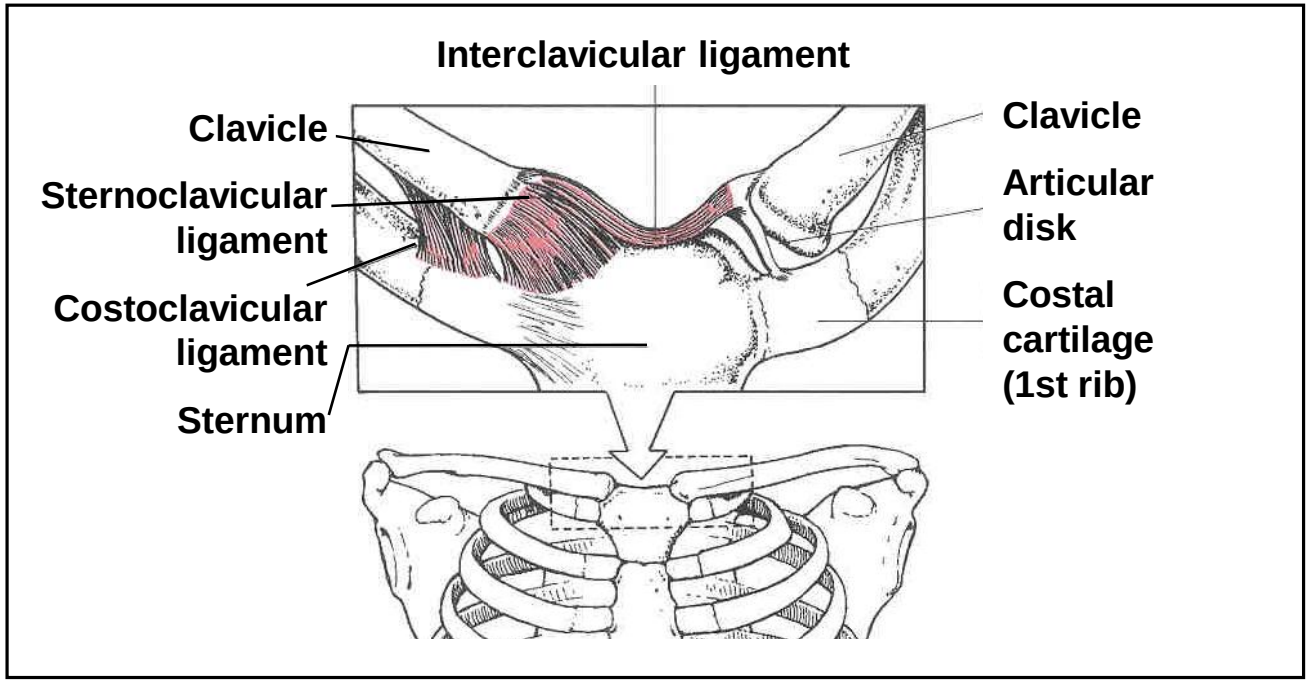
Basic Biomechanics, (5th edition)

by Susan J. Hall, Ph.D.

Chapter 7

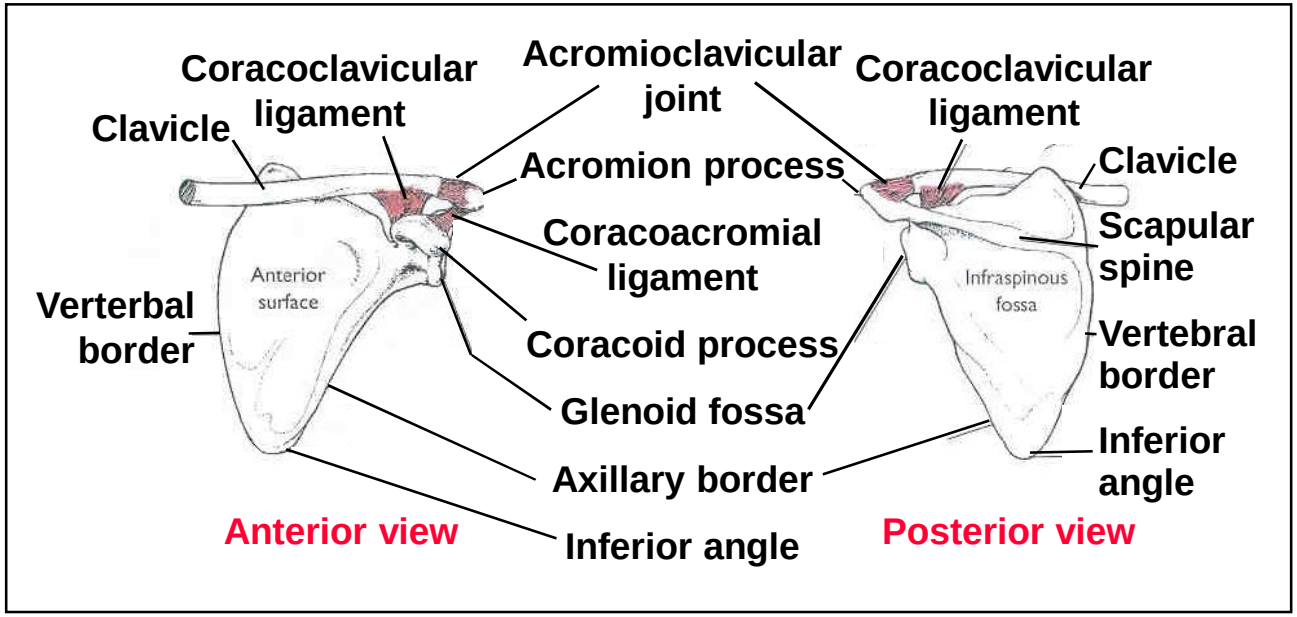
The Biomechanics of the Human Upper Extremity

Structure of the Shoulder



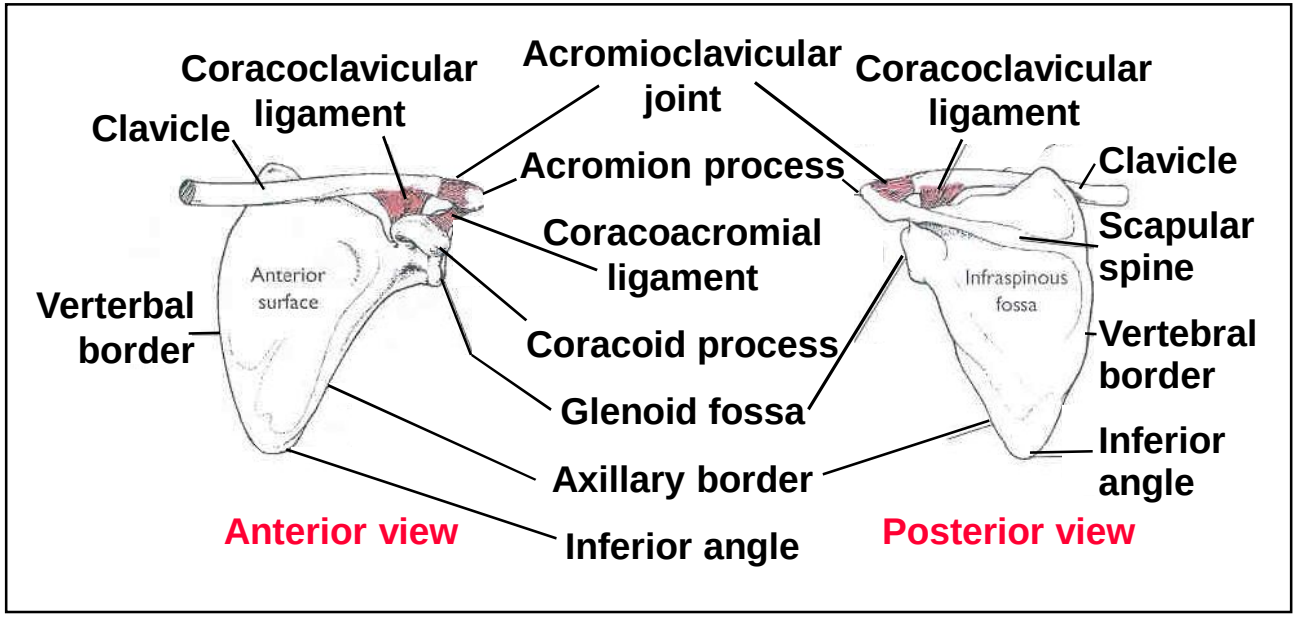
Sternoclavicular joint: modified ball and socket joint between the proximal clavicle and the manubrium of the sternum

Structure of the Shoulder



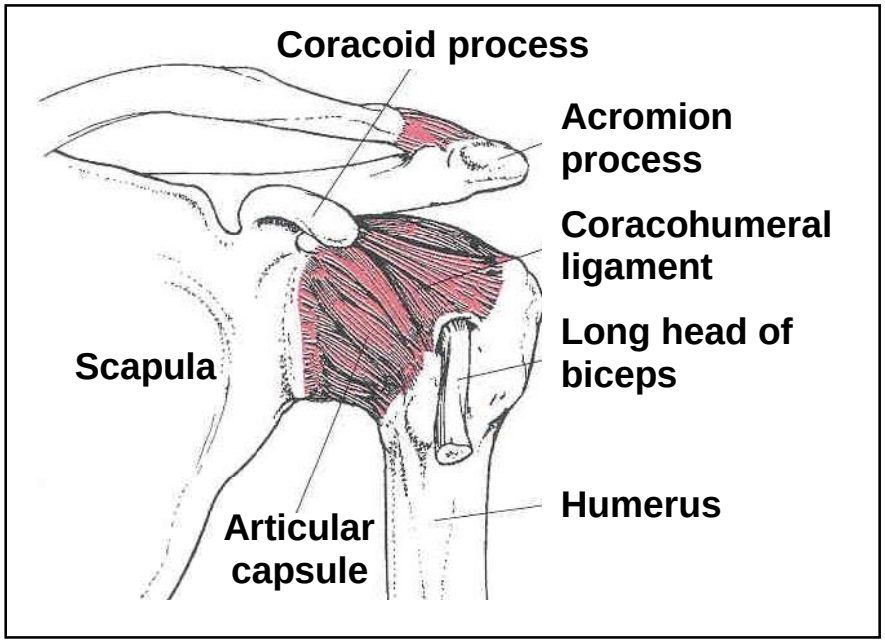
Acromioclavicular joint: irregular joint between the acromion process of the scapula and the distal clavicle

Structure of the Shoulder



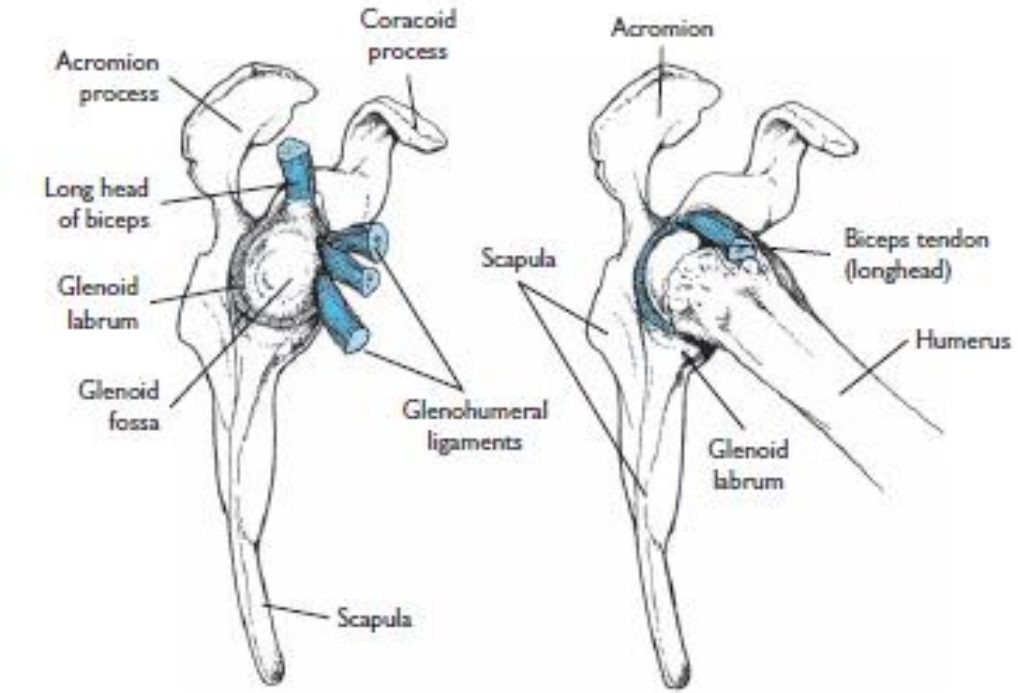
Coraoclavicular joint: syndesmosis with the coracoid process of the scapula bound to the inferior clavicle by the coracoclavicular ligament

Structure of the Shoulder



Glenohumeral joint: ball and socket joint in which the head of the humerus articulates with the glenoid fossa of the scapula

Structure of the Shoulder

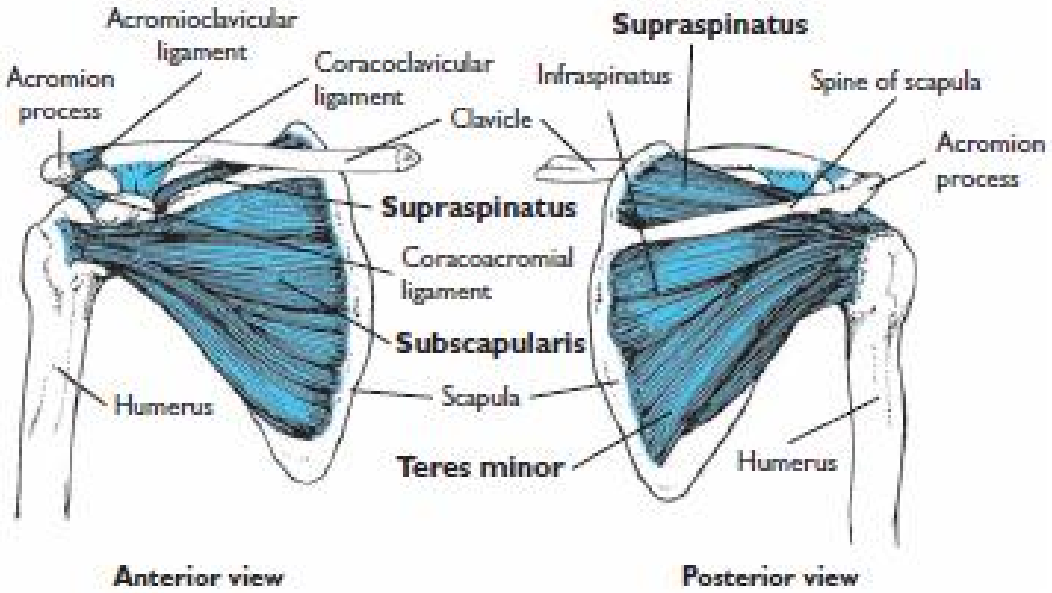


Structure of the Shoulder

What is the scapulothoracic joint?

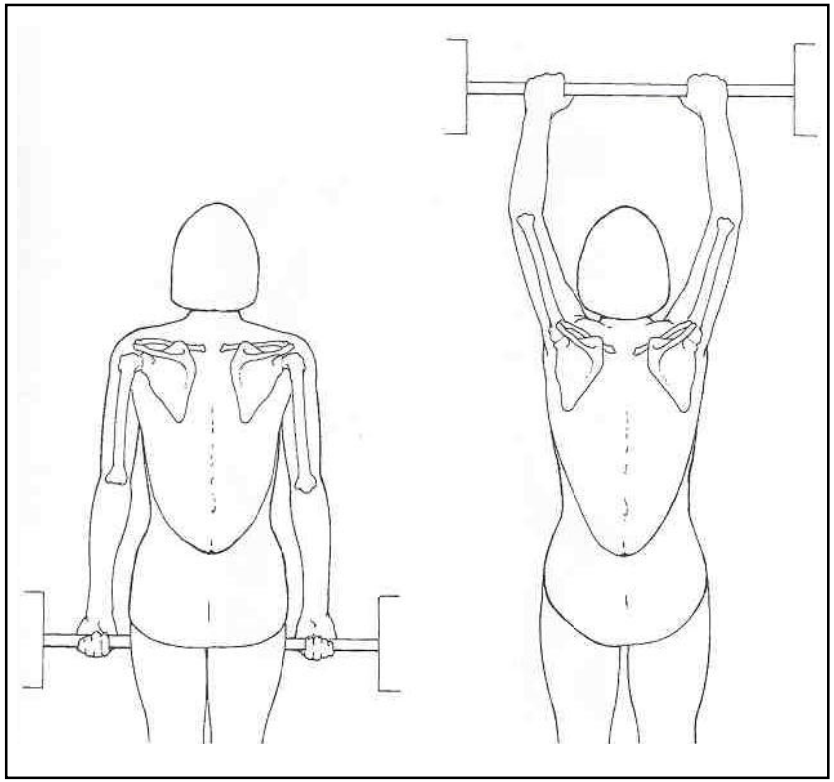
(articulation between the anterior scapula and the thoracic wall)

Structure of the Shoulder

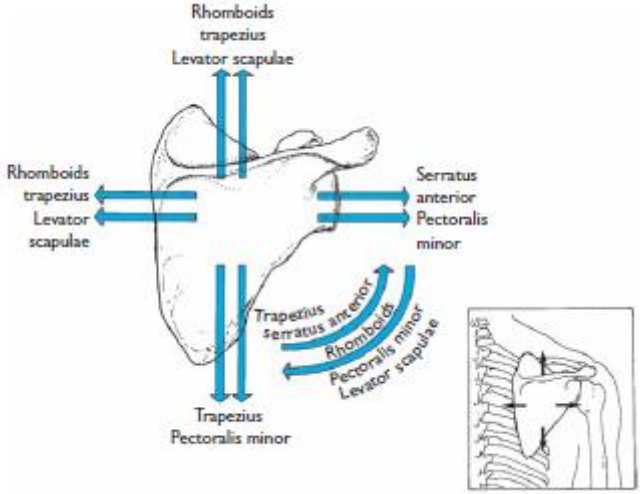


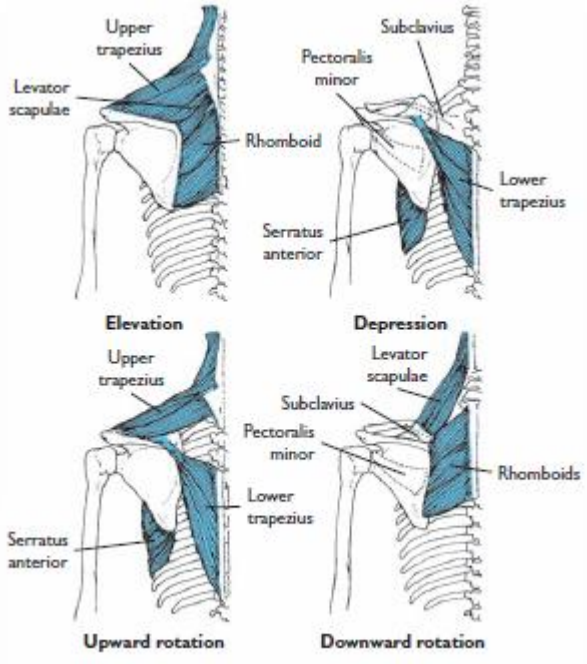
Movements of the Shoulder Complex

scapulohumeral rhythm: a regular pattern of scapular rotation that accompanies and facilitates humeral abduction



Movements of the Shoulder Complex



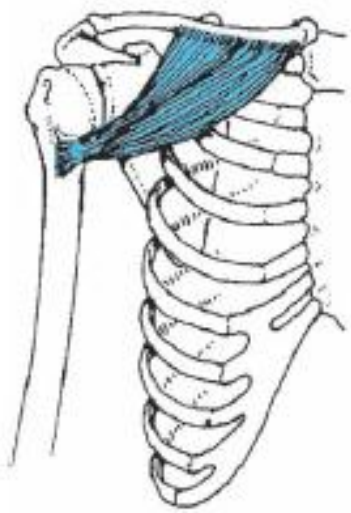


Movements of the Shoulder Complex

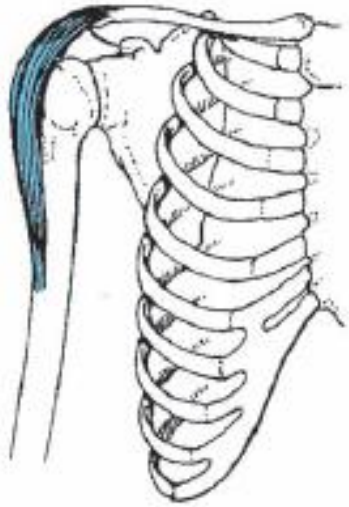
What muscles contribute to flexion at the glenohumeral joint?

- anterior deltoid
- clavicular pectoralis major
- assisted by:
  - coracobrachialis
  - short head of biceps brachii

Movements of the Shoulder Complex



Clavicular pectoralis major



Anterior deltoid

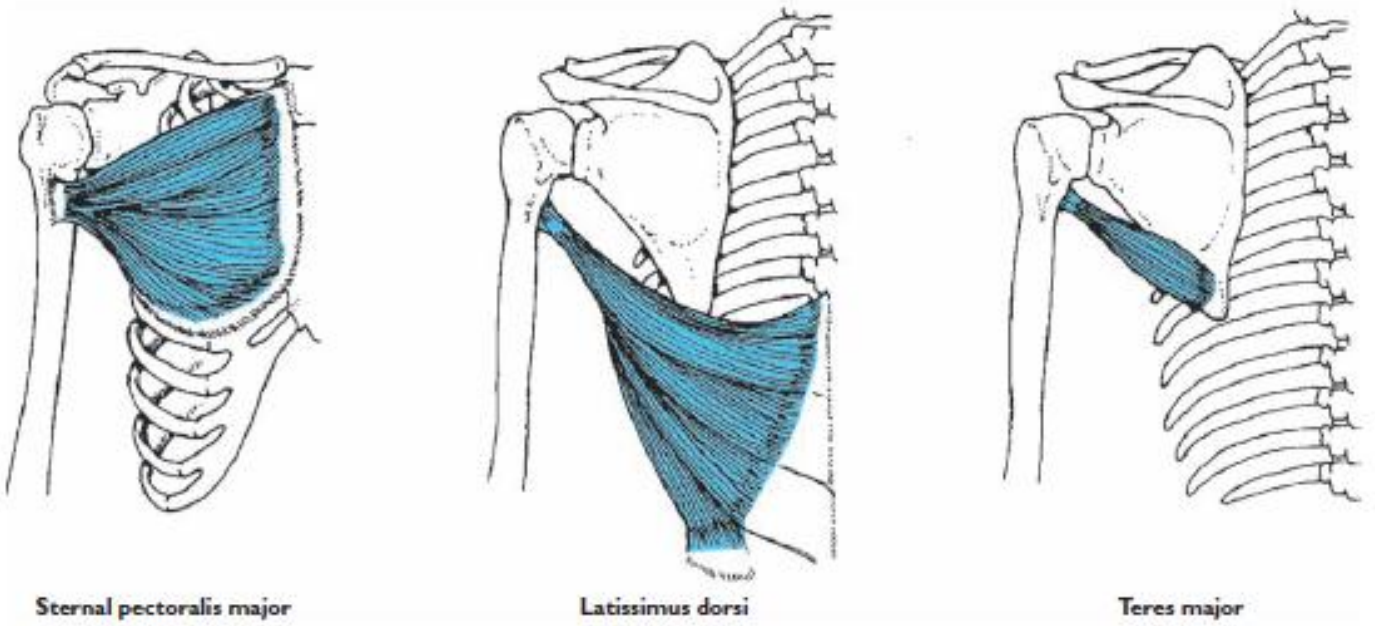
Coracobrachialis

Movements of the Shoulder Complex

What muscles contribute to extension at the glenohumeral joint?

- Åsternal pectoralis major
- Ålatissimus dorsi
- Återes major
- Åassisted by:
  - Ålong head of triceps brachii

Movements of the Shoulder Complex

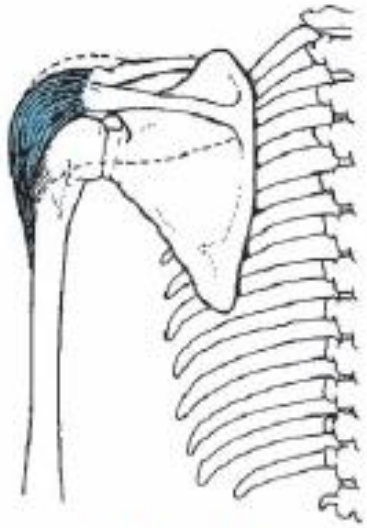


Movements of the Shoulder Complex

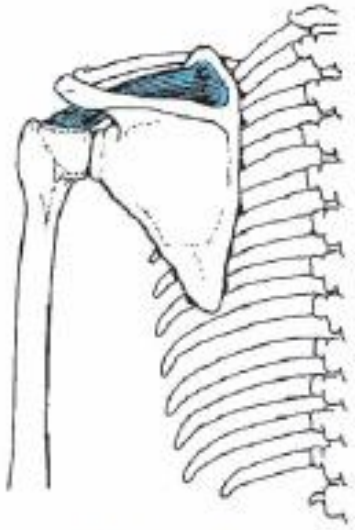
What muscles contribute to abduction at the glenohumeral joint?

Åmiddle deltoid
Åsupraspinatus

Movements of the Shoulder Complex



Middle deltoid



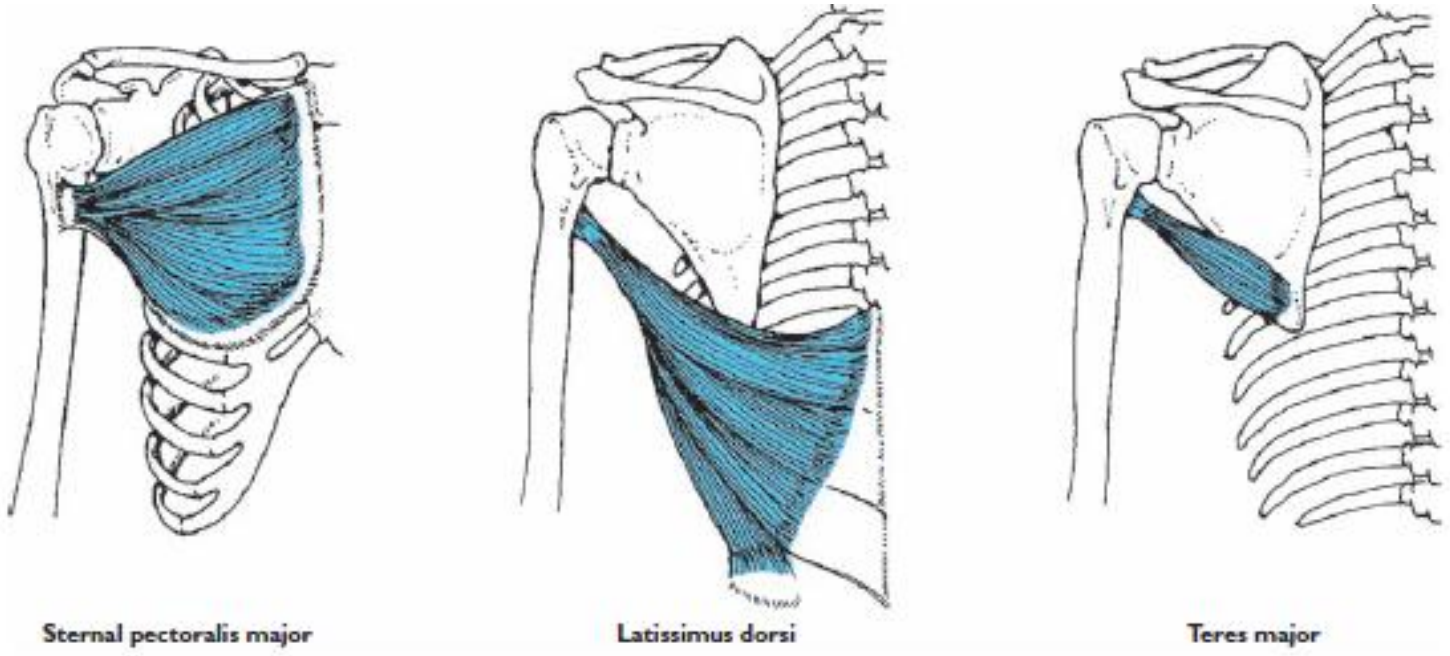
Supraspinatus

Movements of the Shoulder Complex

What muscles contribute to adduction at the glenohumeral joint?

- Ålatissimus dorsi
- Återes major
- Åsternocostal pectoralis
- Åassisted by:
  - Åshort head of biceps brachii
  - Ålong head of triceps brachii

Movements of the Shoulder Complex

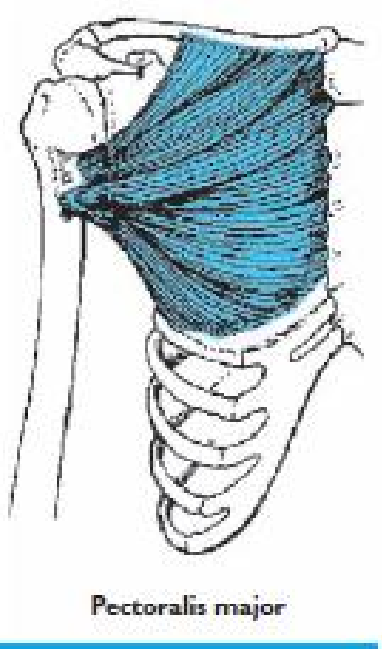


Movements of the Shoulder Complex

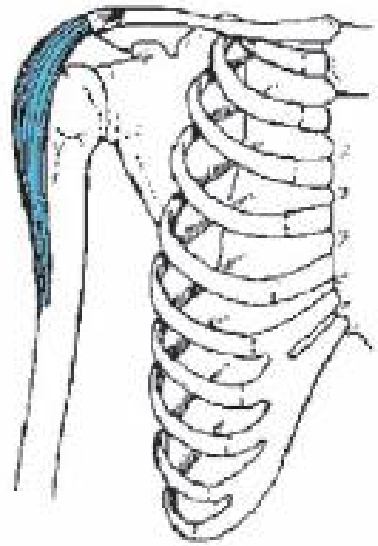
What muscles contribute to medial rotation of the humerus?

- Åsubscapularis
- Återes major
- Åassisted by:
  - Åpectoralis major
  - Åanterior deltoid
  - Ålatissimus dorsi
  - Åshort head of biceps brachii

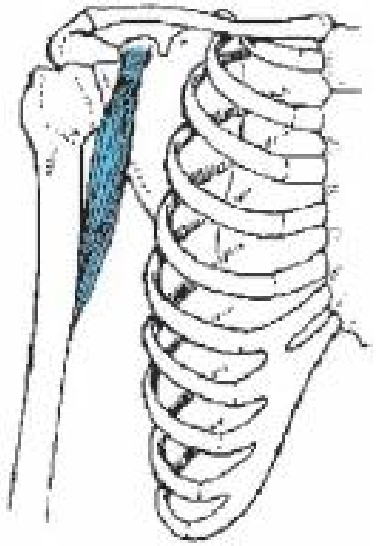
Movements of the Shoulder Complex



Pectoralis major



Anterior deltoid



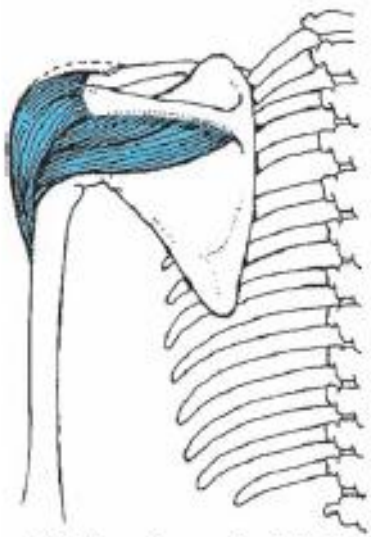
Coracobrachialis

Movements of the Shoulder Complex

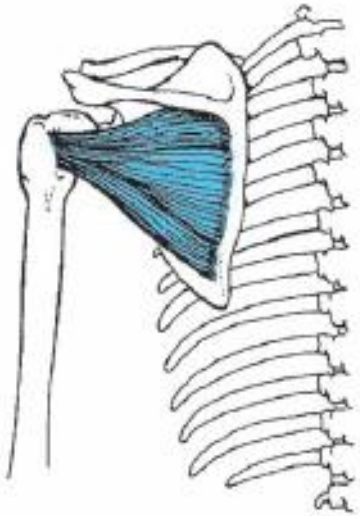
What muscles contribute to lateral rotation of the humerus?

- Åinfraspinatus
- Återes minor
- Åassisted by:
  - Åposterior deltoid

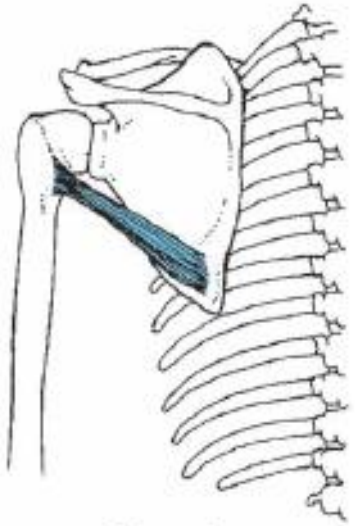
Movements of the Shoulder Complex



Middle and posterior deltoid



Infraspinatus



Teres minor

Movements of the Shoulder Complex

What muscles contribute to horizontal adduction of the humerus?

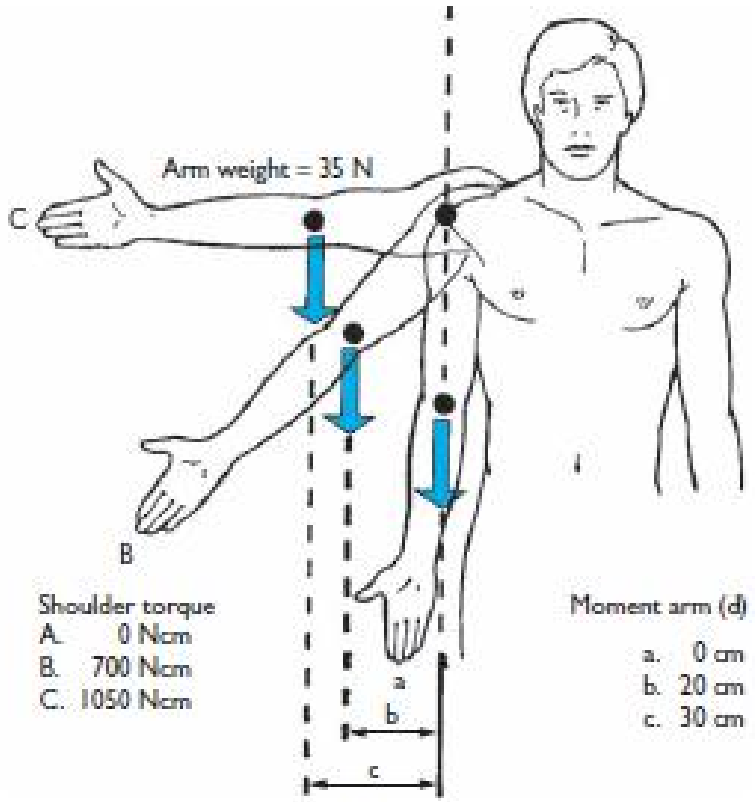
- pectoralis major
- anterior deltoid
- coracobrachialis
- assisted by:
  - short head of biceps brachii

Movements of the Shoulder Complex

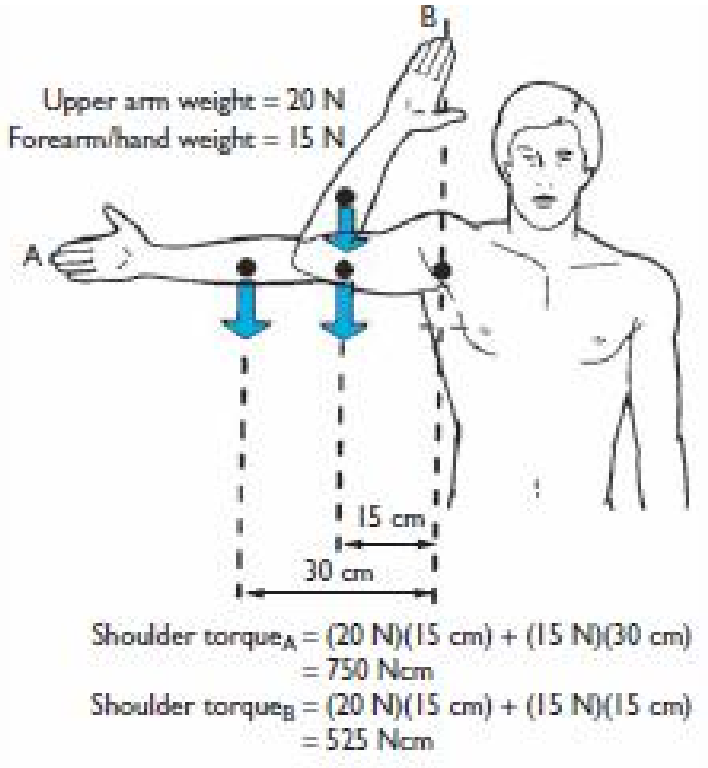
What muscles contribute to horizontal abduction of the humerus?

- Åinfraspinatus
- Åmiddle and posterior deltoid
- Återes minor
- Åassisted by:
  - Återes major
  - Ålatissimus dorsi

Loads on Shoulder

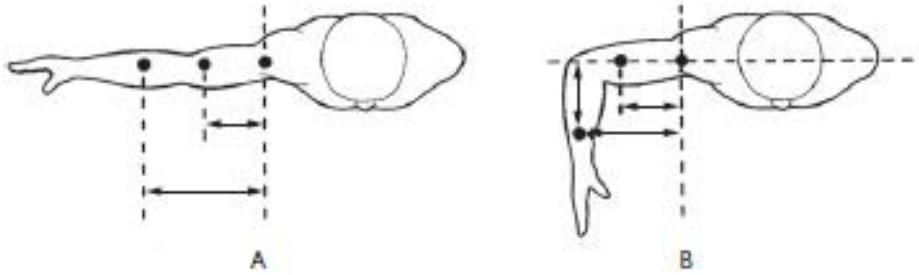


Loads on Shoulder



Shoulder torque$_A$ = (20 N)(15 cm) + (15 N)(30 cm)
= 750 Ncm

Shoulder torque$_B$ = (20 N)(15 cm) + (15 N)(15 cm)
= 525 Ncm

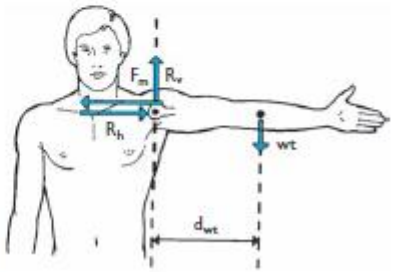


SAMPLE PROBLEM 7.1

Using the simplifying assumptions of Poppen and Walker (38), a free body diagram of the arm and shoulder can be constructed as shown below. If the weight of the arm is 33 N, the moment arm for the total arm segment is 30 cm, and the moment arm for the deltoid muscle (F_m) is 3 cm, how much force must be supplied by the deltoid to maintain the arm in this position? What is the magnitude of the horizontal component of the joint reaction force (R_h)?

Known

$wt = 33\ N$
$d_{wt} = 30\ cm$
$d_m = 3\ cm$



Solution

The torque at the shoulder created by the muscle force must equal the torque at the shoulder created by arm weight, yielding a net shoulder torque of zero.

$$\sum T_s = 0$$

$$\sum T_s = (F_m)(d_m) - (wt)(d_{wt})$$

$$0 = (F_m)(3\ cm) - (33\ N)(30\ cm)$$

$$0 = (F_m)(3\ cm) - (33\ N)(30\ cm)$$

$$F_m = \frac{(33\ N)(30\ cm)}{3\ cm}$$

$$F_m = 330\ N$$

Since the horizontal component of joint reaction force (R_h) and F_m are the only two horizontal forces present, and since the arm is stationary, these forces must be equal and opposite. The magnitude of R_h is therefore the same as the magnitude of F_m.

$$R_h = 330\ N$$

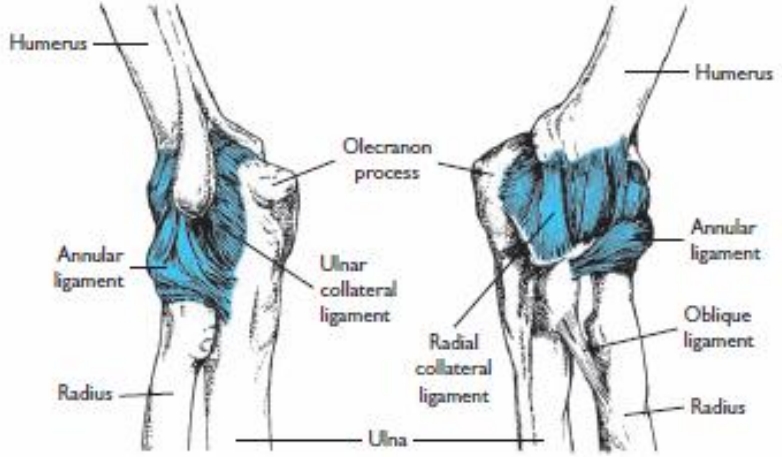
Note: Both components of the joint reaction force are directed through the joint center, and so have a moment arm of zero with respect to the center of rotation.

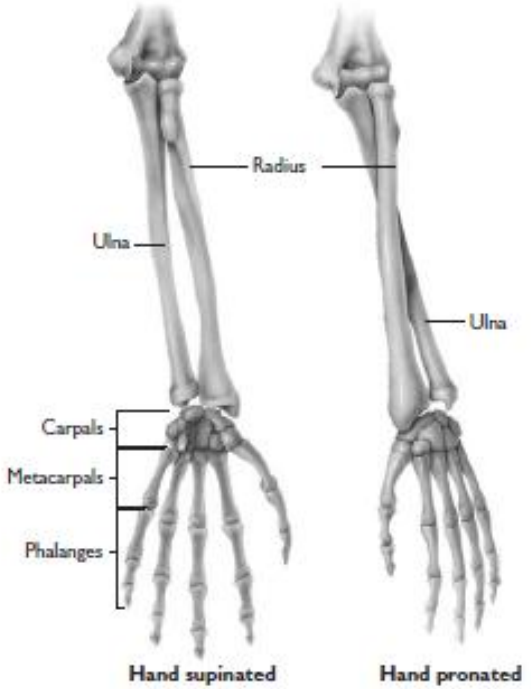
Structure of the Elbow

What is the humeroulnar joint?

Åhinge joint in which the humeral trochlea articulates with the trochlear fossa of the ulna

Åconsidered to be *the* elbow joint





Structure of the Elbow

What is the humeroradial joint?

(gliding joint in which the capitellum of the humerus articulates with the proximal end of the radius)

Structure of the Elbow

What are the radioulnar joints?

- the proximal and distal radioulnar joints are pivot joints
- the middle radioulnar joint is a syndesmosis

Movements at the Elbow

What muscles contribute to flexion at the elbow?

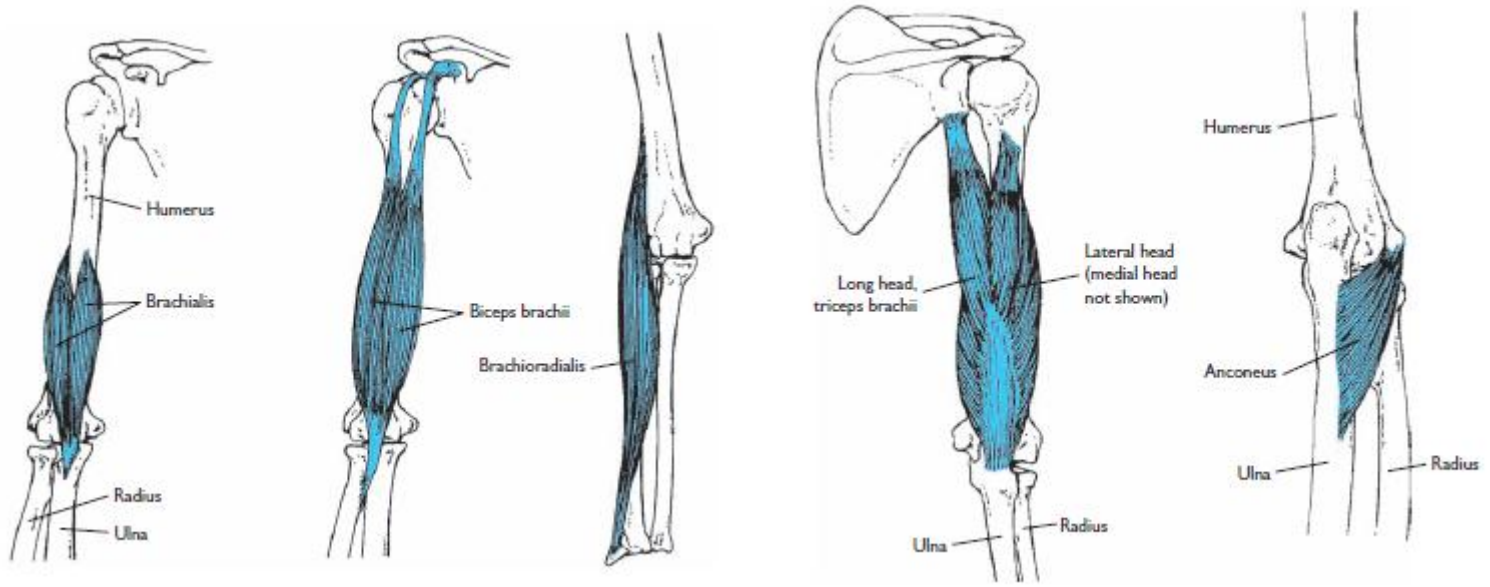
- Åbrachialis
- Åbiceps brachii
- Åbrachioradialis

Movements at the Elbow

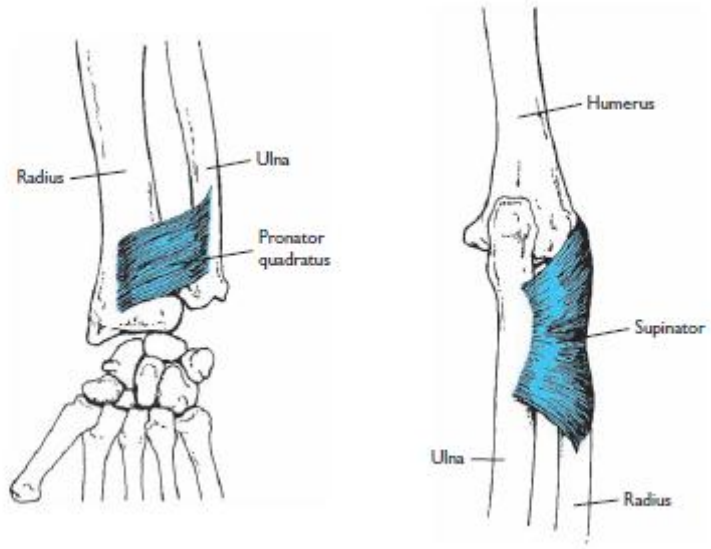
What muscles contribute to extension at the elbow?

- Åtriceps brachii
- Åassisted by:
  - Åanconeus

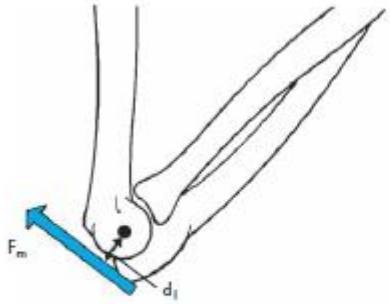
Movements at the Elbow

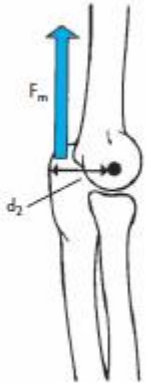


Movements at the Elbow



Loads on Elbow



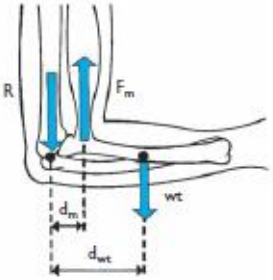


SAMPLE PROBLEM 7.2

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

$wt = 15\ N$
$d_{wt} = 15\ cm$
$d_m = 5\ cm$



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.

$$\sum T_o = 0$$
$$\sum T_o = (F_m)(d_m) - (wt)(d_{wt})$$
$$0 = (F_m)(5\ cm) - (15\ N)(15\ cm)$$
$$F_m = \frac{(15\ N)(15\ cm)}{5\ cm}$$
$$F_m = 45\ N$$

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.

$$\sum F_v = 0$$
$$\sum F_v = F_m - wt - R$$
$$\sum F_v = 45\ N - 15\ N - R$$
$$R = 30\ N$$

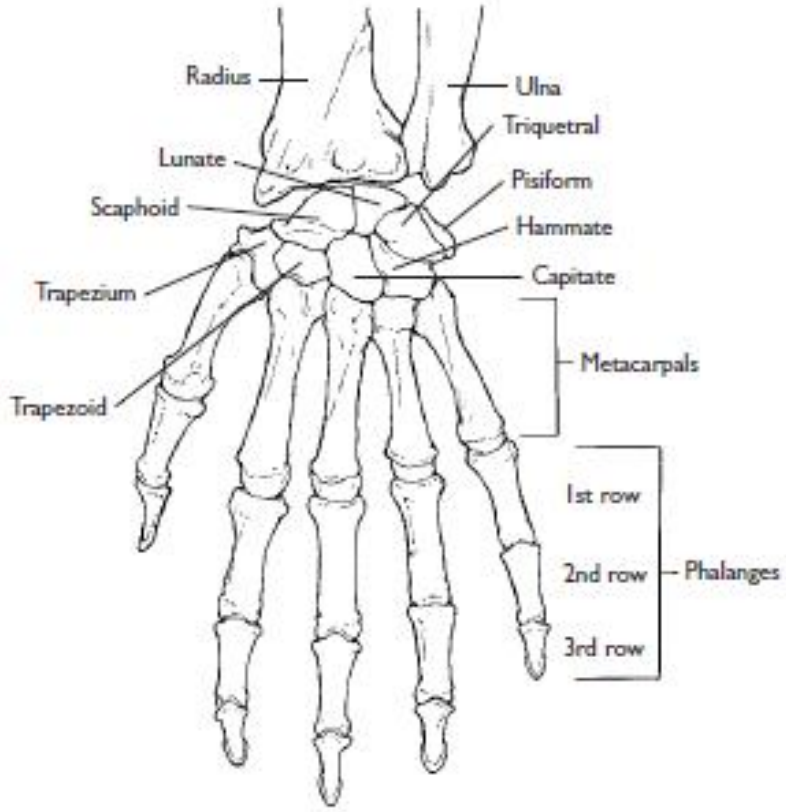
Structure of the Wrist

What are the radiocarpal joints?

Åcondyloid articulations between the radius and the three carpal bones

Å(these joints comprise the wrist)

Structure of the Wrist



Structure of the Wrist

What is the function of the retinacula at the wrist?

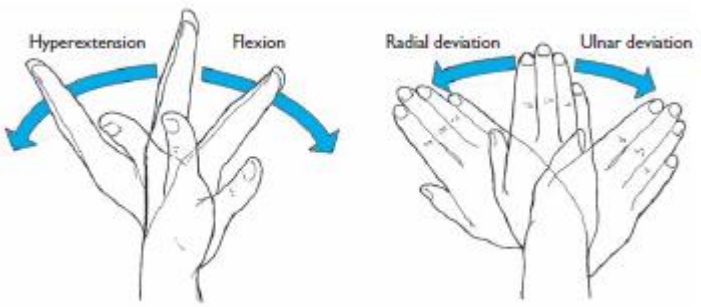
(these fibrous bands of fascia form protective passageways through which tendons, nerves, and blood vessels pass)

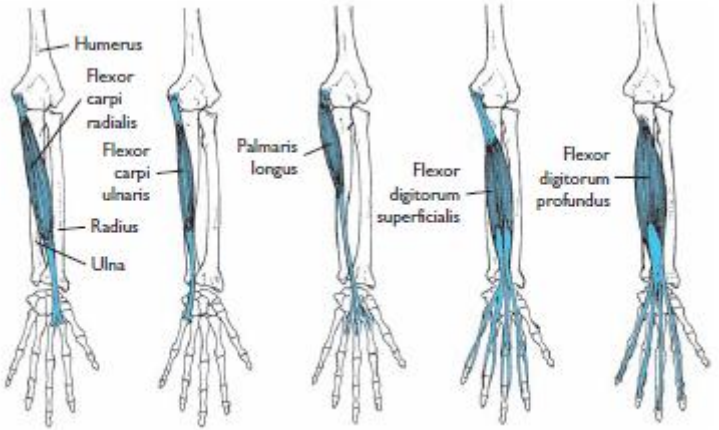
Movements at the Wrist

What muscles contribute to flexion at the wrist?

- Åflexor carpi radialis
- Åflexor carpi ulnaris
- Åpalmaris longus
- Åassisted by:
  - Åflexor digitorum superficialis
  - Åflexor digitorum profundus

Movements at the Wrist



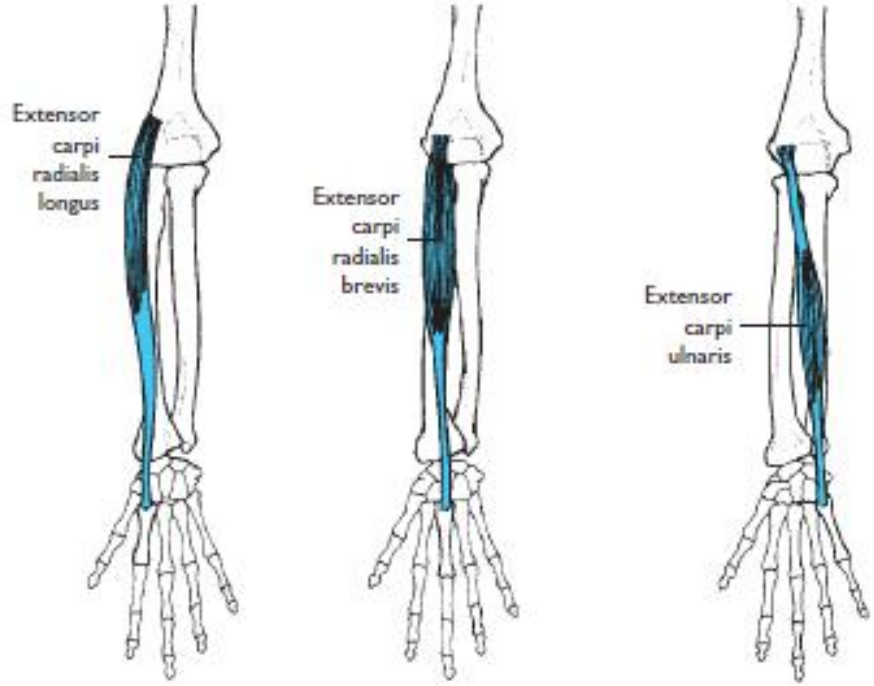


Movements at the Wrist

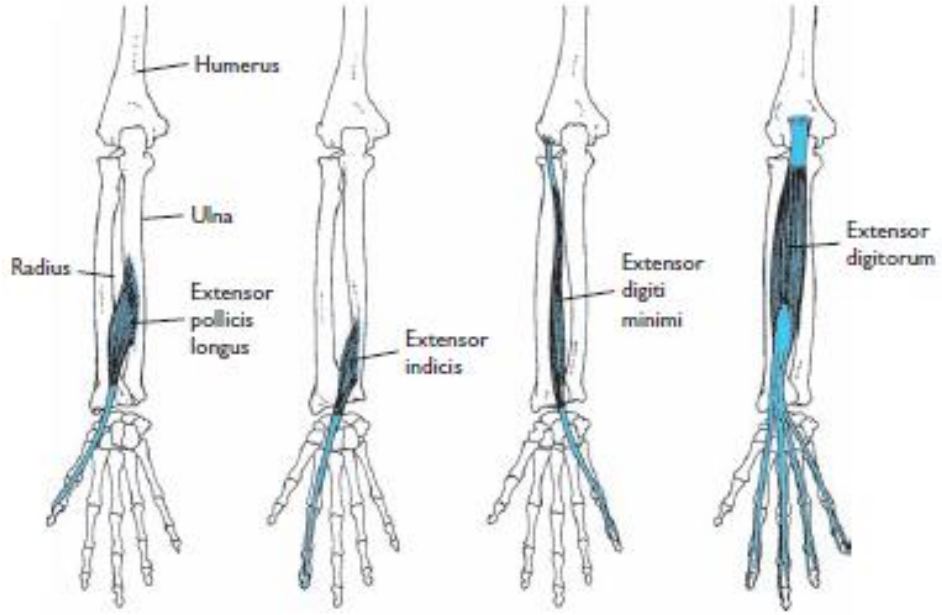
What muscles contribute to extension at the wrist?

- Åextensor carpi radialis longus
- Åextensor carpi radialis brevis
- Åextensor carpi ulnaris
- Åassisted by:
  - Åother wrist extensor muscles

Movements at the Wrist



Movements at the Wrist

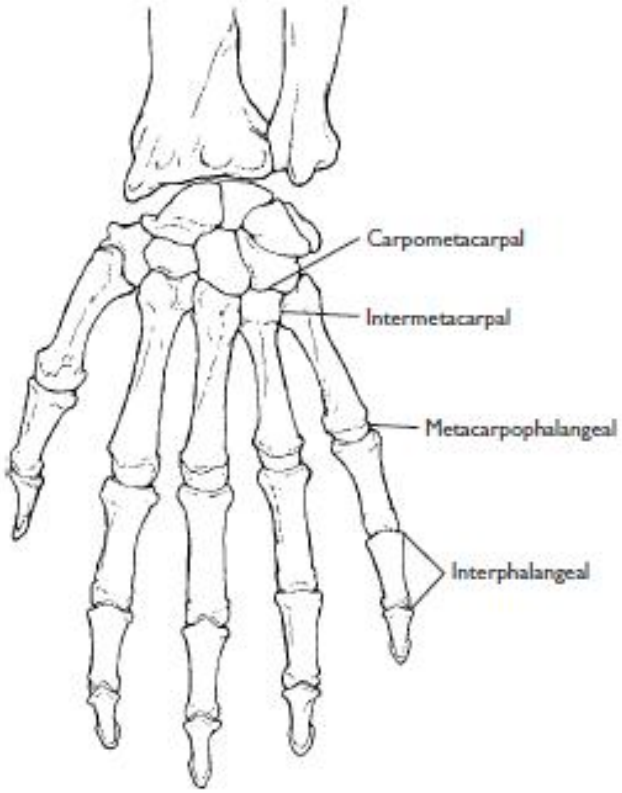


Structure of the Joints of the Hand

What are the carpometacarpal joints?

- the carpometacarpal joint of the thumb is a saddle joint
- the other carpometacarpal joints are gliding joints

Structure of the Joints of the Hand



Structure of the Joints of the Hand

What are the intermetacarpal joints?

(irregular joints between the metacarpals that share joint capsules with the carpometacarpal joints)

Structure of the Joints of the Hand

What are the metacarpophalangeal joints?

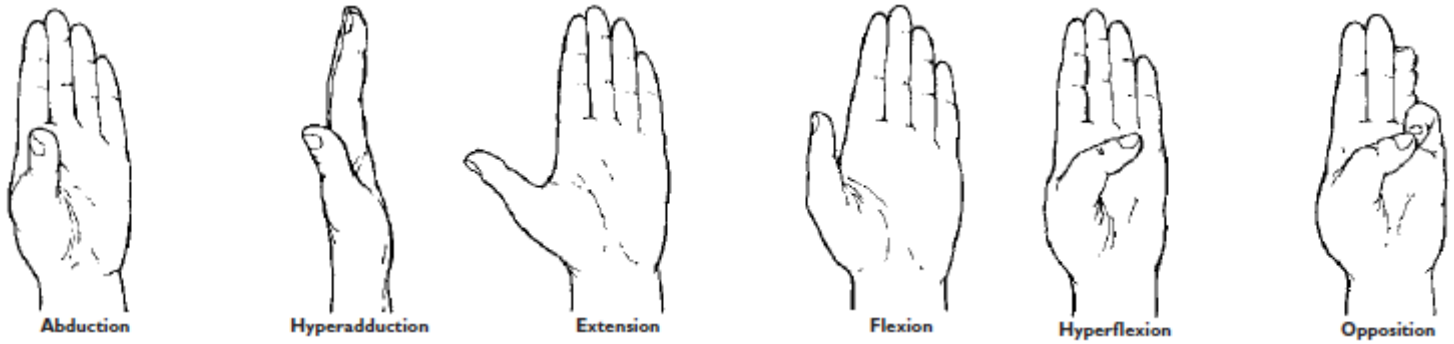
- Åcondyloid joints between the rounded distal heads of the metacarpals and the concave proximal ends of the phalanges
- Åthese joints form the knuckles of the hand

Structure of the Joints of the Hand

What are the interphalangeal joints?

(the proximal and distal interphalangeal joints of the fingers and the single interphalangeal joint of the thumb are all hinge joints)

Movements of the Hand

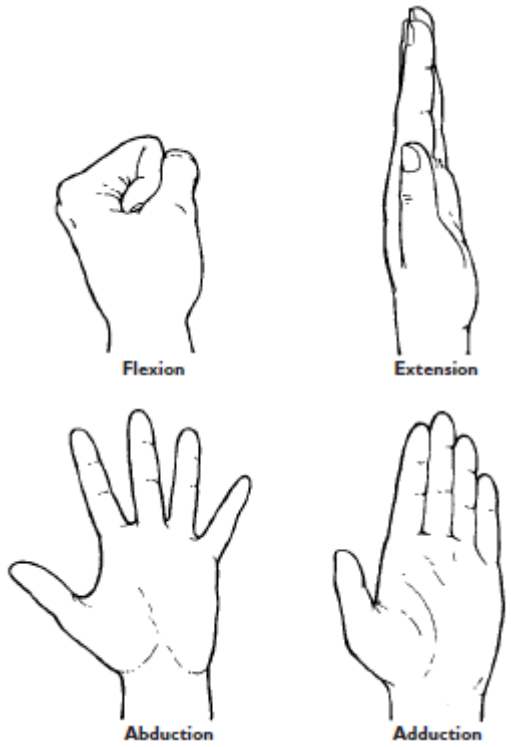


Movements of the Hand

What motions are permitted at metacarpophalangeal joints 2-5?

- Åflexion
- Åextension
- Åabduction
- Åadduction
- Åcircumduction

Movements of the Hand



Movements of the Hand

What muscles are responsible for motions of the hand?

- there are nine extrinsic muscles with attachments both proximal and distal to the wrist
- there are ten intrinsic muscles with both attachments distal to the wrist

Chapter 7

The Biomechanics of the Human Upper Extremity