labrum rather than with the glenoid fossa, contributing to wear on the labrum. Most tears are located in the anterior-superior region of the labrum. Tears of the rotator cuff, primarily of the supraspinatus, have been attributed to the extreme tension requirements placed on the muscle group during the deceleration phase of a vigorous rotational activity. There is a region of low vascularity near the insertion of the supraspinatus tendon, which is the most common site of rotator cuff inflammation and tears (49). The fact that vascularization diminishes with aging may explain why rotator cuff problems occur more frequently in individuals over 40 years of age (49). Tears of the biceps brachii tendon at the site of its attachment to the glenoid fossa may result from the forceful development of tension in the biceps when it negatively accelerates the rate of elbow extension during throwing (51).

Other pathologies of the shoulder attributed to throwing movements are calcifications of the soft tissues of the joint and degenerative changes in the articular surfaces (62). Bursitis, the inflammation of one or more bursae, is another overuse syndrome, generally caused by friction within the bursa (64).

Subscapular Neuropathy

Subscapular neuropathy, or subscapular nerve palsy, most commonly occurs in athletes involved in overhead activities and weight lifting (16). It has been reported in volleyball, baseball, football, and racquetball players, as well as backpackers, gymnasts, and dancers. The condition arises from compression of the subscapular nerve, which occurs most commonly at the suprascapular notch. In volleyball players, it has been attributed to the repeated stretching of the nerve during extreme shoulder abduction and lateral rotation, such as occurs during the serving motion (23).

STRUCTURE OF THE ELBOW

Although the elbow is generally considered a simple hinge joint, it is actually categorized as a trochoginglymus joint that encompasses three articulations: the humeroulnar, humeroradial, and proximal radioulnar joints (2). All are enclosed in the same joint capsule, which is reinforced by the anterior and posterior radial collateral and ulnar collateral ligaments. Bony structure provides about half of the elbow's stability, with the remaining stability provided by the joint capsule and the ulnar and radial ligament complexes (53).

Humeroulnar Joint

The hinge joint at the elbow is the humeroulnar joint, where the ovular trochlea of the humerus articulates with the reciprocally shaped trochlear fossa of the ulna (Figure 7-19). Flexion and extension are the primary movements, although in some individuals, a small amount of hyperextension is allowed. The joint is most stable in the close-packed position of extension.

Humeroradial Joint

The humeroradial joint is immediately lateral to the humeroulnar joint and is formed between the spherical capitellum of the humerus and the proximal end of the radius (Figure 7-19). Although the humeroradial articulation is classified as a gliding joint, the immediately adjacent humeroulnar joint restricts motion to the sagittal plane. In the close-packed position, the elbow is flexed at 90° and the forearm is supinated about 5°.
Proximal Radioulnar Joint

The annular ligament binds the head of the radius to the radial notch of the ulna, forming the proximal radioulnar joint. This is a pivot joint, with forearm pronation and supination occurring as the radius rolls medially and laterally over the ulna (Figure 7-20). The close-packed position is at 5° of forearm supination.

Carrying Angle

The angle between the longitudinal axes of the humerus and the ulna when the arm is in anatomical position is referred to as the carrying angle. The size of the carrying angle ranges from 10° to 15° in adults and tends to be larger in females than in males. The carrying angle changes with skeletal growth and is always greater on the side of the dominant radioulnar joints

the proximal and distal radioulnar joints are pivot joints; the middle radioulnar joint is a synovial joint

- When pronation and supination of the forearm occur, the radius pivots around the ulna.

FIGURE 7-20

hand (57). No particular functional significance has been associated with the carrying angle.

# MOVEMENTS AT THE ELBOW

## Muscles Crossing the Elbow

Numerous muscles cross the elbow, including those that also cross the shoulder or extend into the hands and fingers. The muscles classified as primary movers of the elbow are summarized in Table 7-2.

## Flexion and Extension

The muscles crossing the anterior side of the elbow are the elbow flexors (Figure 7-21). The strongest of the elbow flexors is the brachialis. Since

<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>PROXIMAL ATTACHMENT</th>
<th>DISTAL ATTACHMENT</th>
<th>PRIMARY ACTION(S)</th>
<th>INNERVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biceps brachii</td>
<td>Radial tuberosity</td>
<td>Flexion, assists with supination</td>
<td>Musculocutaneous (C5–C6)</td>
<td></td>
</tr>
<tr>
<td>(Long head)</td>
<td>Upper rim of glenoid fossa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Short head)</td>
<td>Coracoid process of scapula</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brachioradialis</td>
<td>Upper two-thirds of lateral supracondylar ridge of humerus</td>
<td>Scaphoid process of radius</td>
<td>Flexion, pronation from supinated position to neutral, supination from pronated position to neutral</td>
<td>Radial (C5, C6)</td>
</tr>
<tr>
<td>Brachialis</td>
<td>Anterior lower half of humerus</td>
<td>Anterior coronoid process of ulna</td>
<td>Flexion</td>
<td>Musculocutaneous (C5, C6)</td>
</tr>
<tr>
<td>Pronator teres</td>
<td></td>
<td>Lateral midpoint of radius</td>
<td>Pronation, assists with flexion</td>
<td>Median (C4, C7)</td>
</tr>
<tr>
<td>(Humeral head)</td>
<td>Medial epicondyle of humerus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Ulnar head)</td>
<td>Coronoid process of ulna</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pronator quadratus</td>
<td>Lower fourth of anterior ulna</td>
<td>Lower fourth of anterior radius</td>
<td>Pronation</td>
<td>Anterior interosseous (C5, T1)</td>
</tr>
<tr>
<td>Triceps brachii</td>
<td></td>
<td>Olecranon process of ulna</td>
<td>Extension</td>
<td>Radial (C5–C6)</td>
</tr>
<tr>
<td>(Long head)</td>
<td>Just inferior to glenoid fossa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Lateral head)</td>
<td>Upper half of posterior humerus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Medial head)</td>
<td>Lower two-thirds of posterior humerus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anconeus</td>
<td>Posterior, lateral epicondyle of humerus</td>
<td>Lateral olecranon and posterior ulna</td>
<td>Assists with extension</td>
<td>Radial (C5, C6)</td>
</tr>
<tr>
<td>Supinator</td>
<td>Lateral epicondyle of humerus and adjacent ulna</td>
<td>Lateral upper third of radius</td>
<td>Supination</td>
<td>Posterior interosseous (C5, C6)</td>
</tr>
</tbody>
</table>
the distal attachment of the brachialis is the coronoid process of the ulna, the muscle is equally effective when the forearm is in supination or pronation.

Another elbow flexor is the biceps brachii, with both long and short heads attached to the radial tuberosity by a single common tendon. The muscle contributes effectively to flexion when the forearm is supinated, because it is slightly stretched. When the forearm is pronated, the muscle is less taut and consequently less effective.

The brachioradialis is a third contributor to flexion at the elbow. This muscle is most effective when the forearm is in a neutral position (midway between full pronation and full supination) because of its distal attachment to the base of the styloid process on the lateral radius. In this position, the muscle is in slight stretch, and the radial attachment is centered in front of the elbow joint.

The major extensor of the elbow is the triceps, which crosses the posterior aspect of the joint (Figure 7-22). Although the three heads have separate proximal attachments, they attach to the olecranon process of the ulna through a common distal tendon. Even though the distal attachment is relatively close to the axis of rotation at the elbow, the size and strength of the muscle make it effective as an elbow extensor. The relatively small anconeus muscle, which courses from the posterior surface of the lateral epicondyle of the humerus to the lateral olecranon and posterior proximal ulna, also assists with extension. Research has shown that the lateral and medial heads of the triceps contribute 70–90% of the extension moment, with approximately 15% contributed by the anconeus (83). The long head of the triceps, crossing both the elbow and the shoulder, was found to contribute significantly less than the other muscles (83).

**Pronation and Supination**

Pronation and supination of the forearm involve rotation of the radius around the ulna. There are three radioulnar articulations: the proximal, middle, and distal radioulnar joints. Both the proximal and the distal
The major extensor muscles of the elbow.

The major pronator muscle is the pronator quadratus.
LOADS ON THE ELBOW

Although the elbow is not considered to be a weight-bearing joint, it regularly sustains large loads during daily activities. For example, research shows that the compressive load at the elbow reaches an estimated 300 N (67 lb) during activities such as dressing and eating, 1700 N (382 lb) when the body is supported by the arms when rising from a chair, and 1900 N (427 lb) when the individual is pulling a table across the floor (34). Even greater loads are present during the execution of selected sport skills. During baseball pitching, the elbow undergoes a valgus torque of as much as 64 N-m, with muscle force as large as 1000 N required to prevent dislocation (47). The amount of valgus torque generated is most closely related to the pitcher’s body weight (66). During the execution of gymnastic skills such as the handspring and the vault, the elbow functions as a weight-bearing joint. Research indicates that maximal isometric flexion when the elbow is fully extended can produce joint compression forces of as much as two times body weight (29).

Since the attachment of the triceps tendon to the ulna is closer to the elbow joint center than the attachments of the brachialis on the ulna and the biceps on the radius, the extensor moment arm is shorter than the flexor moment arm. This means that the elbow extensors must generate more force than the elbow flexors to produce the same amount of joint torque. This translates to larger compression forces at the elbow during extension than during flexion when movements of comparable speed and force requirements are executed. Sample Problem 7.2 illustrates the relationship between moment arm and torque at the elbow.

Because of the shape of the olecranon process, the triceps moment arm also varies with the position of the elbow. As shown in Figure 7-25, the triceps moment arm is larger when the arm is fully extended than when it is flexed past 90°.
SAMPLE PROBLEM 7.2

How much force must be produced by the brachioradialis and biceps ($F_m$) to maintain the 15 N forearm and hand in the position shown below, given moment arms of 5 cm for the muscles and 15 cm for the forearm/hand weight? What is the magnitude of the joint reaction force?

**Known**

\[
\begin{align*}
wt &= 15 \text{ N} \\
d_{wt} &= 15 \text{ cm} \\
d_m &= 5 \text{ cm}
\end{align*}
\]

**Solution**

The torque at the elbow created by the muscle force must equal the torque at the elbow created by forearm/hand weight, yielding a net elbow torque of zero.

\[
\begin{align*}
\sum T_e &= 0 \\
\sum T_e &= (F_m)(d_m) - (wt)(d_{wt}) \\
0 &= (F_m)(5 \text{ cm}) - (15 \text{ N})(15 \text{ cm}) \\
F_m &= \frac{(15 \text{ N})(15 \text{ cm})}{5 \text{ cm}} \\
F_m &= 45 \text{ N}
\end{align*}
\]

Since the arm is stationary, the sum of all of the acting vertical forces must be equal to zero. In writing the force equation, it is convenient to regard upward as the positive direction.

\[
\begin{align*}
\sum F_v &= 0 \\
\sum F_v &= F_m - wt - R \\
\sum F_v &= 45 \text{ N} - 15 \text{ N} - R \\
R &= 30 \text{ N}
\end{align*}
\]

**Figure 7-25**

Because of the shape of the olecranon process of the ulna, the moment arm for the triceps tendon is shorter when the elbow is in flexion.
COMMON INJURIES OF THE ELBOW

Although the elbow is a stable joint reinforced by large, strong ligaments, the large loads placed on the joint during daily activities and sport participation render it susceptible to dislocations and overuse injuries.

Sprains and Dislocations

Forced hyperextension of the elbow can cause posterior displacement of the coronoid process of the ulna with respect to the trochlea of the humerus. Such displacement stretches the ulnar collateral ligament, which may rupture (sprain) anteriorly.

Continued hyperextension of the elbow can cause the distal humerus to slide over the coronoid process of the ulna, resulting in dislocation. Although dislocations of the elbow do not occur as frequently as dislocations of the glenohumeral joint, elbow dislocations occurring in individuals under age 30 are most likely to arise during participation in sports (37). The mechanism involved typically is a fall on an outstretched hand or a forceful, twisting blow. The subsequent stability of a once-dislocated elbow is impaired, particularly if the dislocation was accompanied by humeral fracture or rupture of the ulnar collateral ligament (37). Because of the large number of nerves and blood vessels passing through the elbow, elbow dislocations are of particular concern.

Elbow dislocations in young children age 1–3 are sometimes referred to as “nursemaid’s elbow” or “pulled elbow.” Adults should avoid lifting or swinging young children by the hands, wrists, or forearms, as this type of injury can result.

Overuse Injuries

With the exception of the knee, the elbow is the joint most commonly affected by overuse injuries (35). Stress injuries to the collagenous tissues at the elbow are progressive. The first symptoms are inflammation and swelling, followed by scarring of the soft tissues. If the condition progresses further, calcium deposits accumulate and ossification of the ligaments ensues.

Lateral epicondylitis involves inflammation or microdamage to the tissues on the lateral side of the distal humerus, including the tendinous attachment of the extensor carpi radialis brevis and possibly that of the extensor digitorum. Although a host of factors may contribute to the development of the condition, overuse of the wrist extensors is cited as a major culprit (26).

Because of the relatively high incidence of lateral epicondylitis among tennis players, the injury is commonly referred to as tennis elbow. A reported 30–40% of tennis players develop lateral epicondylitis, with onset typically in players age 35–50 (35). The amount of force to which the lateral aspect of the elbow is subjected during tennis play increases with poor technique and improper equipment. For example, hitting off-center shots and using an overstrung racquet increase the amount of force transmitted to the elbow (26). Activities such as swimming, fencing, and hammering can contribute to lateral epicondylitis as well.

Medial epicondylitis, which has been called Little Leaguer’s elbow, is the same type of injury to the tissues on the medial aspect of the distal humerus. During pitching, the valgus strain imparted to the medial aspect of the elbow during the initial stage, when the trunk and shoulder are
brought forward ahead of the forearm and hand, contributes to development of the condition. Valgus torque increases with late trunk rotation, reduced external rotation of the throwing shoulder, and increased elbow flexion (1). Medial epicondyle avulsion fractures have also been attributed to forceful terminal wrist flexion during the follow-through phase of the pitch (35). More commonly, however, throwing injuries to the elbow are chronic rather than acute. Injury or stretching of the ulnar collateral ligament can result in valgus instability, which, with repeated valgus overload during repetitive throwing, can provoke the development of bony changes that further exacerbate the problem (9, 19). Although uncommon among athletes in general, valgus instability is seen with a higher incidence in individuals who throw repetitively (32). Proper pitching mechanics in young pitchers can help prevent shoulder and elbow injuries by lowering internal rotation torque on the humerus and reducing the valgus load on the elbow (14).

Medial and lateral epicondylitis occur with about equal frequency in golfers, particularly amateurs (4, 70). Among right-handed golfers, lateral epicondylitis occurs more often on the left side, and medial epicondylitis is found more often on the right side (4). Lateral epicondylitis may be related to gripping the club with excessive pronation of the right hand, while medial epicondylitis appears to be associated with repeatedly striking the ground with the club (4).

**STRUCTURE OF THE WRIST**

The wrist is composed of radiocarpal and intercarpal articulations (Figure 7-26). Most wrist motion occurs at the radiocarpal joint, a condylar joint where the radius articulates with the scaphoid, the lunate, and the triquetrum. The joint allows sagittal plane motions (flexion, extension, and hyperextension) and frontal plane motions (radial deviation and ulnar deviation), as well as circumduction. Its close-packed position is

---

**Figure 7-26**

The bones of the wrist.
in extension with radial deviation. A cartilaginous disc separates the
distal head of the ulna from the lunate and triquetral bones and the
radius. Although this articular disc is common to both the radiocarpal
joint and the distal radioulnar joint, the two articulations have separate
joint capsules. The radiocarpal joint capsule is reinforced by the volar
radiocarpal, dorsal radiocarpal, radial collateral, and ulnar collateral
ligaments. The intercarpal joints are gliding joints that contribute little
to wrist motion.

The fascia around the wrist is thickened into strong fibrous bands
called retinacula, which form protective passageways through which
tendons, nerves, and blood vessels pass. The flexor retinaculum pro-
tects the extrinsic flexor tendons and the median nerves where they
cross the palmar side of the wrist. On the dorsal side of the wrist, the
extensor retinaculum provides a passageway for the extrinsic extensor
tendons.

MOVEMENTS OF THE WRIST

The wrist is capable of sagittal and frontal plane movements, as well as
rotary motion (Figure 7-27). Flexion is motion of the palmar surface of the
hand toward the anterior forearm. Extension is the return of the hand
to anatomical position, and in hyperextension, the dorsal surface of the
hand approaches the posterior forearm. Movement of the hand toward the
thumb side of the arm is radial deviation, with movement in the opposite
direction designated as ulnar deviation. Movement of the hand through
all four directions produces circumduction. Because of the complex struc-
ture of the wrist, rotational movements at the wrist are also complex,
with different axes of rotation and different mechanisms through which
wrist motions occur (55).

Flexion

The muscles responsible for flexion at the wrist are the flexor carpi ra-
dialis and the powerful flexor carpi ulnaris (Figure 7-28). The palmaris
longus, which is often absent in one or both forearms, contributes to
flexion when present. All three muscles have proximal attachments on
the medial epicondyle of the humerus. The flexor digitorum superficia-
lis and flexor digitorum profundus can assist with flexion at the wrist
when the fingers are completely extended, but when the fingers are in
flexion, these muscles cannot develop sufficient tension due to active
insufficiency.

FIGURE 7-27
Movements occurring at the wrist.
Extension and Hyperextension

Extension and hyperextension at the wrist result from contraction of the extensor carpi radialis longus, extensor carpi radialis brevis, and extensor carpi ulnaris (Figure 7-29). These muscles originate on the lateral epicondyle of the humerus. The other posterior wrist muscles may also assist with extension, particularly when the fingers are in flexion. Included in this group are the extensor pollicis longus, extensor indicis, extensor digiti minimi, and extensor digitorum (Figure 7-30).

Radial and Ulnar Deviation

Cooperative action of both flexor and extensor muscles produces lateral deviation of the hand at the wrist. The flexor carpi radialis and extensor carpi radialis longus and brevis contract to produce radial deviation, and the flexor carpi ulnaris and extensor carpi ulnaris cause ulnar deviation.
STRUCTURE OF THE JOINTS OF THE HAND

A large number of joints are required to provide the extensive motion capabilities of the hand. Included are the carpometacarpal (CM), intermetacarpal, metacarpophalangeal (MP), and interphalangeal (IP) joints (Figure 7-31). The fingers are referred to as digits one through five, with the first digit being the thumb.

FIGURE 7-30
Muscles that assist with extension of the wrist.

FIGURE 7-31
The bones of the hand.
Carpometacarpal and Intermetacarpal Joints

The carpometacarpal (CM) joint of the thumb, the articulation between the trapezium and the first metacarpal, is a classic saddle joint. The other CM joints are generally regarded as gliding joints. All carpometacarpal joints are surrounded by joint capsules, which are reinforced by the dorsal, volar, and interosseous CM ligaments. The irregular intermetacarpal joints share these joint capsules.

Metacarpophalangeal Joints

The metacarpophalangeal (MP) joints are the condyloid joints between the rounded distal heads of the metacarpals and the concave proximal ends of the phalanges. These joints form the knuckles of the hand. Each joint is enclosed in a capsule that is reinforced by strong collateral ligaments. A dorsal ligament also merges with the MP joint of the thumb. Close-packed positions of the MP joints in the fingers and thumb are full flexion and opposition, respectively.

FIGURE 7-32
Movements of the thumb.
Interphalangeal Joints

The proximal and distal interphalangeal (IP) joints of the fingers and the single interphalangeal joint of the thumb are all hinge joints. An articular capsule joined by volar and collateral ligaments surrounds each IP joint. These joints are most stable in the close-packed position of full extension.

MOVEMENTS OF THE HAND

The carpometacarpal (CM) joint of the thumb allows a large range of movement similar to that of a ball-and-socket joint (Figure 7-32). Motion at CM joints two through four is slight due to constraining ligaments, with somewhat more motion permitted at the fifth CM joint.

The metacarpophalangeal (MP) joints of the fingers allow flexion, extension, abduction, adduction, and circumduction for digits two through five, with abduction defined as movement away from the middle finger and adduction being movement toward the middle finger (Figure 7-33). Because the articulating bone surfaces at the metacarpophalangeal joint of the thumb are relatively flat, the joint functions more as a hinge joint, allowing only flexion and extension.

The interphalangeal (IP) joints permit flexion and extension, and in some individuals, slight hyperextension. These are classic hinge joints. Due to passive tension in the extrinsic muscles, when the hand is relaxed and the wrist moves from full flexion to full extension, the distal interphalangeal joints go from approximately 12° to 31° of flexion, and the proximal IP joints go from about 19° to 70° of flexion (73).

A relatively large number of muscles are responsible for the many precise movements performed by the hand and fingers (Table 7-3). There

\[ \text{FIGURE 7-33} \]
Movements of the fingers.

- The large range of movement of the thumb compared to that of the fingers is derived from the structure of the thumb’s carpometacarpal joint.
<table>
<thead>
<tr>
<th>MUSCLE</th>
<th>PROXIMAL ATTACHMENT</th>
<th>DISTAL ATTACHMENT</th>
<th>PRIMARY ACTION(S)</th>
<th>INNERVATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EXTRINSIC MUSCLES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extensor pollicis longus</td>
<td>Middle dorsal ulna</td>
<td>Dorsal distal phalanx of thumb</td>
<td>Extension at MP and IP joints of thumb, adduction at MP joint of thumb</td>
<td>Radial (C_5, C_6)</td>
</tr>
<tr>
<td>Extensor pollicis brevis</td>
<td>Middle dorsal radius</td>
<td>Dorsal proximal phalanx of thumb</td>
<td>Extension at MP and CM joints of thumb</td>
<td>Radial (C_5, C_6)</td>
</tr>
<tr>
<td>Flexor pollicis longus</td>
<td>Middle palmar radius</td>
<td>Palmar distal phalanx of thumb</td>
<td>Flexion at IP and MP joints of thumb</td>
<td>Median (C_8, T_1)</td>
</tr>
<tr>
<td>Abductor pollicis longus</td>
<td>Middle dorsal ulna and radius</td>
<td>Radial base of 1ˢᵗ metacarpal</td>
<td>Abduction at CM joint of thumb</td>
<td>Radial (C_5, C_6)</td>
</tr>
<tr>
<td>Extensor indicis</td>
<td>Distal dorsal ulna</td>
<td>Ulnar side of extensor digitorum tendon</td>
<td>Extension at MP joint of 2ⁿᵈ digit</td>
<td>Radial (C_5, C_6)</td>
</tr>
<tr>
<td>Extensor digitorum</td>
<td>Lateral epicondyle of humerus</td>
<td>Base of 2ⁿᵈ and 3ⁿᵈ phalange, digits 2–5</td>
<td>Extension at MP, proximal and distal IP joints, digits 2–5</td>
<td>Radial (C_5, C_6)</td>
</tr>
<tr>
<td>Extensor digiti minimi</td>
<td>Proximal tendon of extensor digitorum</td>
<td>Tendon of extensor digitorum distal to 5ᵗʰ MP joint</td>
<td>Extension at 5ᵗʰ MP joint</td>
<td>Radial (C_5, C_6)</td>
</tr>
<tr>
<td>Flexor digitorum profundus</td>
<td>Proximal three-fourths of ulna</td>
<td>Base of distal phalanx, digits 2–5</td>
<td>Flexion at distal and proximal IP joints and MP joints, digits 2–5</td>
<td>Ulnar and median (C_8, T_1)</td>
</tr>
<tr>
<td>Flexor digitorum superfcials</td>
<td>Medial epicondyle of humerus</td>
<td>Base of middle phalanx, digits 2–5</td>
<td>Flexion at proximal IP and MP joints, digits 2–5</td>
<td>Median (C_7, C_8, T_1)</td>
</tr>
<tr>
<td><strong>INTRINSIC MUSCLES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexor pollicis brevis</td>
<td>Ulnar side, 1ˢᵗ metacarpal</td>
<td>Ulnar, palmar base of proximal phalanx of thumb</td>
<td>Flexion and adduction at MP joint of thumb</td>
<td>Median (C_8, T_1)</td>
</tr>
<tr>
<td>Abductor pollicis brevis</td>
<td>Trapezium and scaphoid bones</td>
<td>Radial base of 1ˢᵗ phalanx of thumb</td>
<td>Abduction at 1ˢᵗ CM joint</td>
<td>Median (C_8, T_1)</td>
</tr>
<tr>
<td>Opponens pollicis</td>
<td>Scaphoid bone</td>
<td>Radial side of 1ˢᵗ metacarpal</td>
<td>Flexion and abduction at CM joint of thumb</td>
<td>Median (C_8, T_1)</td>
</tr>
<tr>
<td>Adductor pollicis</td>
<td>Capitate, distal 2ⁿᵈ and 3ⁿᵈ metacarpals</td>
<td>Ulnar proximal phalanx of thumb</td>
<td>Adduction and flexion at CM joint of thumb</td>
<td>Ulnar (C_8, T_1)</td>
</tr>
<tr>
<td>Abductor digiti minimi</td>
<td>Pisiform bone</td>
<td>Ulnar base of proximal phalanx, 5ᵗʰ digit</td>
<td>Abduction and flexion at 5ᵗʰ MP joint</td>
<td>Ulnar (C_8, T_1)</td>
</tr>
<tr>
<td>Flexor digiti minimi brevis</td>
<td>Hamate bone</td>
<td>Ulnar base of proximal phalanx, 5ᵗʰ digit</td>
<td>Flexion at 5ᵗʰ MP joint</td>
<td>Ulnar (C_8, T_1)</td>
</tr>
<tr>
<td>Opponens digiti minimi</td>
<td>Hamate bone</td>
<td>Ulnar metacarpal of 5ᵗʰ metacarpal</td>
<td>Opposition at 5ᵗʰ CM joint</td>
<td>Ulnar (C_8, T_1)</td>
</tr>
<tr>
<td>Dorsal interossei (four muscles)</td>
<td>Sides of metacarpals, all digits</td>
<td>Base of proximal phalanx, all digits</td>
<td>Abduction at 2ⁿᵈ and 4ᵗʰ MP joints, radial and ulnar deviation at 3ᵗʰ MP joint, flexion at MP joints 2–4</td>
<td>Ulnar (C_8, T_1)</td>
</tr>
<tr>
<td>Palmar interossei (three muscles)</td>
<td>2ⁿᵈ, 4ⁿᵗʰ, and 5ᵗʰ metacarpals</td>
<td>Base of proximal phalanx, digits 2, 4, and 5</td>
<td>Adduction and flexion at MP joints, digits 2, 4, and 5</td>
<td>Ulnar (C_8, T_1)</td>
</tr>
<tr>
<td>Lumbricales (four muscles)</td>
<td>Tendons of flexor digitorum profundus, digits 2–5</td>
<td>Tendons of extensor digitorum, digits 2–5</td>
<td>Flexion at MP joints of digits 2–5</td>
<td>Median and ulnar (C_8, T_1)</td>
</tr>
</tbody>
</table>
are 9 extrinsic muscles that cross the wrist and 10 intrinsic muscles with both of their attachments distal to the wrist.

The extrinsic flexor muscles of the hand are more than twice as strong as the strongest of the extrinsic extensor muscles (78). This should come as little surprise, given that the flexor muscles of the hand are used extensively in everyday activities involving gripping, grasping, or pinching movements, while the extensor muscles rarely exert much force. Multidirectional force measurement for the index finger shows the highest force production in flexion with forces generated in extension, abduction, and adduction being about 38%, 98%, and 79%, respectively, of the flexion force (45). The strongest of the extrinsic flexor muscles are the flexor digitorum profundus and the flexor digitorum superficialis, collectively contributing over 80% of all flexion force (46).

COMMON INJURIES OF THE WRIST AND HAND

The hand is used almost continuously in daily activities and in many sports. Wrist sprains or strains are fairly common and are occasionally accompanied by dislocation of a carpal bone or the distal radius. These types of injuries often result from the natural tendency to sustain the force of a fall on the hyperextended wrist. It has been shown that falls from heights greater than 0.6 m can readily result in wrist fracture, since the peak force sustained exceeds the average fracture force for the distal radius (10). Fracture of the distal radius is the most common type of fracture in the population under 75 years of age and is second only to vertebral fractures among the elderly (10). Fractures of the scaphoid and lunate bones are relatively common for the same reason.

Certain hand/wrist injuries are characteristic of participation in a given sport. Examples are metacarpal (boxer’s) fractures and mallet or drop finger deformity resulting from injury at the distal interphalangeal joints among football receivers and baseball catchers. Forced abduction of the thumb leading to ulnar collateral ligament injury often results from wrestling, football, hockey, and skiing (36). The most common injuries encountered in skateboarding and snowboarding are fractures of or close to the wrist (17). In sport rock climbing, 62% of all injuries are to the elbow, forearm, wrist, and hand, with many injuries specific to the handholds employed (30).

The wrist is the most frequently injured joint among golfers, with right-handed golfers tending to injure the left wrist (4). Both overuse injuries such as De Quervains disease (tendinitis of the extensor pollicis brevis and the abductor pollicis longus) and impact-related injuries are common (54). According to one study, golfers with overuse injuries of the wrist use a larger-than-average range of motion of the wrists during the swing (5).

Carpal tunnel syndrome is a fairly common disorder. The carpal tunnel is a passageway between the carpal bones and the flexor retinaculum on the palmar side of the wrist. Although the cause of this disorder in a given individual is often unknown, any swelling caused by acute or chronic trauma in the region can compress the median nerve, which passes through the carpal tunnel, thus bringing on the syndrome. Tendon and nerve movement during prolonged repetitive hand movement and incursion of the flexor muscles into the carpal tunnel during wrist extension have been hypothesized as causes for carpal tunnel syndrome (39, 75). Symptoms include pain and numbness along the median nerve, clumsiness of finger function, and eventually weakness and atrophy of extrinsic muscles

muscles with proximal attachments located proximal to the wrist and distal attachments located distal to the wrist

intrinsic muscles

muscles with both attachments distal to the wrist
the muscles supplied by the median nerve. Workers at tasks requiring large handgrip forces, repetitive movements, or use of vibrating tools are particularly susceptible to carpal tunnel syndrome (69, 76). Likewise, office workers who repeatedly rest the arms on the palmar surface of the wrists are vulnerable. Research indicates that modifications in keyboard design can dramatically affect tendon motion at the wrist, with promising implications for reducing the incidence of overuse injuries (74). The goal of workstation modifications in preventing carpal tunnel syndrome is enabling work with the wrist in neutral position (22, 44). Carpal tunnel syndrome has also been reported among athletes in badminton, baseball, cycling, gymnastics, field hockey, racquetball, rowing, skiing, squash, tennis, and rock climbing (16).

**SUMMARY**

The shoulder is the most complex joint in the human body, with four different articulations contributing to movement. The glenohumeral joint is a loosely structured ball-and-socket joint in which range of movement is substantial and stability is minimal. The sternoclavicular joint enables some movement of the bones of the shoulder girdle, clavicle, and scapula. Movements of the shoulder girdle contribute to optimal positioning of the glenohumeral joint for different humeral movements. Small movements are also provided by the acromioclavicular and coracoclavicular joints.

The humeroulnar articulation controls flexion and extension at the elbow. Pronation and supination of the forearm occur at the proximal and distal radioulnar joints.

The structure of the condyloid joint between the radius and the three carpal bones controls motion at the wrist. Flexion, extension, radial flexion, and ulnar flexion are permitted. The joints of the hand at which most movements occur are the carpometacarpal joint of the thumb, the metacarpophalangeal joints, and the hinges at the interphalangeal articulations.

**INTRODUCTORY PROBLEMS**

1. Construct a chart listing all muscles crossing the glenohumeral joint according to whether they are superior, inferior, anterior, or posterior to the joint center. Note that some muscles may fall into more than one category. Identify the action or actions performed by muscles in each of the four categories.

2. Construct a chart listing all muscles crossing the elbow joint according to whether they are medial, lateral, anterior, or posterior to the joint center with the arm in anatomical position. Note that some muscles may fall into more than one category. Identify the action or actions performed by muscles in each of the four categories.

3. Construct a chart listing all muscles crossing the wrist joint according to whether they are medial, lateral, anterior, or posterior to the joint center with the arm in anatomical position. Note that some muscles may fall into more than one category. Identify the action or actions performed by muscles in each of the four categories.

4. List the muscles that develop tension to stabilize the scapula during each of the following activities:
   a. Carrying a suitcase
   b. Water-skiing
   c. Performing a push-up
   d. Performing a pull-up