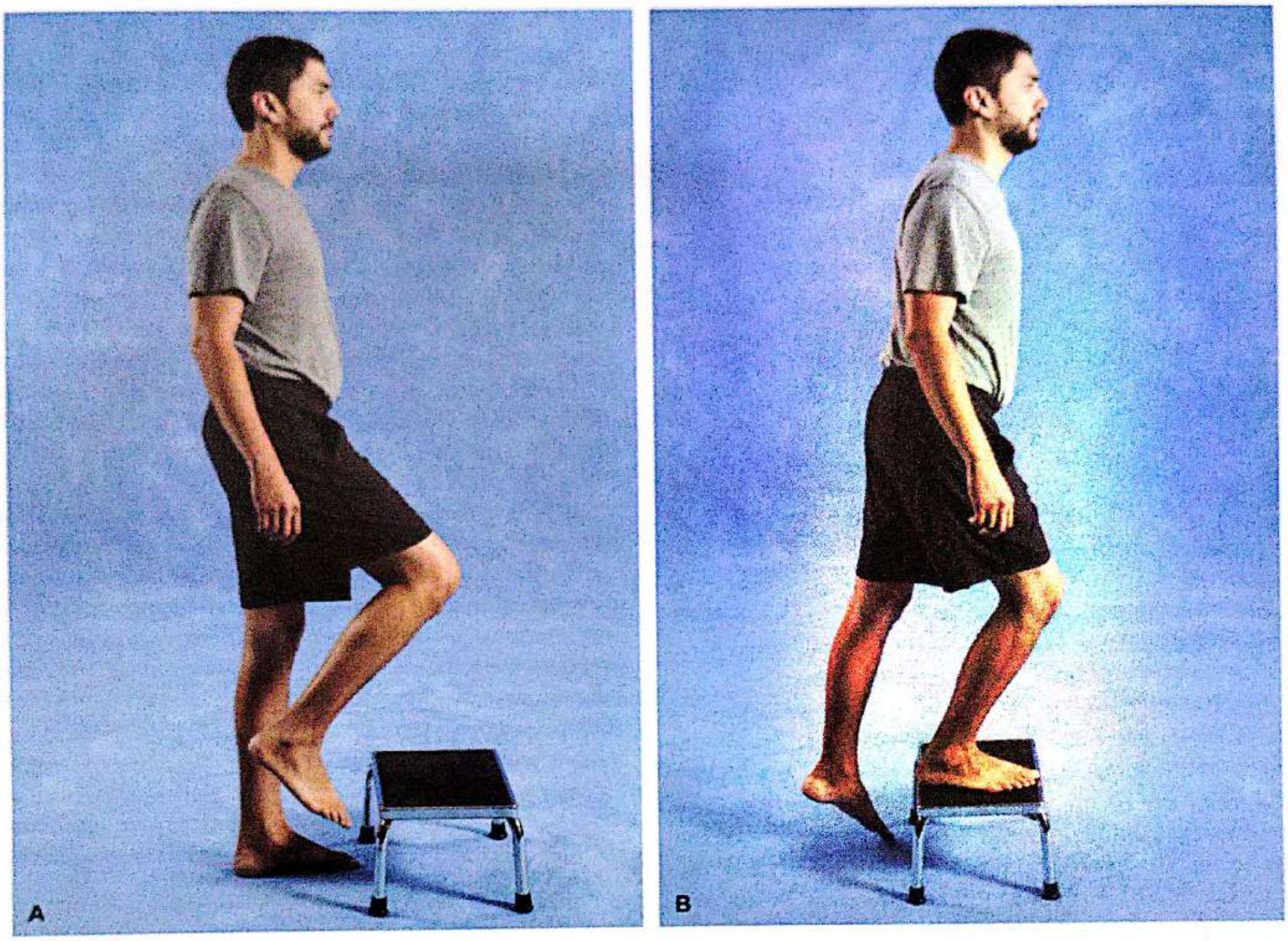


Figure 1.13 Open and closed chain movement. (A) Open chain movement of the hip, knee, and ankle on a stable fixed trunk and pelvis as the leg is lifted up toward the step. (B) Closed chain movement of the hip and knee extending on a fixed foot to lift the body weight up onto the higher step.

the movement produced by a moving bus that disturbs the balance of a person standing while riding in the bus. In response to this external force, the body can produce internal forces to produce movement, change direction of the movement, or stop movement, as when a muscle contracts to stabilize the person standing while riding in a moving bus. When the total sum of forces acting on an object results in movement and changes the position of the object, **displacement** of the object occurs. If these forces do not result in movement and the object remains in a static position, **stabilization** occurs. Internal forces that produce movement or stabilization provide the means for accomplishing functional tasks throughout everyday life. However, forces applied to the body that are excessive, even for a short duration, or submaximal, occurring repetitively over a period of time, have the potential to injure the body. The lack of typical forces related to prolonged bedrest or immobilization can weaken body systems, causing degeneration and disability. Forces can also be used therapeutically to promote healing and increase function of the human body. Appropriate forces applied during therapeutic movement of a joint or when stretching a muscle can increase joint mobility and improve function.

INTERNAL FORCES

Internal forces considered in biomechanics include active contractile and passive noncontractile forces generated from structures within the body. Muscle contractions generate internal contractile forces that cause muscles to work as stabilizers preventing movement or as movers responsible for producing motion as the body moves during daily activities. Noncontractile forces consist of the passive tension produced from connective tissues: ligaments, joint capsules, intramuscular connective tissue, and bones. The passive forces provide static stability for joints and can augment forces generated during movement. Connective tissue structures surrounding myofibrils in a muscle play a role in generating passive forces during eccentric active muscle contractions. When the arm controls the lowering

Clinical Connection 1.3

Lateral elbow tendinopathy is a common injury seen in recreational golfers, tennis players, and those with occupations that require powerful/repetitive wrist and hand movements. Lateral elbow pain, pain with gripping, and upper extremity dysfunction can result from this condition. Wrist extensor muscles produce internal forces over and over in a repetitive pattern that contributes to the chronic overuse injury. Wrist, grip, and proximal muscle weakness of the core, shoulder girdle, and proximal joints can also contribute to the condition. External forces stemming from inadequate equipment (e.g., an inappropriately sized equipment grip), inadequate playing surfaces, poor technique, and poor ergonomic environments can play additional roles in the resultant tissue injury. Although excessive or inappropriate forces produce this dysfunction, correct forces applied during rehabilitation can increase mobility, strength, endurance, power, motor control, and body function.

of a weight against gravitational forces, both the active force of the muscle fibers and the passive forces of the connective tissue counter the weight being held by the arm. The concepts related to forces produced by internal structures are discussed in greater detail in later chapters.

EXTERNAL FORCES

Forces produced outside of the body are considered external forces and must be overcome by internal forces if movement is to occur. These forces include externally applied forces, friction, and gravity. Gravity is a constant force that acts on all objects as an external force playing a major role in human movement and balance. Other forces in nature include wind, water, terrain—virtually anything that comes in contact with a body segment. External forces to the human body can also be applied by manual resistance or through the use of exercise equipment. These forces can be encountered as one lifts objects or opens doors. External forces can move, stabilize, or, if applied in excess, injure the body. Friction is an external force that produces resistance to movement between objects in contact with each other. Increased friction can improve stability, as seen when irregular tread is put on a shoe. It can also result in damage, as when the rubbing between a shoe and the skin causes skin damage and produces a blister.

TYPES OF FORCES

Forces, often referred to as loads, acting on the body can produce movement or stabilize the body against other forces. These loads also have the ability to injure or damage body structures. Figure 1.14 illustrates the various types of forces that are encountered by body structures. Internal muscle contractions and externally applied forces can produce **tension** or **tensile (distraction) forces** to joints and their structures when forces pull on the same object in opposite directions, producing a strain on the object. Ligament and tendon tissues produce internal resistance to tension forces that stretch them during movement and activity. The tension forces act in opposite directions to pull materials apart. However, structures debilitated by disease or immobilization may be incapable of resisting tension forces that elongate and overstretch tissues, and injury can result. The skeletal system undergoes continuous **compressive forces** during weight-bearing activities of the extremities and spine. These forces act in directions toward each other, compressing structures. Compression forces from muscle contractions can also produce forces directed toward the joint tissue and surfaces. These forces approximate the joint surfaces, causing compression stresses. Axial compression describes compression forces along the long axis of a structure such as the spine. Skeletal systems that

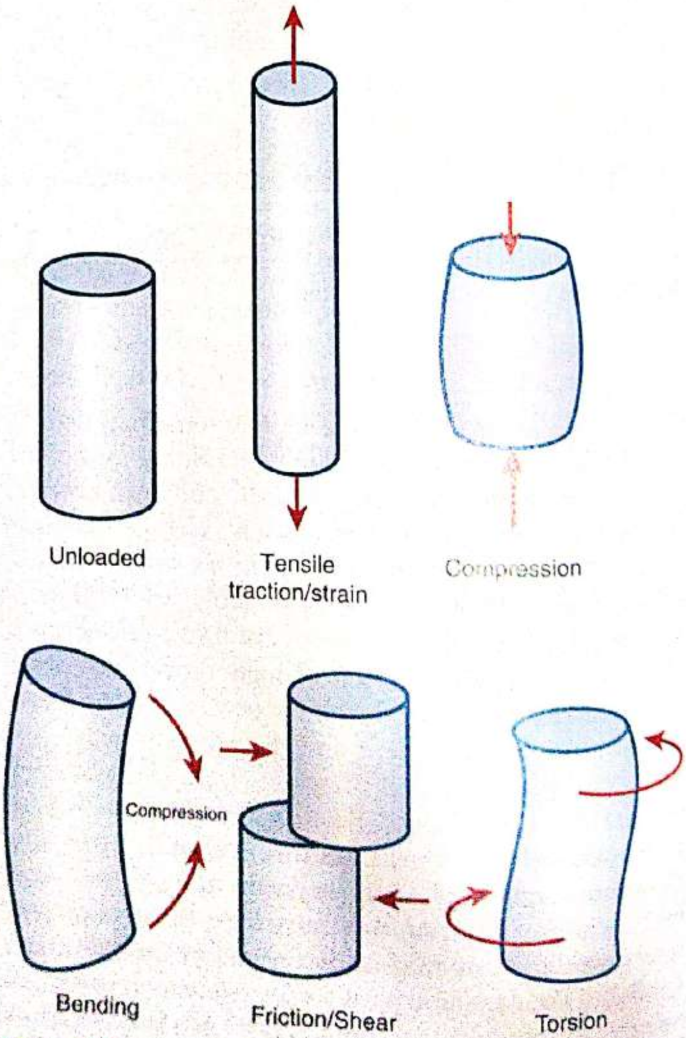


Figure 1.14 Types of forces and loads encountered by body structures.