CHAPTER 1

Basic Principles of Kinesiology

Chapter Outline

Kinematics

Terminology
Osteokinematics
Planes of Motion
Anatomic Position
Axis of Rotation
Degrees of Freedom
Fundamental Movements
Osteokinematics: It's All Relative
Arthrokinematics
Fundamental Movements Between Joint Surfaces
Functional Considerations

Kinetics

Torque
Biomechanical Levers
Three Classes of Levers
Biomechanical Levers: Designed for Force, or Speed and Range of Motion?
Line of Pull
Line of Pull About a Medial-Lateral Axis of Rotation
Line of Pull about an Anterior-Posterior Axis of Rotation
Line of Pull About a Vertical Axis of Rotation
Vectors

Summary

Objectives

- Define commonly used anatomic and kinesiologic terminology.
- Describe the common movements of the body.
- Differentiate between osteokinematic and arthrokinematic movement.
- Describe the arthrokinematic principles of movement.
- Analyze the planes of motion and axes of rotation for common motions.
- Describe how force, torque, and levers affect biomechanical movement.
- Describe the three biomechanical lever systems, and explain their advantages and disadvantages.
- Analyze how muscular lines of pull produce specific biomechanical motions.
- Explain how muscular force vectors are used to describe movement.

Key Terms

abduction
active movements
adduction
anatomic position
anterior
arthrokinematics
axis of rotation
caudal
center of mass
cephalad
circumduction
closed-chain motion
congruency
deep
degrees of freedom
distal
dorsiflexion
eversion
extension
external force
external moment arm
external rotation
external torque
flexion
force
frontal plane
horizontal abduction
horizontal adduction
horizontal (transverse) plane
inferior
insertion
internal force
internal moment arm
internal rotation
internal torque
inversion
kinematics
kinesiology
kinetics
lateral
leverage
line of pull
medial
midline
open-chain motion
origin
osteokinematics
passive movements
plantar flexion
posterior
pronation
prone
protraction
proximal
radial deviation
resultant force
retraction
rotation
sagittal plane
superficial
superior
supination
supine
torque
translation
ulnar deviation
vector

The word **kinesiology** has its origin in the Greek words *kinesis,* "to move," and *ology,* "to study." *Essentials of Kinesiology* serves as a guide to kinesiology by focusing on the anatomic and biomechanical interactions within the musculoskeletal system.

The primary intent of this book is to provide physical therapist assistant students and clinicians with a fundamental understanding of the kinesiology of the musculoskeletal system. A detailed review of the musculoskeletal system, including innervation, is presented as a background to the structural and functional concepts of normal and abnormal movement. The discussions within this text are intended to provide insight and provoke thoughtful dialogue about commonly used therapeutic models and treatments.

Kinematics

Kinematics is a branch of biomechanics that describes the motion of a body without regard to the **forces** that produce the motion. In biomechanics, the word *body* is used rather loosely to describe the entire body, particular segments such as an individual bone, or an area of the body such as the arm. In general, two types of motion exist: translation and rotation.

Translation occurs when all parts of a "body" move in the same direction as every other part. This can occur in a straight line (rectilinear motion), for example, sliding a book across a table, or in a curved line (curvilinear motion), such as the arc of a ball being tossed to a friend. Fig. 1.1 illustrates the curvilinear motion that occurs during walking, reflecting the normal up-and-down translation of the head as the entire body moves forward.

Rotation describes the arc of movement of a "body" about an axis of rotation. The axis of rotation is the "pivot point" about which the rotation of the body occurs. Fig. 1.2 illustrates rotation of the forearm around the axis of rotation of the elbow.

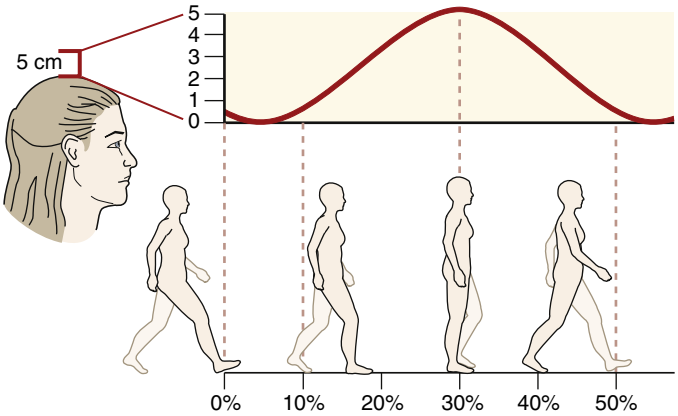

Fig. 1.1 A point on the top of the head is shown translating upward and downward in a curvilinear fashion while walking. (From Neumann DA: Kinesiology of the musculoskeletal system: foundations for physical rehabilitation, ed 2, St Louis, 2010, Mosby, Fig. 1.2.)

Movement of the entire human body is generally described as a translation of the body's center of mass, or center of gravity (Fig. 1.3). An activity such as walking results from forward translation of the body's **center of mass,** thus the entire body. It is interesting to note, however, that movement

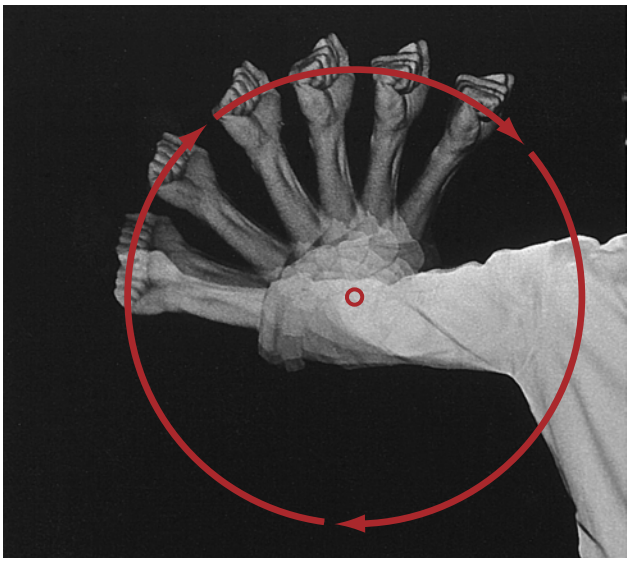

Fig. 1.2 Rotation of the forearm around the axis of rotation of the elbow. (From Neumann DA: Kinesiology of the musculoskeletal system: foundations for physical rehabilitation, ed 2, St Louis, 2010, Mosby, Fig. 1.3.)

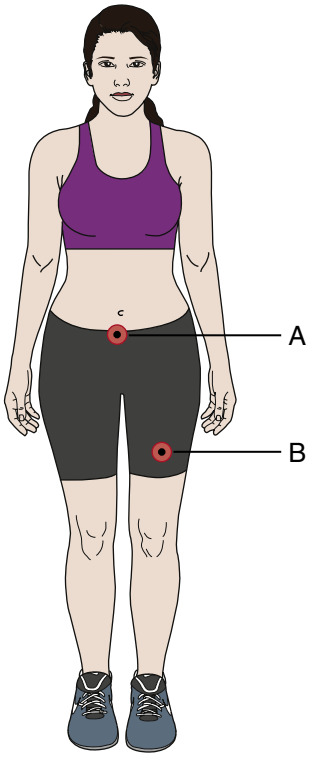

Fig. 1.3 *A,* Center of mass of the entire body. *B,* Center of mass of the thigh. (From Neumann DA: Kinesiology of the musculoskeletal system: foundations for physical rehabilitation, St Louis, 2002, Mosby, Fig. 4.1.)

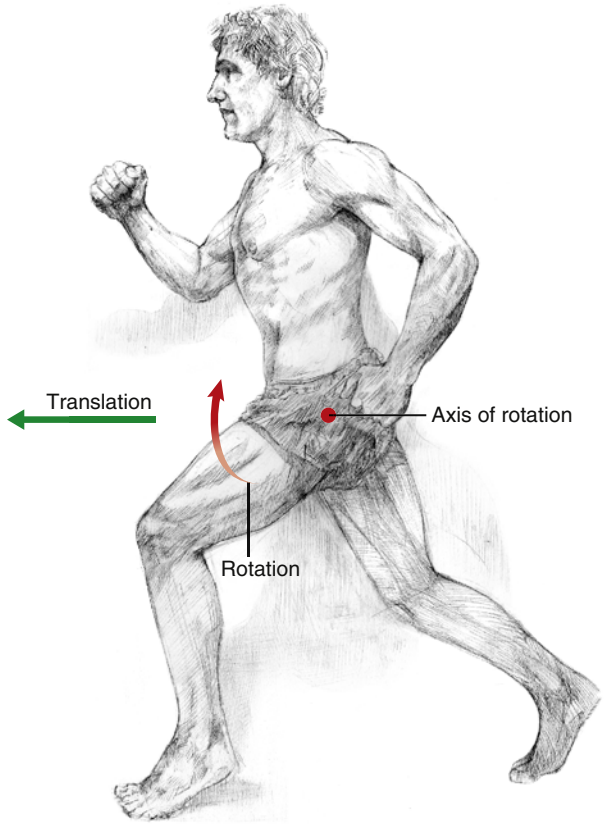

Fig. 1.4 Forward translation of the body resulting from rotation of the lower extremities.

or translation of the entire body is powered by muscles that rotate the limbs. This concept is illustrated in Fig. 1.4, which shows an individual running (anterior translation of the center of mass) as a result of muscles rotating the legs around the axis of rotation of each hip. It is important to note that the functional movement of nearly all joints in the body occurs through rotation.

Regardless of the type of body movement, a movement can be classified as either active or passive. **Active movements** are generated by stimulated or "active" muscle; for example, when an individual raises his or her arm overhead, this is considered an active movement. **Passive movements,** on the other hand, are generated by sources other than muscular activation, such as gravity, the resistance of a stretched ligament, or a push from another person. For example, when a clinician provides the force to move an individual's limb through various ranges of motion, this is considered a passive movement—thus the common clinical term *passive range of motion.*

Terminology

The study of kinesiology requires the use of specific terminology to describe movement, position, and location of anatomic features. Many of these terms are illustrated in Fig. 1.5.

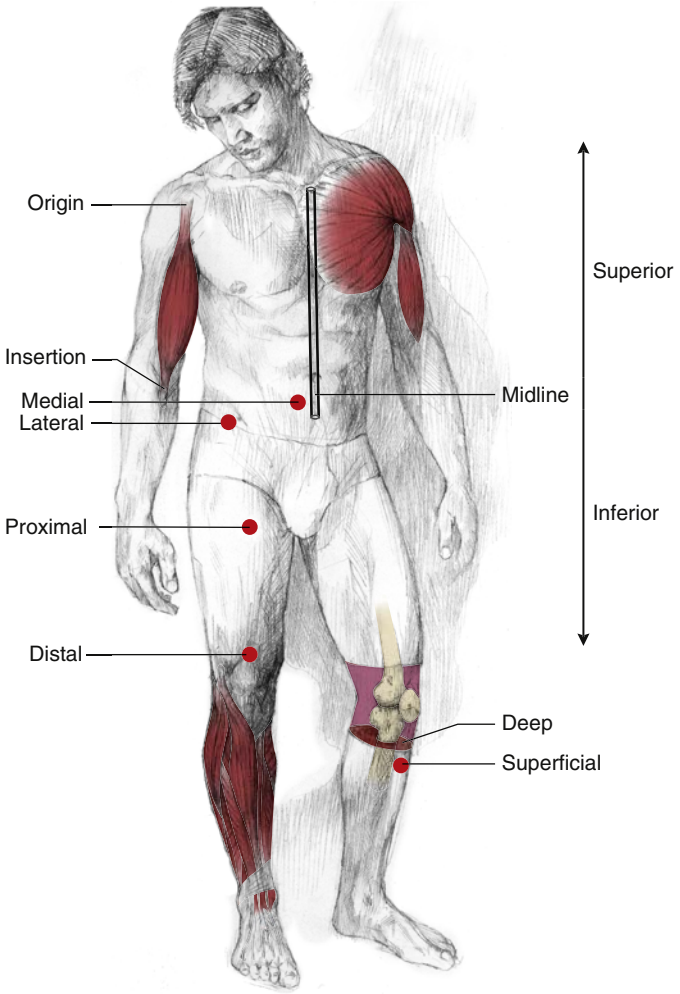

Fig. 1.5 Anatomic terminology.

- **Anterior:** Toward the front of the body
- **Posterior:** Toward the back of the body
- **Midline:** An imaginary line that courses vertically through the center of the body
- **Medial:** Toward the midline of the body
- **Lateral:** Away from the midline of the body
- **Superior:** Above, or toward the head
- **Inferior:** Below, or toward the feet
- **Proximal:** Closer to, or toward the torso
- **Distal:** Away from the torso
- **Cephalad:** Toward the head
- **Caudal:** Toward the feet (or "tail")
- **Superficial:** Toward the surface (skin) of the body
- **Deep:** Toward the inside (core) of the body
- **Origin:** The proximal attachment of a muscle or ligament
- **Insertion:** The distal attachment of a muscle or ligament
- **Prone:** Describes the position of an individual lying face down
- **Supine:** Describes the position of an individual lying face up

Osteokinematics

Planes of Motion

Osteokinematics describes the motion of bones relative to the three cardinal planes of the body: sagittal, frontal, and horizontal (Fig. 1.6; Box 1.1).

- **Sagittal plane:** Divides the body into left and right halves. Typically, flexion and extension movements occur in the sagittal plane.
- **Frontal plane:** Divides the body into front and back sections. Nearly all abduction and adduction motions occur in the frontal plane.
- **Horizontal (transverse) plane:** Divides the body into upper and lower sections. Nearly all rotational movements such as internal and external rotation of the shoulder or hip and rotation of the trunk occur in the horizontal plane.

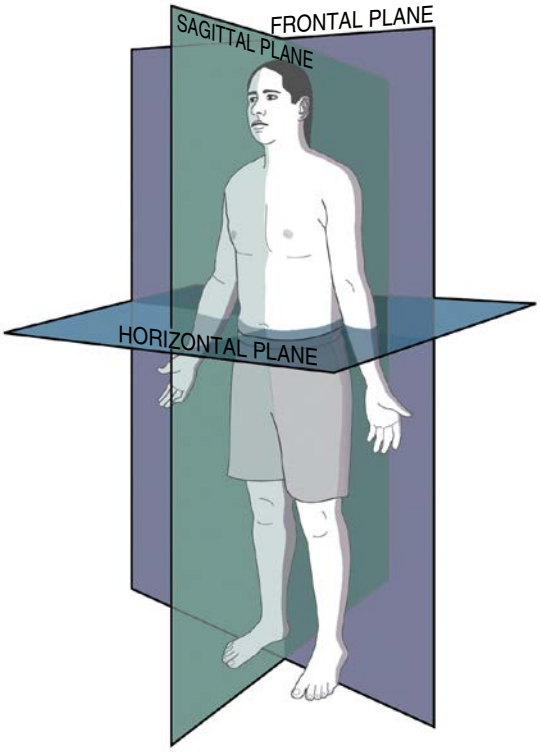

Fig. 1.6 The three cardinal planes of the body are shown on an individual in the anatomic position. (From Neumann DA: Kinesiology of the musculoskeletal system: foundations for physical rehabilitation, ed 2, St Louis, 2010, Mosby, Fig. 1.4.)

Box 1.1 Common Osteokinematic Terms

Sagittal Plane	Frontal Plane	Horizontal Plane
• Flexion and extension	• Abduction and adduction	• Internal (medial) and external (lateral) rotation
• Dorsiflexion and plantar flexion	• Lateral flexion	• Axial rotation
• Forward and backward bending	• Ulnar and radial deviation	
	• Eversion and inversion	

(From Neumann DA: Kinesiology of the musculoskeletal system: foundations for physical rehabilitation, St Louis, 2002, Mosby, Table 1.2.)
Many of the terms are specific to a particular region of the body. The thumb, for example, uses different terminology.

Anatomic Position

The **anatomic position,** illustrated in Fig. 1.6, serves as a standard reference for anatomic descriptions, axis of rotation, and planes of motion. For example, the action of a muscle is based on the assumption that it contracts with the body in the anatomic position.

Axis of Rotation

The **axis of rotation** of a joint may be considered the pivot point about which joint motion occurs. Consequently, the axis of rotation is always perpendicular to the plane of motion. Traditionally, movements of the body are described as occurring about three separate axes of rotation: anterior-posterior, medial-lateral, and vertical—sometimes referred to as the longitudinal axis (Fig. 1.7).

The anterior-posterior axis of rotation is oriented in an anterior-posterior direction through the convex member of the joint and allows movement to occur in the frontal plane, such as in abduction and adduction of the hip.

The medial-lateral axis of rotation is oriented in a medial-lateral direction through the convex member of the joint. The medial-lateral axis of rotation allows motion to occur in the sagittal plane, such as in flexion or extension of the elbow.

The vertical (longitudinal) axis of rotation is oriented vertically when in the anatomic position. However, if motion occurs out of the anatomic position, it is often described as occurring about the longitudinal axis; this axis courses through the shaft of the bone. Motion about the vertical or longitudinal axis of rotation occurs in the horizontal (or transverse) plane. Typically these are called *rotational movements* and are seen in rotation of the trunk when twisting side to side or in internal and external rotation of the shoulder. A summary of these axes can be found in Table 1.1.

Degrees of Freedom

Degrees of freedom refers to the number of planes of motion allowed at a joint. A joint can have 1, 2, or 3 degrees of angular freedom, corresponding to the three cardinal planes (see the earlier section on terminology). As depicted in Fig. 1.7, for example, the shoulder has 3 degrees of freedom, meaning the shoulder can move freely in all three planes. The wrist, on the other hand, allows motion in two planes, so it is considered to have 2 degrees of freedom. Joints such as the elbow (humeroulnar joint) allow motion in only one plane and therefore are considered to have just 1 degree of freedom.

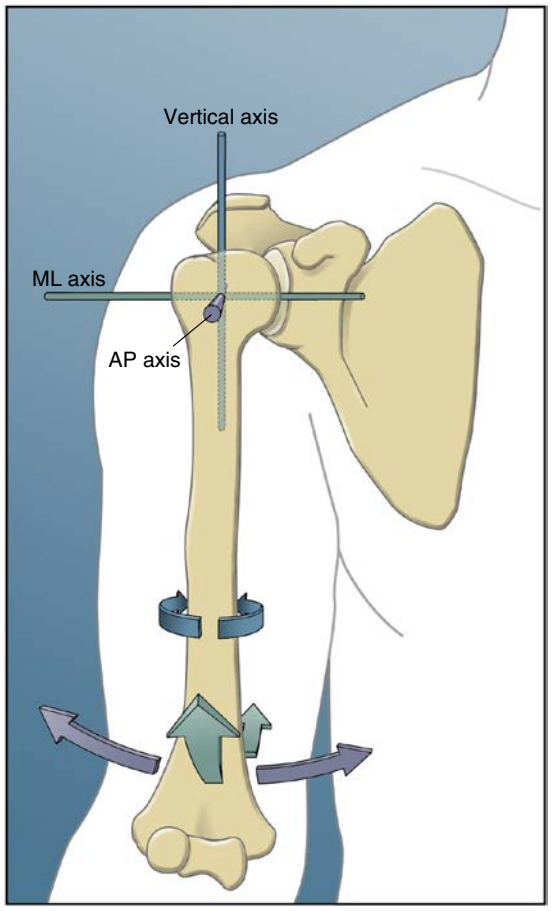

Fig. 1.7 The right glenohumeral (shoulder) joint highlights the axes of rotation and associated planes of motion: Flexion and extension *(green curved arrows)* occur about a medial-lateral *(ML)* axis of rotation; abduction and adduction *(purple curved arrows)* occur about an anterior-posterior *(AP)* axis of rotation; and internal rotation and external rotation *(blue curved arrows)* occur about a vertical axis of rotation. (Modified from Neumann DA: Kinesiology of the musculoskeletal system: foundations for physical rehabilitation, ed 2, St Louis, 2010, Mosby, Fig. 1.5.)

Table 1.1 Axes of Rotation and Associated Movements

Axis of Rotation	Plane of Motion	Examples of Movement
Anterior-posterior	Frontal	Hip abduction-adduction Shoulder abduction-adduction
Medial-lateral	Sagittal	Elbow flexion-extension Knee flexion-extension
Vertical or longitudinal	Horizontal	Shoulder internal-external rotation Rotation of the trunk

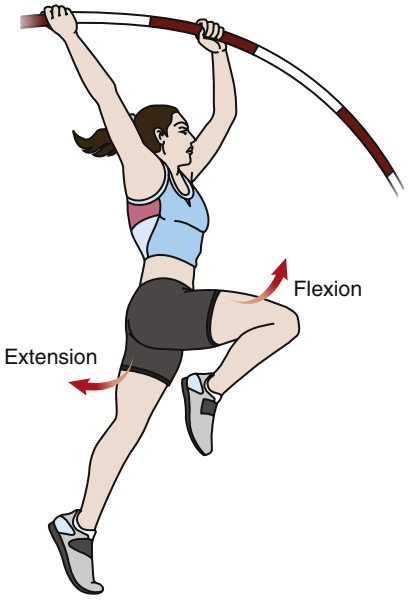

Fig. 1.8 Flexion and extension.

Fundamental Movements

For movements of the body, specific terminology is used to help describe the motion at a joint or region of the body.

Flexion and Extension

The motions of flexion and extension occur in the sagittal plane about a medial-lateral axis of rotation (Fig. 1.8). Generally, **flexion** describes the motion of one bone as it approaches the flexor surface of the other bone. **Extension** is considered a movement opposite that of flexion; it is an approximation of the extensor surfaces of two bones.

Abduction and Adduction

Abduction describes movement of a body segment in the frontal plane, away from the midline, whereas **adduction** describes a frontal plane movement toward the midline (Fig. 1.9).

Exceptions to this definition occur in the hands and feet; these are described in the joint-specific chapters.

Rotation

Rotation describes the movement of a bony segment (or segments) as it spins about its longitudinal axis of rotation. For example, turning the head and turning the trunk side to side are considered rotational movements (Fig. 1.10A). Motions of the extremities can be further classified into internal and external rotation.

Internal rotation describes the motion of a bony segment that results in the anterior surface of the bone rotating toward the midline. **External rotation** involves rotation of the anterior surface of a bone rotating away from the midline (Fig. 1.10B).

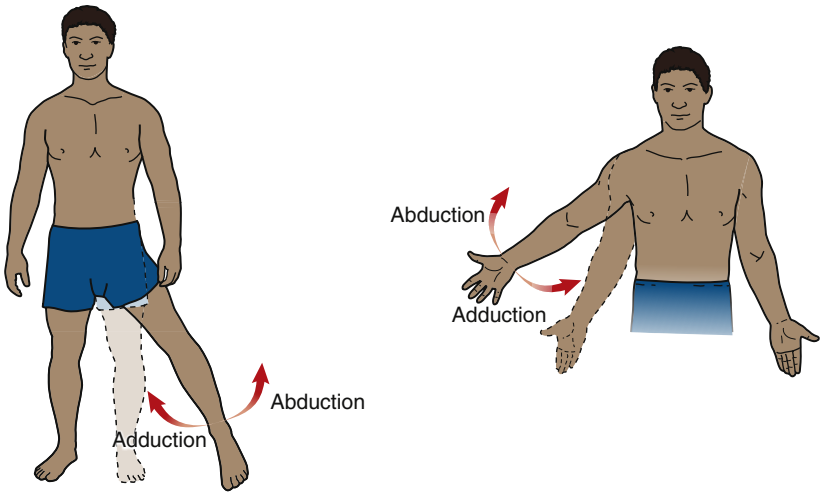

Fig. 1.9 Abduction and adduction.

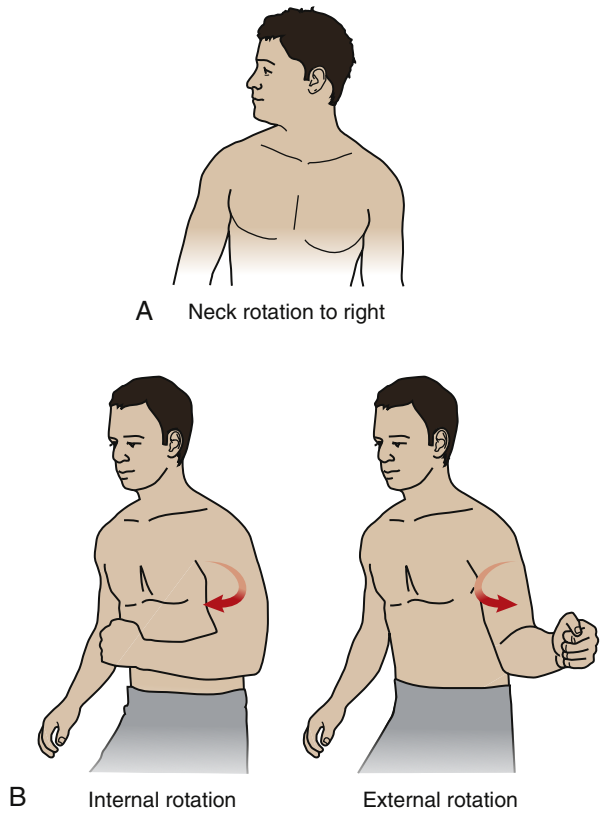

Fig. 1.10 (A) Rotation of the head and neck. (B) Internal and external rotation of the shoulder.

Circumduction

Circumduction describes a circular motion through two planes; therefore joints must have at least 2 degrees of freedom if they are to circumduct. A general rule is that if a joint allows a circle to be "drawn in the air," the joint can circumduct (Fig. 1.11).

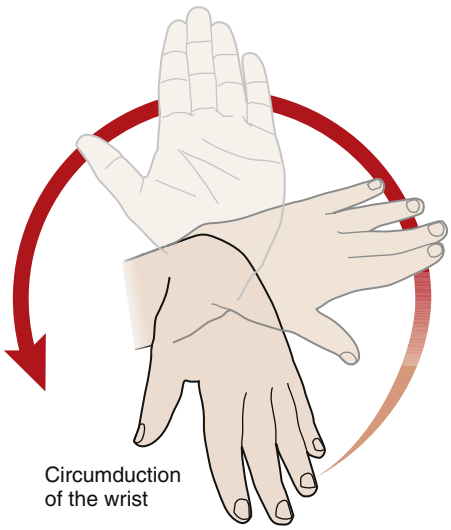

Fig. 1.11 Circumduction of the wrist.

Protraction and Retraction

Protraction describes the translation of a bone away from the midline in a plane parallel to the ground. **Retraction,** conversely, is movement of a bony segment toward the midline in a plane parallel to the ground. These terms are generally used to describe motions of the scapula or jaw (Fig. 1.12).

Horizontal Adduction and Abduction

These terms generally describe motions of the shoulder in the horizontal plane (Fig. 1.13). With the shoulder in an abducted position (near 90 degrees), movement of the upper extremities that results in the hands being brought together is considered **horizontal adduction.** Movement of the upper extremities away from the midline (in the horizontal plane) is considered **horizontal abduction.**

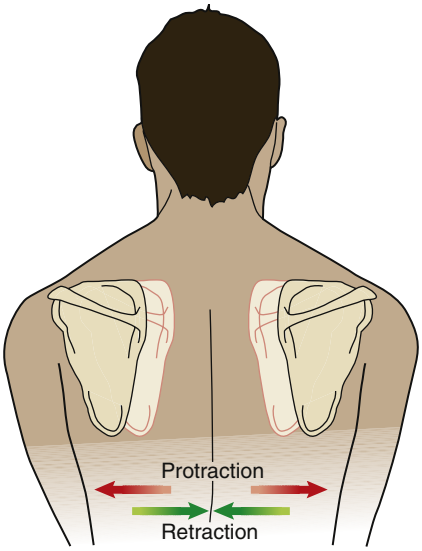

Fig. 1.12 Protraction and retraction of the scapula.

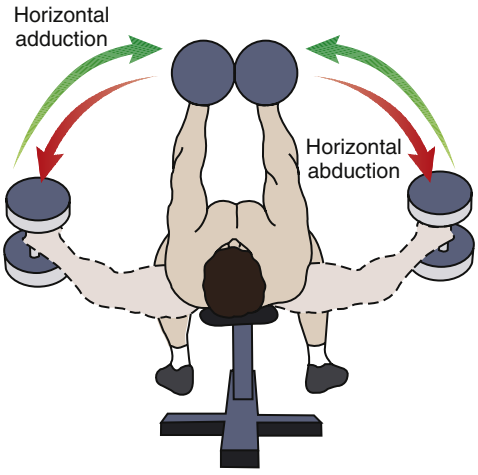

Fig. 1.13 Horizontal abduction and adduction of the shoulder.

Pronation and Supination

Pronation describes a rotational movement of the forearm that results in the palm facing posteriorly (when in the anatomic position). **Supination** describes the motion of turning the palm anteriorly (Fig. 1.14). Most often these motions occur with the hands in front of the body to accommodate grasping and holding types of activities, so supination is considered turning the palm of the hand upward, and pronation is considered turning the palm downward. Pronation and supination also describe complex motions of the ankle and foot and are described in detail in Chapter 11.

Radial and Ulnar Deviation

Radial and ulnar deviation describes frontal plane motions of the wrist (Fig. 1.15). **Radial deviation** results in the hand moving laterally—toward the radius. **Ulnar deviation** results in the hand moving medially—toward the ulna.

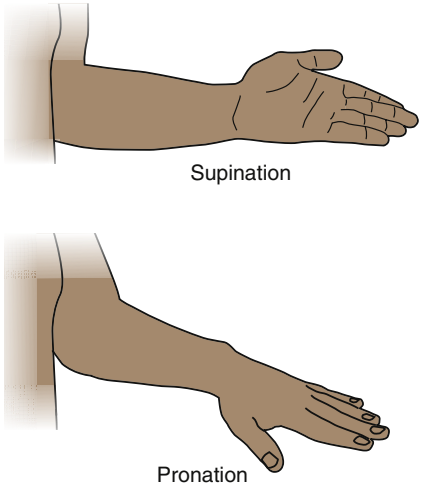

Fig. 1.14 Supination and pronation of the forearm.

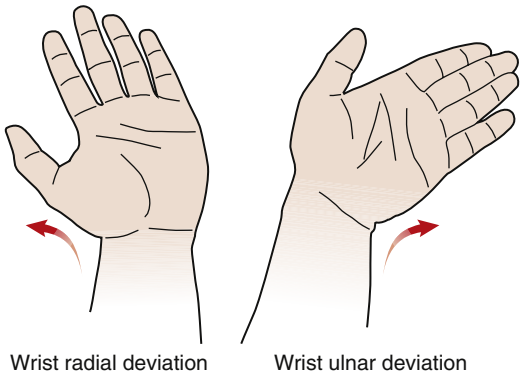

Fig. 1.15 Radial and ulnar deviation of the wrist.

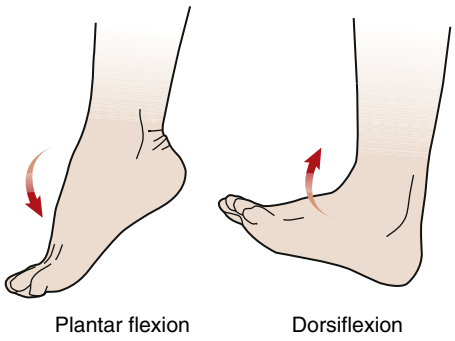

Fig. 1.16 Plantar flexion and dorsiflexion of the ankle.

Remember that all motions are described in the anatomic position.

Dorsiflexion and Plantar Flexion

Dorsiflexion and plantar flexion are sagittal plane motions of the ankle (Fig. 1.16). **Dorsiflexion** describes the motion of bringing the foot upward, whereas **plantar flexion** describes pushing the foot downward.

Inversion and Eversion

Inversion is a frontal plane motion of the foot that results in the sole of the foot facing medially; **eversion** is the opposite, resulting in the sole of the foot facing laterally (Fig. 1.17).

Osteokinematics: It's All Relative

In general, the articulation of two bones constitutes a joint. Movement at a joint therefore can be considered from two perspectives, depending on which bone is moving. Movement of the distal segment of bone about a relatively fixed proximal segment is often referred to as an **open-chain motion.** Conversely, movement of the proximal segment of bone about a relatively fixed, or stationary, distal segment is referred to as a **closed-chain motion.**

Fig. 1.18 illustrates these two different movement perspectives for knee flexion. Fig. 1.18A illustrates tibial-on-femoral flexion of the knee, indicating that the tibia (distal segment) is moving on a relatively fixed femur; this is considered open-chain knee flexion. Fig. 1.18B also illustrates knee flexion, but in this case the femur (proximal segment) is moving on a relatively fixed tibia (distal segment). This motion is referred to as closed-chain or femoral-on-tibial flexion of the knee.

Although these two motions appear to be different, both motions result in equal amounts of knee flexion. The only differences involve which bone is moving and which bone remains stationary.

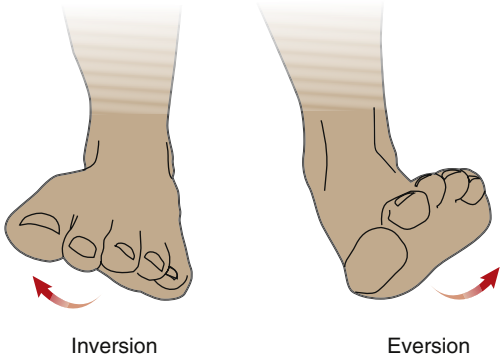

Fig. 1.17 Inversion and eversion of the ankle and foot.

Consider this...

Open-Chain and Closed-Chain Motion

The terms *open-chain* and *closed-chain* are often used clinically to describe which bone is moving during a joint motion. Open-chain motion describes motion in which the distal segment of bone is moving about a relatively fixed proximal segment (see Fig. 1.18A). Closed-chain motion, on the other hand, indicates movement of the proximal segment on a relatively fixed distal segment of bone (see Fig. 1.18B).

Closed-chain exercises are widely used by physical therapists and physical therapist assistants. These types of exercises tend to be more functional in nature and capitalize on the benefits of weight bearing and the natural biomechanical advantages that closed-chain positions often provide. Open-chain motions, although not nearly as functional, are widely used therapeutically. Open-chain exercises offer an increased ability to target specific muscle groups and are easily performed through the use of weights, elastic bands, or tubing.

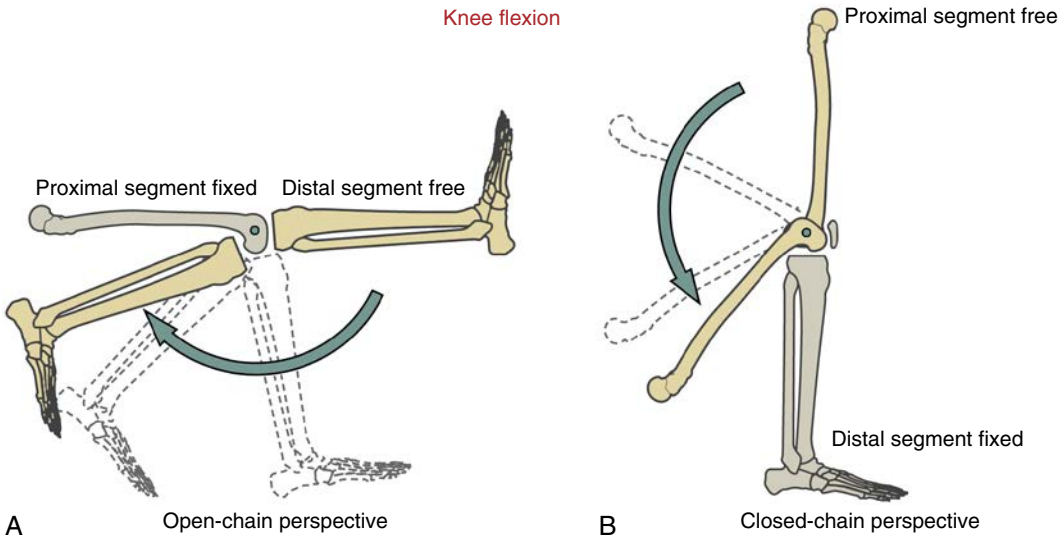

Fig. 1.18 Two different ways to flex the knee. (A) Open-chain or tibial-on-femoral flexion of the knee. (B) Closed-chain or femoral-on-tibial flexion of the knee. (From Neumann DA: Kinesiology of the musculoskeletal system: foundations for physical rehabilitation, ed 2, St Louis, 2010, Mosby, Fig. 1.6.)