# Shoulder Biomechanics

Lecture originally developed by
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# Outline

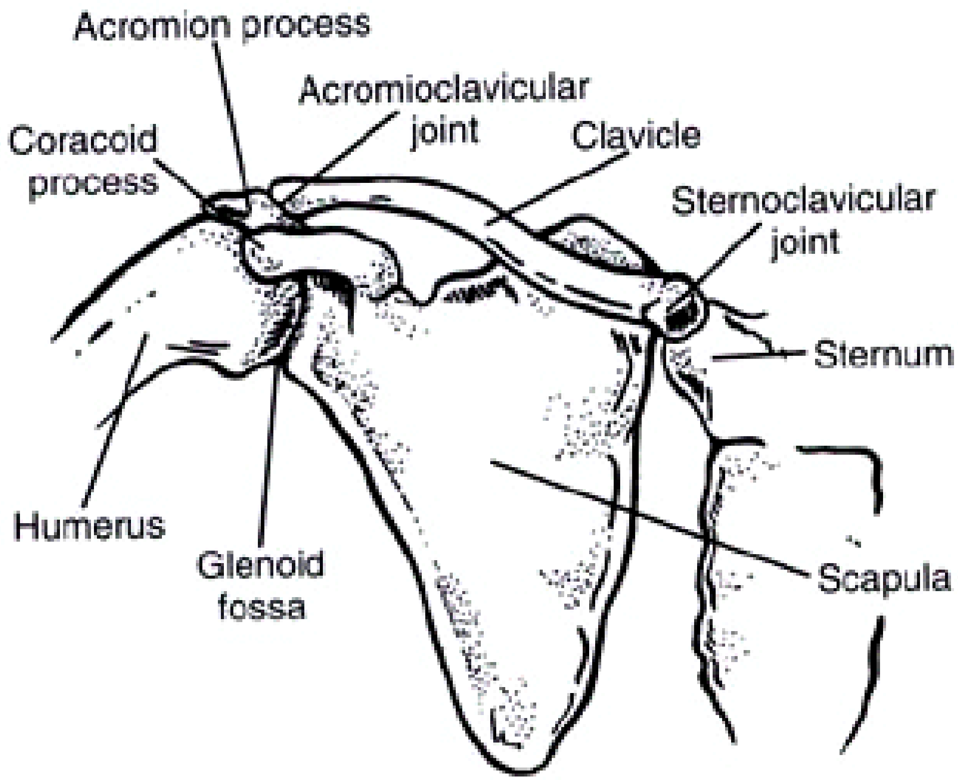
- **Anatomy**
- Biomechanics
- Problems

# Shoulder Complex

- Greatest _______________
- Greatest Predisposition for Dislocation
- Little ______ Stability (Mainly Ligaments)
- Range of Motion Starts at ______° or Greater in all Planes and Decreases with Age (activity slows this process)

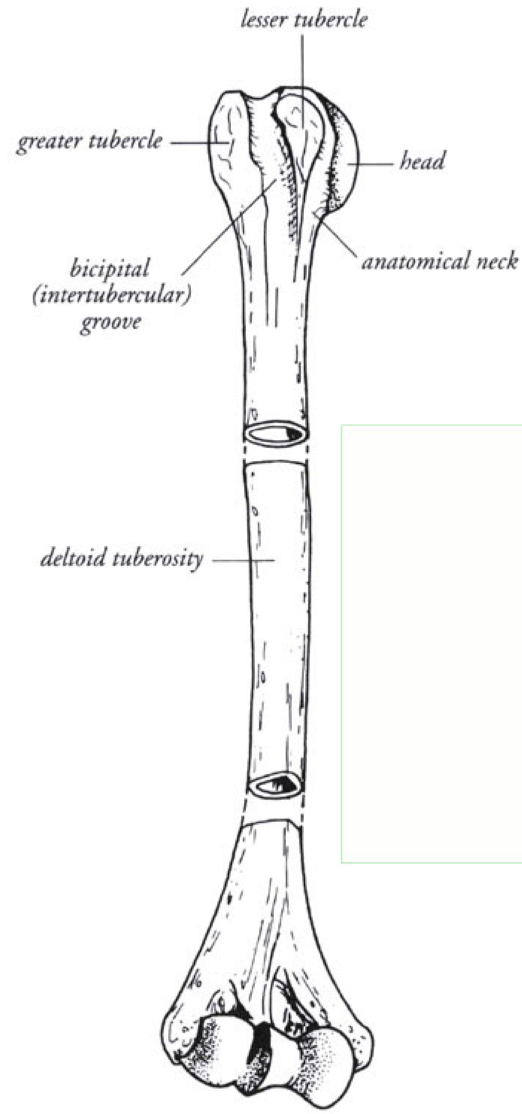
# Bones

- Humerus
- Clavicle
- Scapula
- Ribs



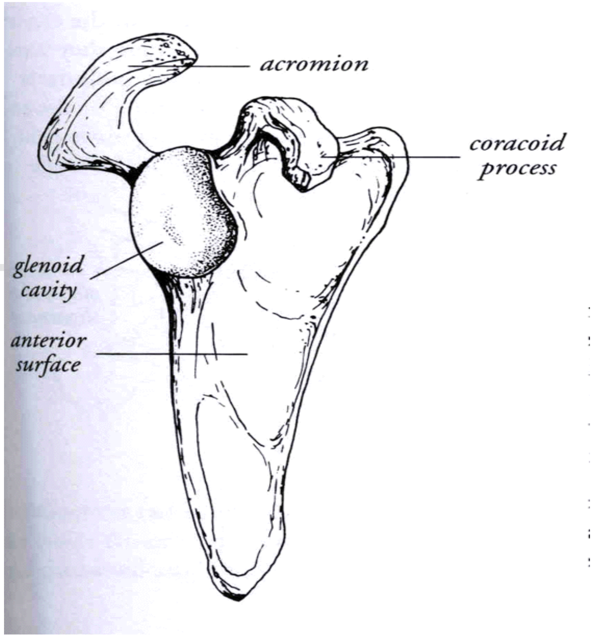
# Humerus

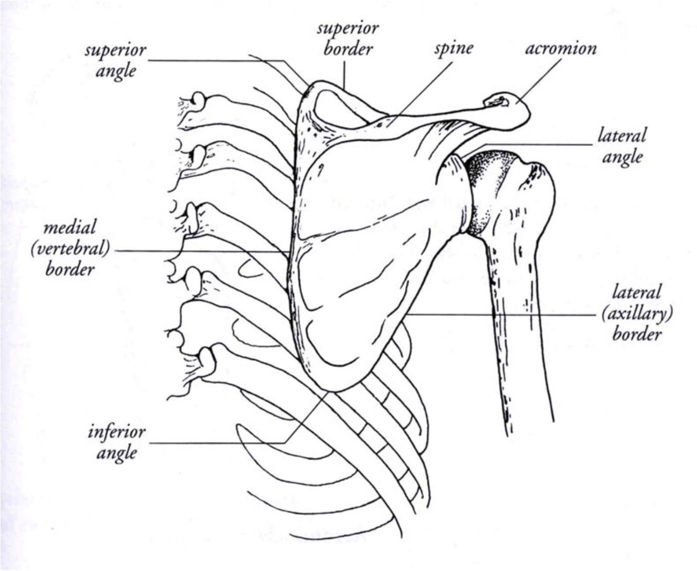
- Articular Surface (33-55 mm)
- ____° from Shaft
- 32° Retroverted (Rotated _________)



# Scapula

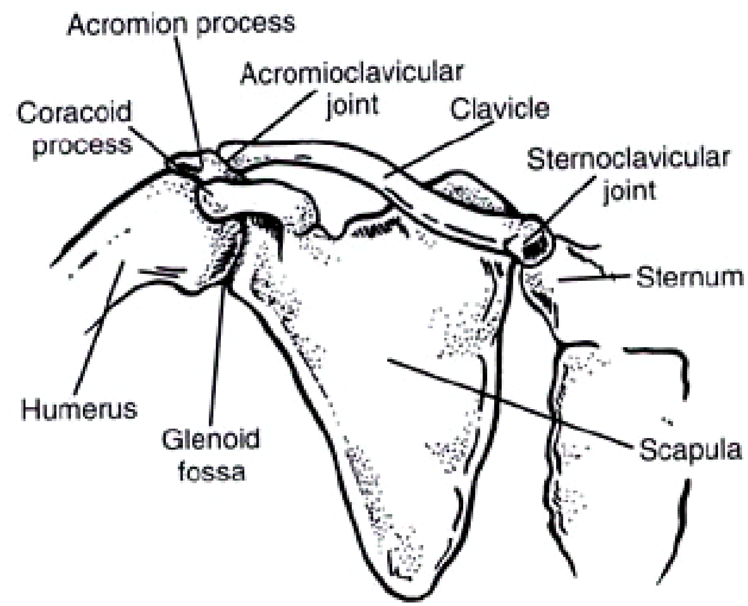
- Glenoid Fossa
  - 41 by 25 mm
  - Pear Shaped
  - _____ Degree Tilt (Posterior)(Retrotilted)
- Glenoid Labrum
  - Joint Capsule
  - Glenohumeral Ligaments
  - Long Head of the Biceps Tendon
- Minimal ___________ Contact (Large Range of Motion)



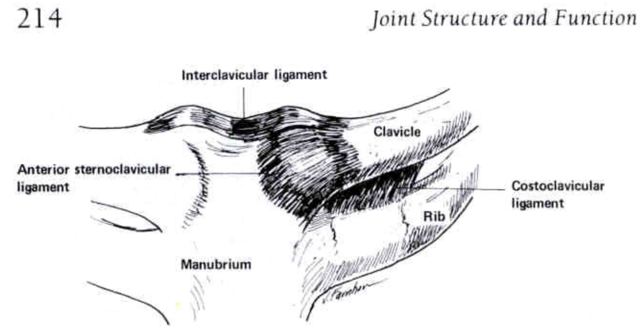



# Joints

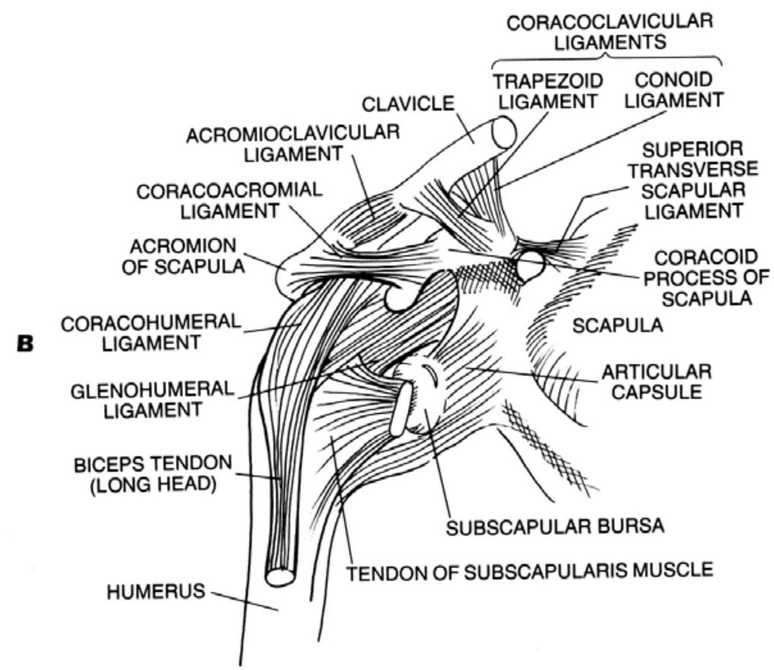
- Glenohumeral
- ______________
- *Acromioclavicular*
- ______________
    - Last 3 Collectively Called Shoulder Girdle



# Ligaments

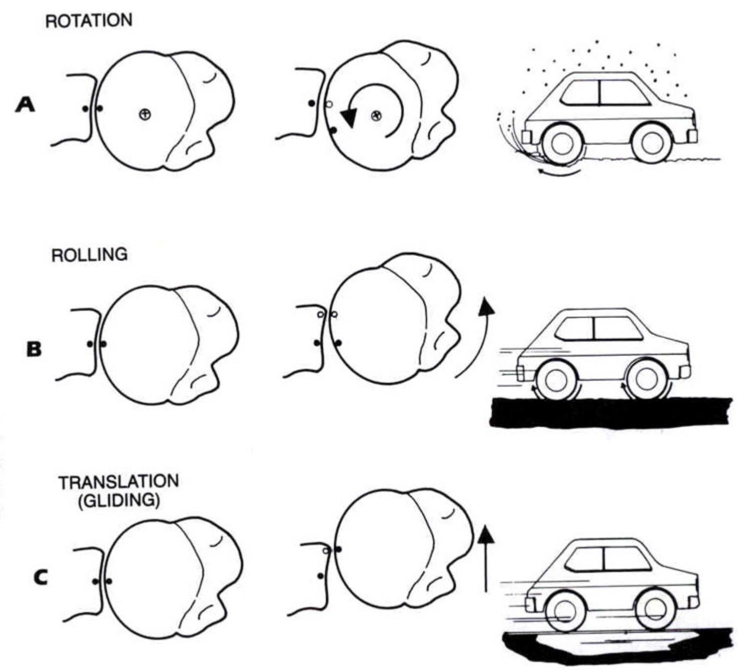



- Glenohumeral
  - ______________
  - Superior, Middle, Inferior Glenohumeral
- Acromioclavicular
  - Conoid
  - Trapezoid
- Sternoclavicular
  - ______________
  - Sternoclavicular
  - Costoclavicular



# Glenohumeral Joint Movement

- Flexion (____)/Extension (____) (Sagittal)
- Abduction(180)/Adduction (-75) (_____________)
- Internal(____)/External Rotation(-90) (_________________)
- Horizontal Abduction(____) /Adduction(-45) (Flexion/Extension)
- Primarily Rotational (____)



# Elevation Planes

- Frontal
- Sagittal
- Scapular
  - ____________ Advantageous

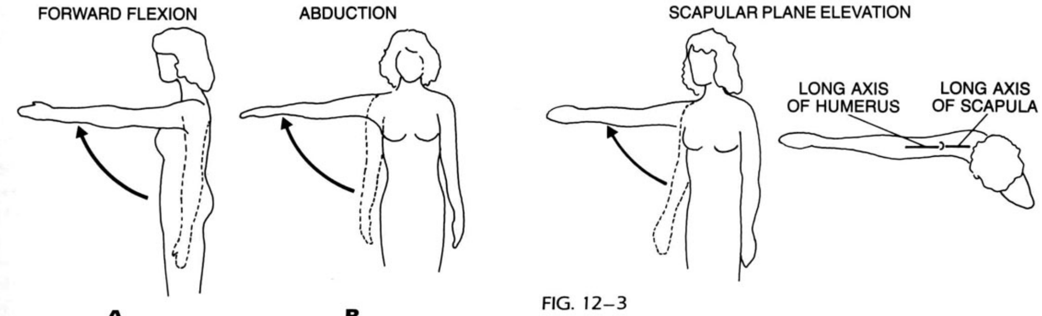



FIG. 12–2
**A.** Forward flexion. The humerus is in the sagittal plane. **B.** Abduction. The humerus is in the frontal plane.

FIG. 12–3
Elevation in the scapular plane, which is midway between forward flexion and abduction. The humerus is in the plane of the scapula.

# Shoulder Girdle Movement

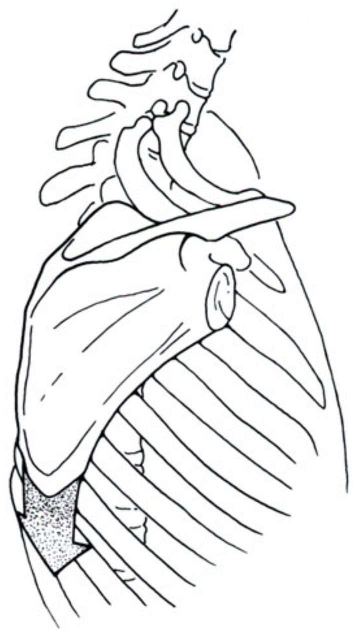
- Upward/ Downward Rotation (________)
- Protraction/Retraction (___________/___________)(Transverse)
- Upward/ Downward Tilt (___________)
- Elevation/Depression (____________)

# Elevation and Tilting

## Movements of the scapula

These movements were shown in external view on page 102. We will now look at the bones themselves.

In **elevation**, the scapula moves upward and away from the ribcage.



In **depression**, it moves downward and fits more snugly against the ribcage.

*Figure 7–1.*

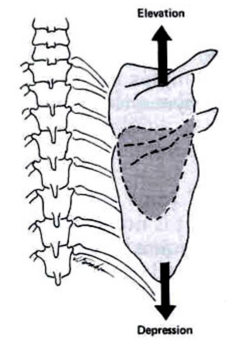



*Figure 7–2.*

***Figure 7–1.*** Resting position of the scapula on the thorax.

***Figure 7–2.*** Elevation/depression of the scapula at the scapulothoracic joint.

# Protraction and Rotation

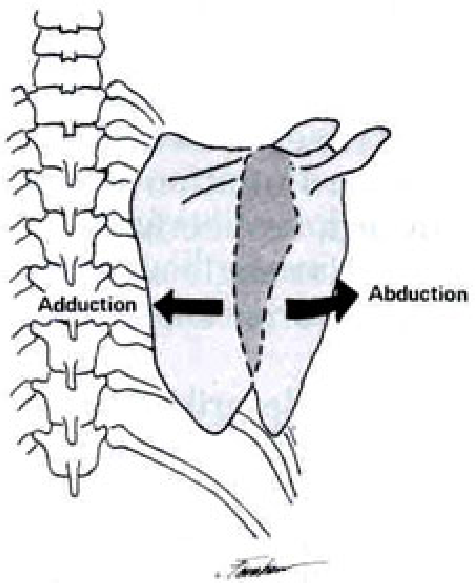



*Figure 7–3.*

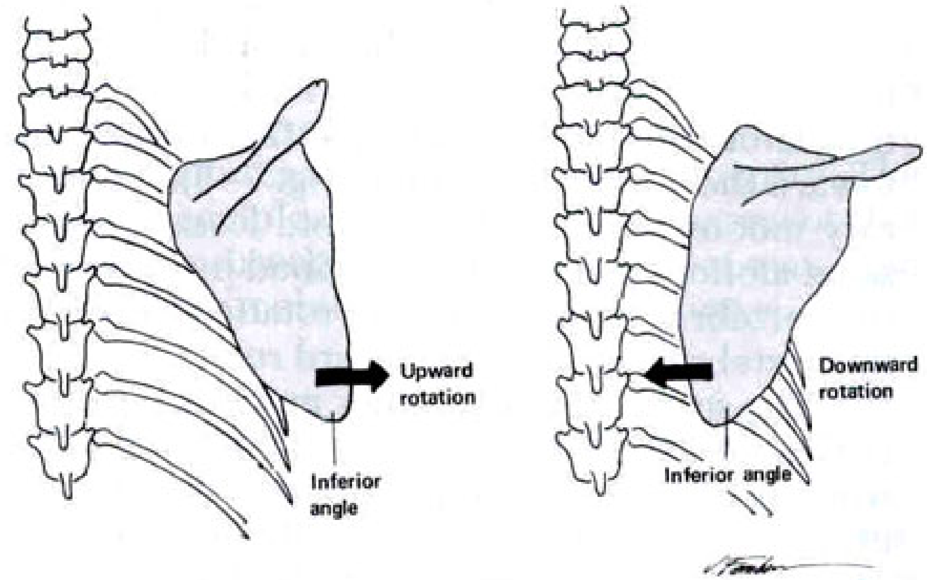



*Figure 7–4.*

*Figure 7–3.* Abduction/adduction of the scapulothoracic joint.

*Figure 7–4.* Upward-downward rotation of the scapula at the scapulothoracic joint.

# Large Range of Motion

- Motion Spread Through All articulations (Synchronous and Simultaneous)
- Glenoid Fossa Mobility (Scapular Motion)
- Optimal Portion of Length-Tension Curve
- Minimal Constraints

# Joint Movement Patterns

- Many Ways a Joint Could Move
- Glenohumeral Joint Initial movement
  - __° Flexion
  - __° Abduction
- Spine
- Reasons for Different Opinions
  - Measurement Techniques
  - Planes
  - Anatomic Variations

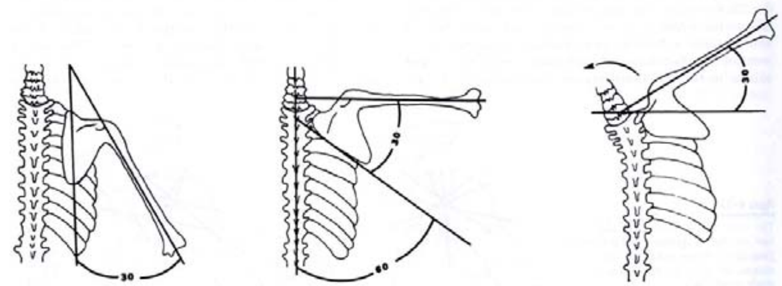
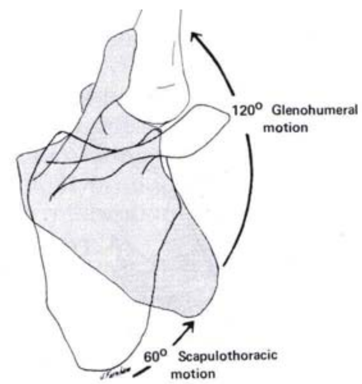



**Figure 6–25**
Arthrodesis of the glenohumeral joint in the optimum position allows arm elevation to and above the horizontal by scapulothoracic motion as well as by tilting of the trunk.



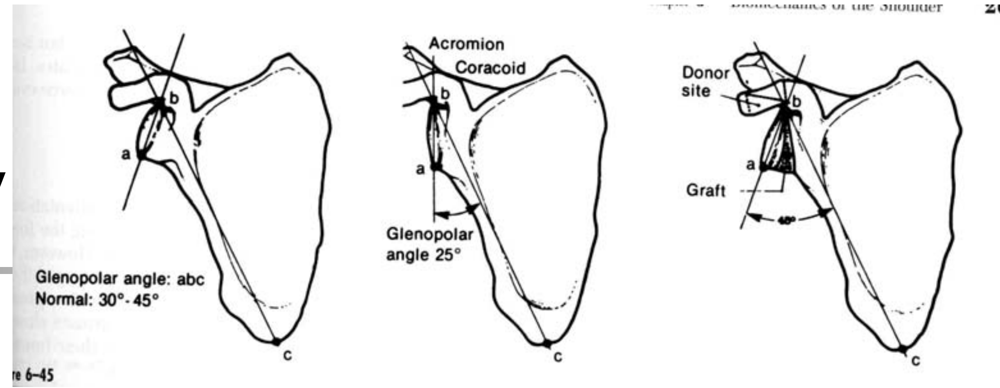
# Opinions on Movement

| | Glenohumeral/ Shoulder Girdle |
|---|---|
| Innman (1944)<br>Flexion/Abduction | 2/1 after 60°/30° - 120°/60° Total Motion |
| Freedman<br>(Scapular Plane) | |
| Doody (Scapular Plane) | |
| Saha (Scapular Plane) | |
| Poppen<br>(Scapular Plane) | |

# Codman's Paradox

- Flex
- Horizontally Abduct
- Adduct
- Rotation with out Rotation

# Joint Stability

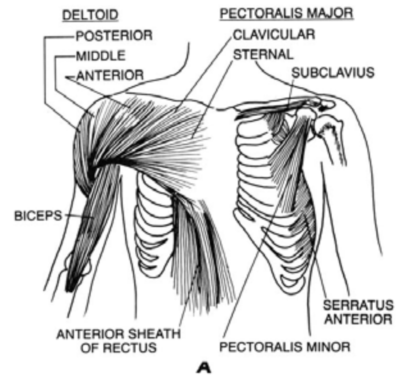


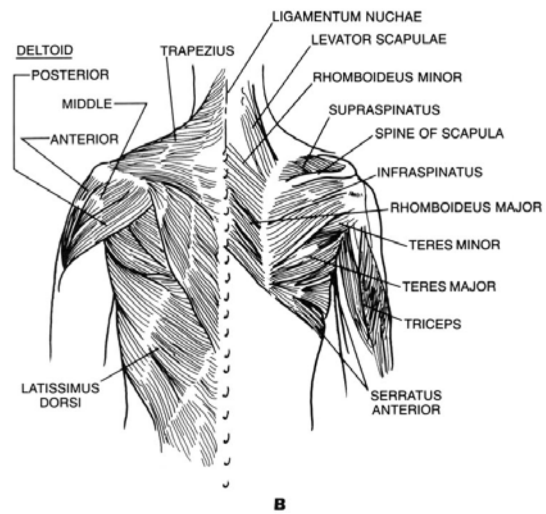

- Glenoid Fossa
  - >___% Longitudinal Length
  - >___% Transverse Length
- __________ Tilt of Glenoid Fossa
- Humeral Head Retroversion
- Intact Capsule and Glenoid Labrum
  - ___________ Pressure
- Muscular Function of the Rotator Cuff
  - Subscapularis
  - Supraspinatus
  - Infraspinatus
  - Upper Teres Minor

•Glenoid Osteotomy

# Glenohumeral Muscles

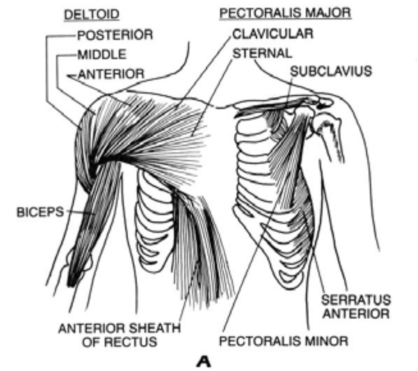
- Deltoid (A, Middle, P)
- Rotator Cuff
  - _______________
  - _______________
  - _______________
  - _______________
- Teres Major
- Coracobrachialis

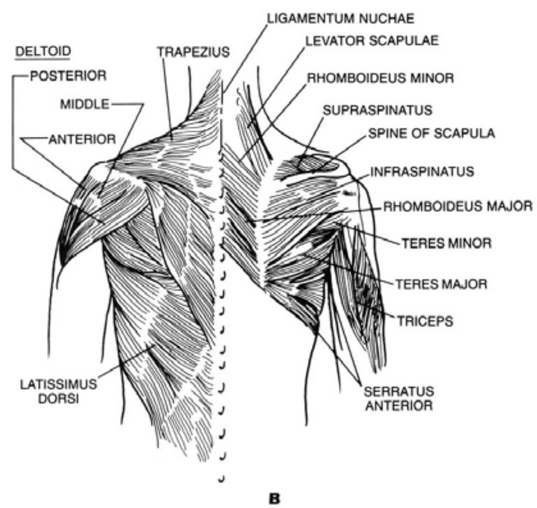


# Scapulothoracic Muscles

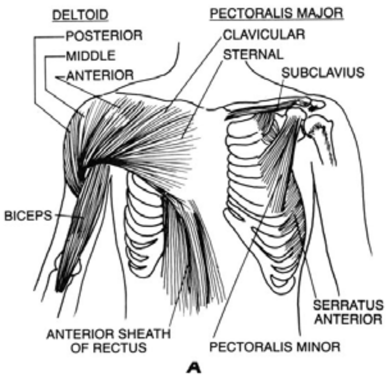
- Trapezius
- Rhomboids
- Levator Scapulae
- ____________________
- Pectoralis Minor

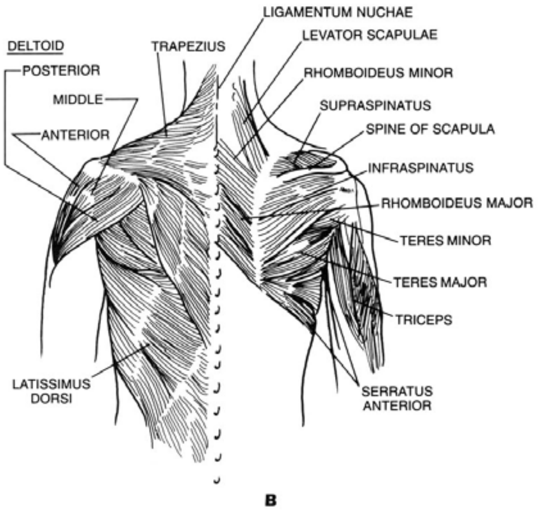


# Multiple Joint Muscles

- Pectoralis Major
- Latissimus Dorsi
- Biceps Brachii
- Triceps (__________)



# Muscular Motions Glenohumeral

| | |
|---|---|
| Ant. Deltoid | Flex, Add <90, Abd >90, _________ Rotation, Horiz. _________ |
| Middle Deltoid | |
| Pos. Deltoid | Extend, Add <90, Abd >90, Ext. Rotation, Horiz. Abd |
| Supraspinatus | Abduct, Int. Rotation |
| Infraspinatus | |
| Teres Minor | |
| Subscapularis | Int. Rotation |
| Teres Major | Extend, Int. Rotation, Add, Horiz. Abd |
| Coracobrachialis | Flex, Horiz. Add |

# Muscular Motions Scapulothoracic

| | |
|---|---|
| Trapezius | |
| | Add, Downward Rotation, Elevation |
| Levator Scapulae | |
| Serratus Anterior | |
| Pectoralis Minor | Abd, Inf-Upward Rotation, Depression, Sup-Downward Rotation, Elevation |

# Muscular Motions of Multiple Joint Muscles

| | |
|---|---|
| Pectoralis Major | |
| | Extend, Int. Rotation, Add, Horiz. Abd |
| Biceps Brachii | |

# Outline

- Anatomy
- **Biomechanics**
- Problems

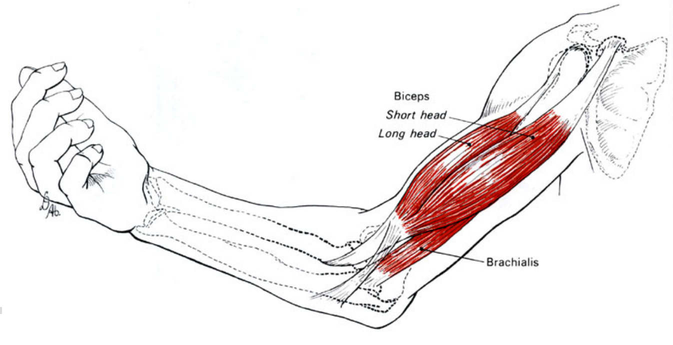
# Reasons for Biomechanical Analysis

- Rehabilitation
  - Therapy Loads
  - Repair Strengths
- Injury
  - Motions That Transfer Higher Loads
  - Injury Mechanisms
    - Dislocation
- Prosthetic Design
  - Stress (Load) Analysis

# Injuries

- Broken Bones
  - Clavicle
  - Scapula
  - Humerus
- Impingement
  - ____________
  - Biceps Tendon
- Bursitis
- Dislocation
  - Subluxation
- Tendon Ruptures
  - __________
  - Biceps

# Impingement




- Compartment
- Inflammation
- Increase in Pressure
- Feedback

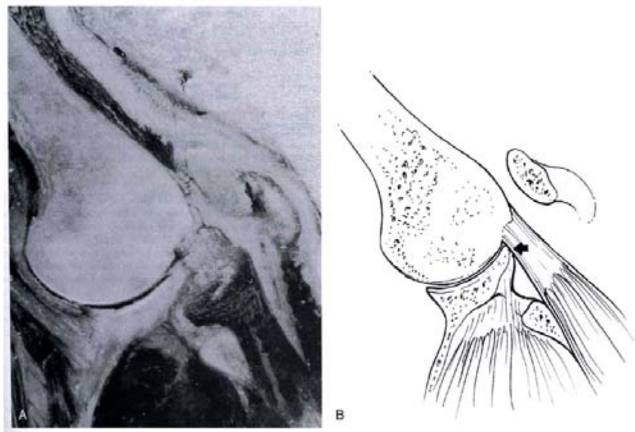
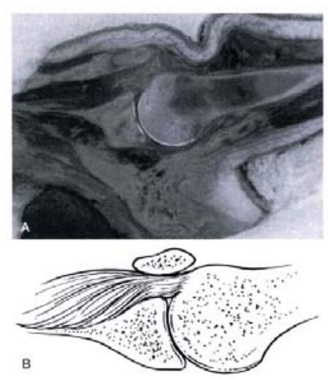
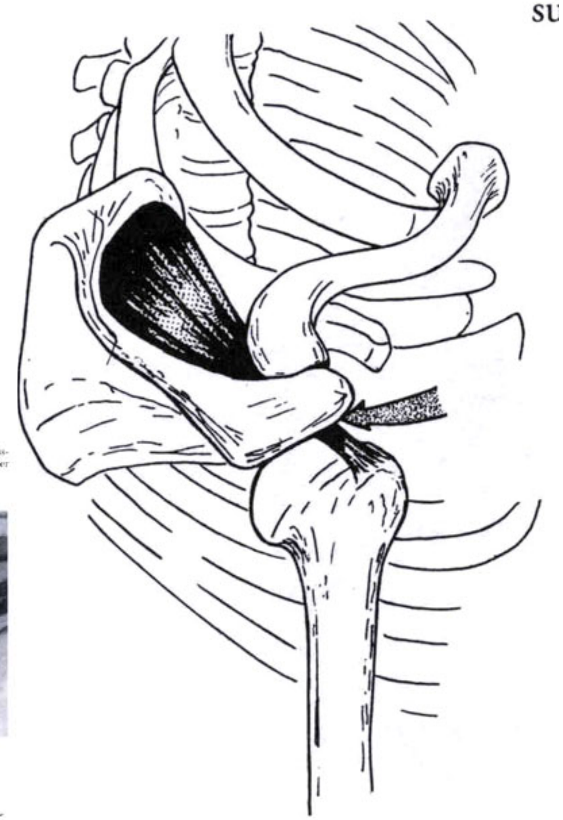


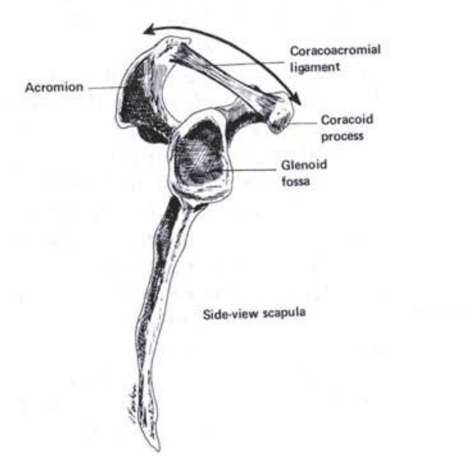

Figure 25–7
Impingement of the rotator cuff on the anterosuperior glenoid labrum during maximal humeral flexion and forceful internal rotation. *A*, Cross-section of a cadaver. *B*, Schematic of *A*. (From Jobe CM, et al: Theories and concepts. *In* Jobe FW, et al [eds]: Operative Techniques in Upper Extremity Sports Injuries. St Louis, MO: Mosby-Year Book, 1996.)

Figure 25–8
Impingement of the rotator cuff between the acromion and glenoid rim during the Hawkins test. *A*, Cross-section of a cadaver. *B*, Schematic of *A*.

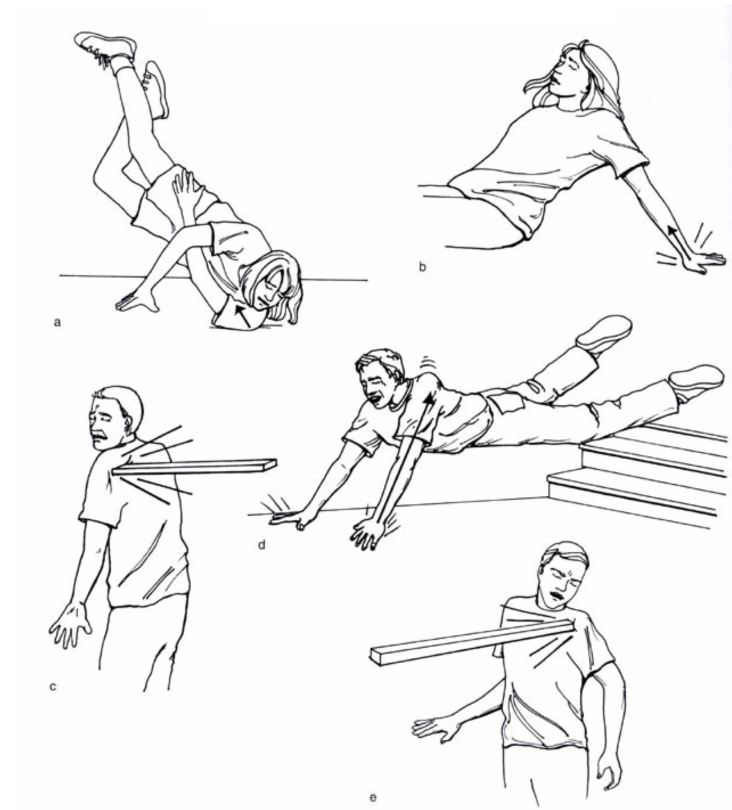


# Dislocation

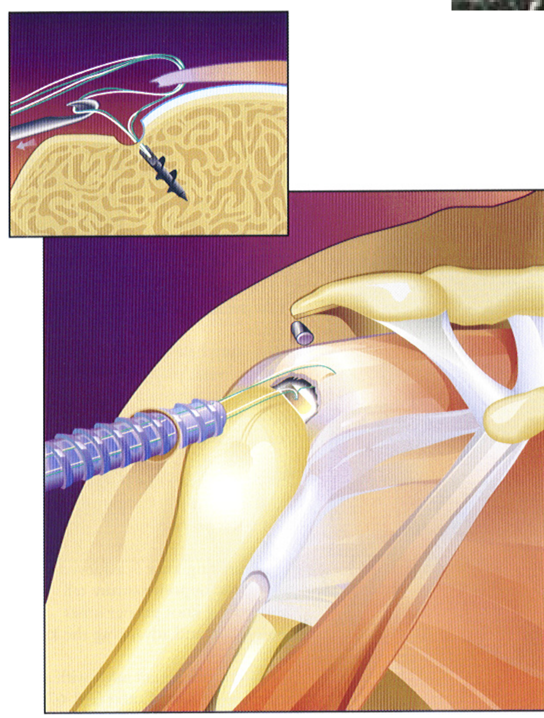


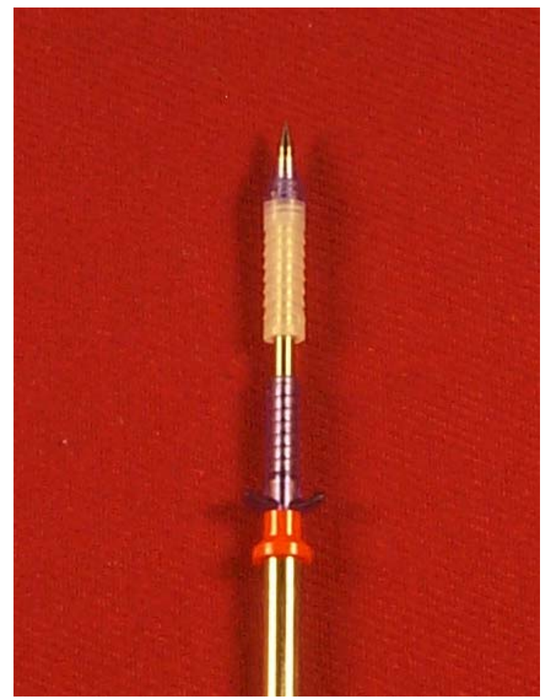

- _______________ Most Common
- Superior Subluxation Difficult
  - Acromion
  - Coracohumeral Ligament
  - Coracoacromial Ligament
- Rotator Cuff
  - Provides Dynamic Stability
  - Protects Inferior, Anterior, Posterior Displacements



# Rotator Cuff Repair

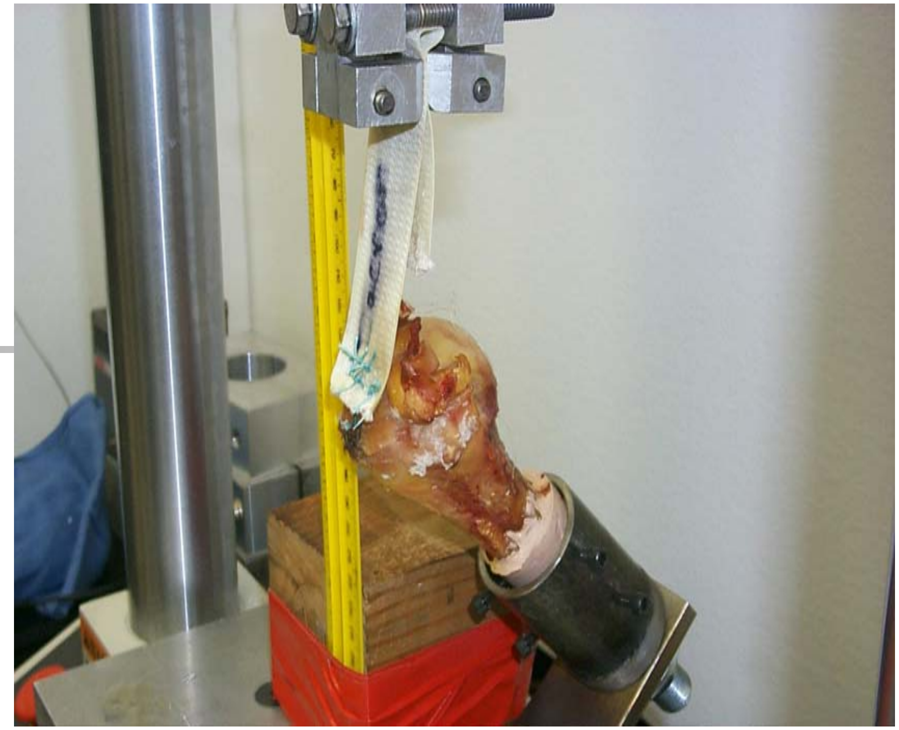
- Suture Anchor
- Bioscrew
- Tack
- Cyclic Loads to ____N (2/3 Max Contraction Force)
- 45°





# Testing

- Suture Anchor Good Overall
- Tack Best for Good Cuff-Weak Bone
- Screw Best for Strong Bone-Any Cuff




# Joint Replacement

- Loosening
  - Cemented
  - Uncemented
- Prostheses Design
- Stress Shielding

**Figure 6–60**

Glenoid loosening patterns are consistent with increased superior forces across the glenohumeral joint, noted particularly during the first 60 degrees of elevation.

# Troubles with Biomechanical Analysis

- Mobility
  - High Number of Degrees of Freedom
- Muscles
  - Large Number of Muscles Contributing
    - Different Contributions
      - ______________.
      - ______________.
      - Angle of Elevation
  - Multiple Movements
  - Arm Position (example: Biceps)
    - Abductor while humerus is Externally Rotated

# Multiple Motions of Single Muscle

- Anterior Deltoid - Muscle Flexion/Internal Rotation
- Teres Major - Muscle Extension/Internal Rotation
  - ___________.

# Coupling - Forces Acting in Different Directions to Produce the Same Movement

- Downward Rotation
  - Rhomboids-Pectoralis Minor-Serratus Anterior (Superior)
- Upward Rotation (figure)
- Elevation (Frontal)
  - A. Deltoid-Teres Minor-Infraspinatus

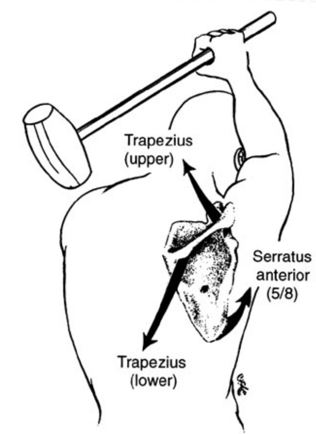



**Figure 7.1.** Representation of the action of the serratus anterior and the lower fibers of the trapezius as a force couple.

# Muscle Pair Ratios

- Flex:**Extension** (____)
- Abd:**Add** (___)
- **Internal**:External (____)
- Adduction-Extension-Flexion-Abduction-Internal Rotation-External Rotation

# Forces at the Shoulder (Innman et al., 1944)

- 90° Abduction
- Deltoid ___Extremity Weight (70% BW)
- GH Joint ___EW (90% BW)
- Rotator Cuff ___EW (85% BW)
- Load Bearing (Approximately 1BW)

# Forces at the Shoulder (Poppen et al., 1978)

- Abduction in the Frontal Plane Elevation
- Bent Arm Reduces Shoulder Force by

____ %

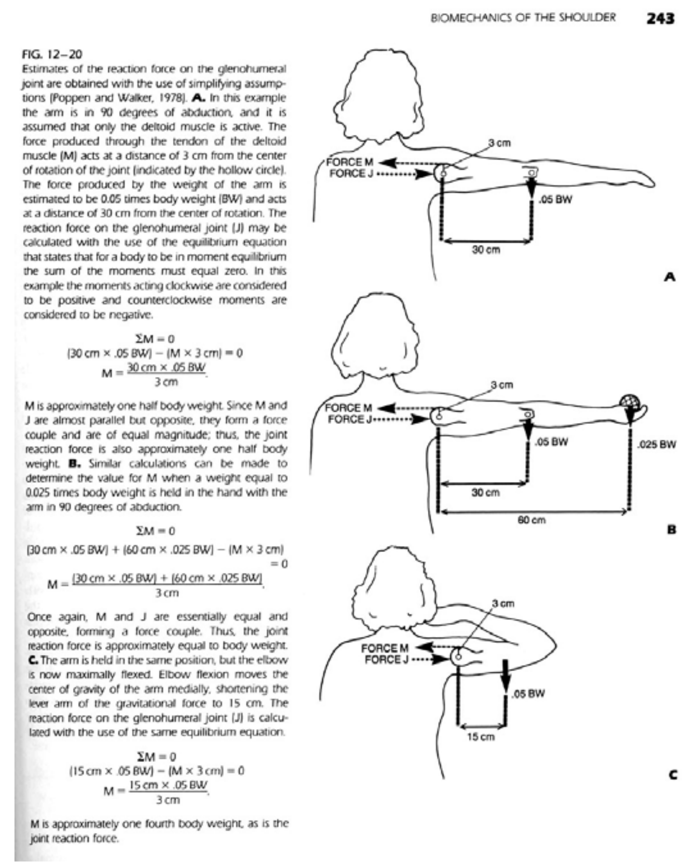



FIG. 12–20

Estimates of the reaction force on the glenohumeral joint are obtained with the use of simplifying assumptions (Poppen and Walker, 1978). **A.** In this example the arm is in 90 degrees of abduction, and it is assumed that only the deltoid muscle is active. The force produced through the tendon of the deltoid muscle (M) acts at a distance of 3 cm from the center of rotation of the joint (indicated by the hollow circle). The force produced by the weight of the arm is estimated to be 0.05 times body weight (BW) and acts at a distance of 30 cm from the center of rotation. The reaction force on the glenohumeral joint (J) may be calculated with the use of the equilibrium equation that states that for a body to be in moment equilibrium the sum of the moments must equal zero. In this example the moments acting clockwise are considered to be positive and counterclockwise moments are considered to be negative.

$$\Sigma M = 0$$
$$(30\text{ cm} \times .05\text{ BW}) - (M \times 3\text{ cm}) = 0$$
$$M = \frac{30\text{ cm} \times .05\text{ BW}}{3\text{ cm}}.$$

M is approximately one half body weight. Since M and J are almost parallel but opposite, they form a force couple and are of equal magnitude; thus, the joint reaction force is also approximately one half body weight. **B.** Similar calculations can be made to determine the value for M when a weight equal to 0.025 times body weight is held in the hand with the arm in 90 degrees of abduction.

$$\Sigma M = 0$$
$$(30\text{ cm} \times .05\text{ BW}) + (60\text{ cm} \times .025\text{ BW}) - (M \times 3\text{ cm}) = 0$$
$$M = \frac{(30\text{ cm} \times .05\text{ BW}) + (60\text{ cm} \times .025\text{ BW})}{3\text{ cm}}.$$

Once again, M and J are essentially equal and opposite, forming a force couple. Thus, the joint reaction force is approximately equal to body weight. **C.** The arm is held in the same position, but the elbow is now maximally flexed. Elbow flexion moves the center of gravity of the arm medially, shortening the lever arm of the gravitational force to 15 cm. The reaction force on the glenohumeral joint (J) is calculated with the use of the same equilibrium equation.

$$\Sigma M = 0$$
$$(15\text{ cm} \times .05\text{ BW}) - (M \times 3\text{ cm}) = 0$$
$$M = \frac{15\text{ cm} \times .05\text{ BW}}{3\text{ cm}}.$$

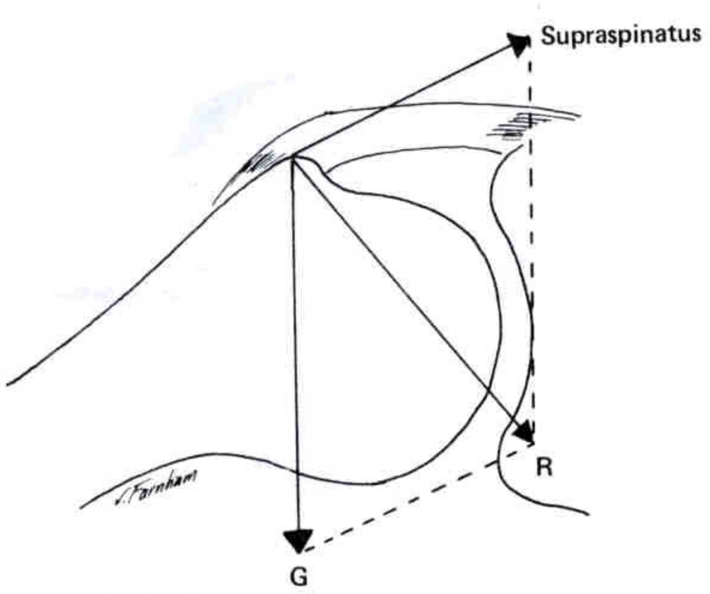
M is approximately one fourth body weight, as is the joint reaction force.

# Shoulder Dynamics

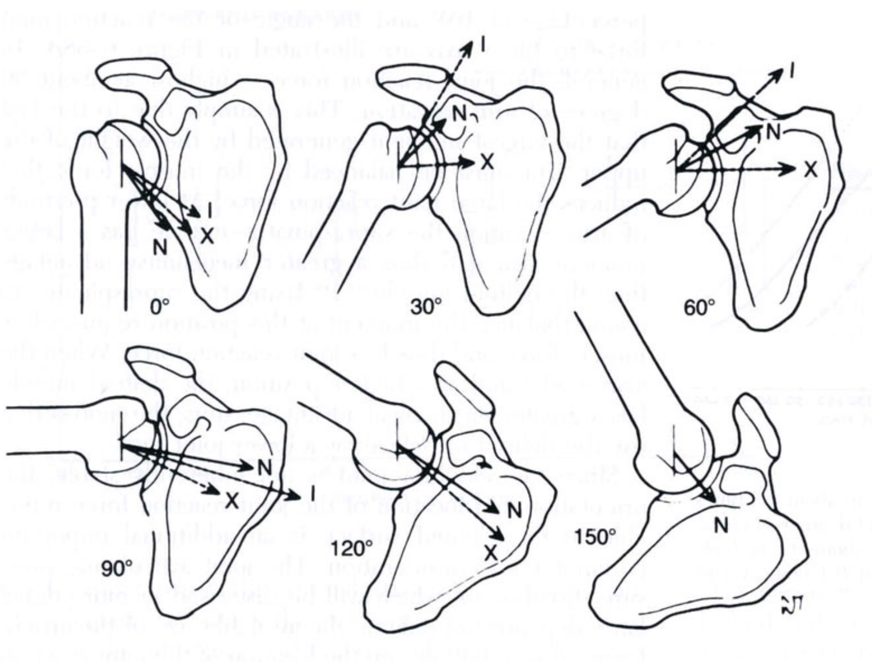
- Fatigue and Injury (Working with Arm Elevated)
  - Supraspinatus
  - Trapezius
- Supraspinatus Tendonitis
- Neck Pain (Trapezius Fatigue)
- Less Fatigue (Herberts, 1980)
  - A. Deltoid (45° and 90°)
  - Supraspinatus (45°)
  - Trapezius (45°)
- ____________had Highest Fatigue

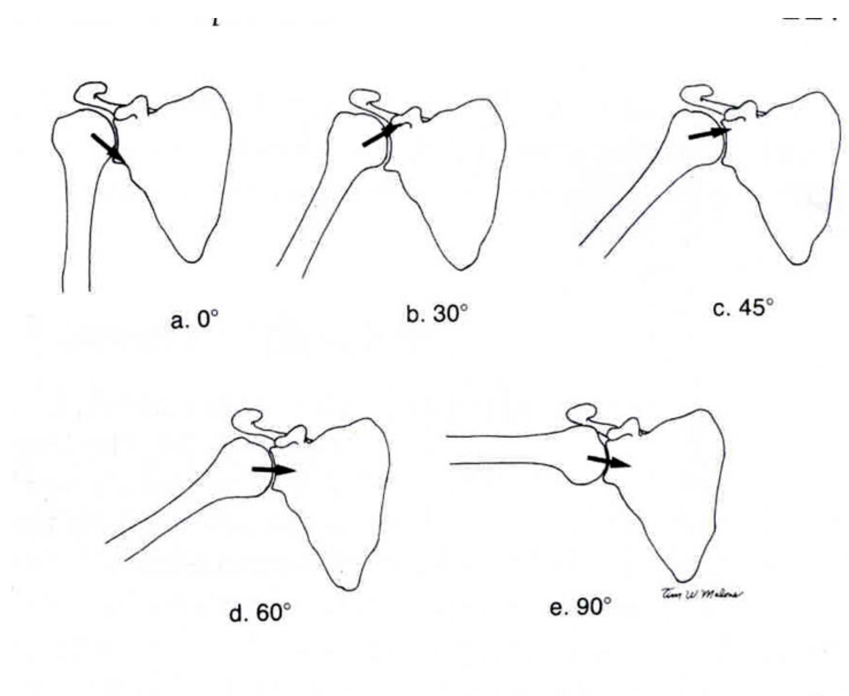
# Simplified Joint Force

- 1 Muscle
- Segment Weight
- Vector Addition



# Joint Force and Stability



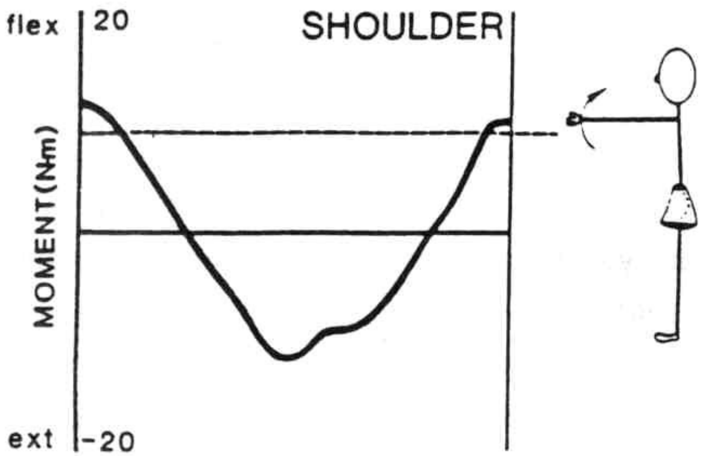




A

B

# Moment (Hinrichs, 1981)

- Reference Line from Anthropometric Data
- Average Limb Weight (    BW)
- Average Center of Mass Distance
- F*d=Moment

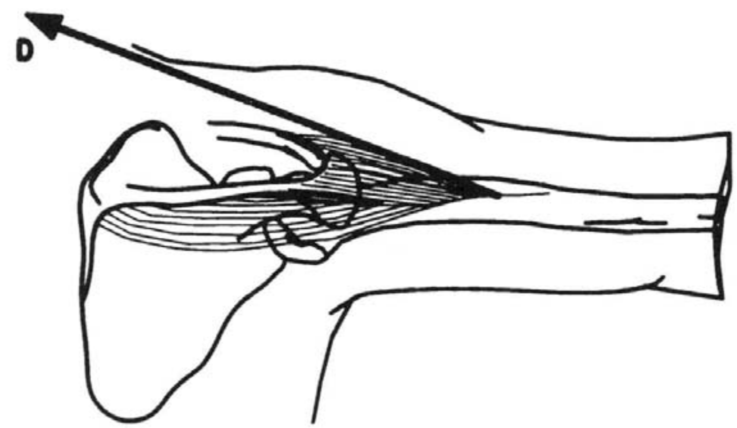


# Outline

- Anatomy
- Biomechanics
- **Problems**

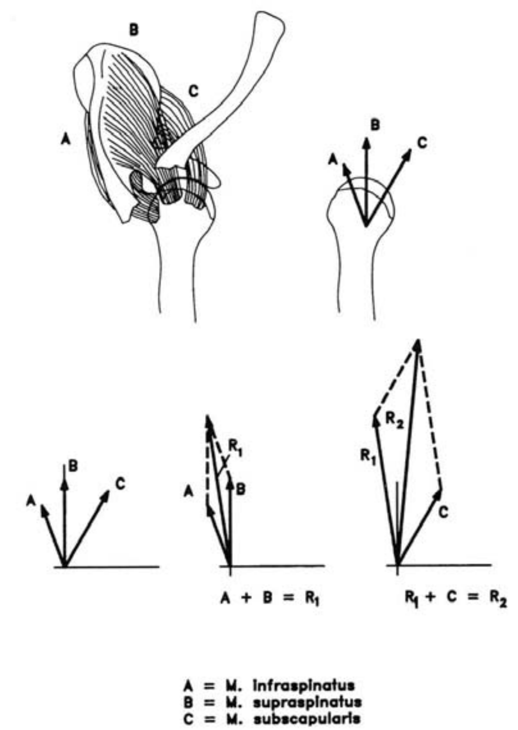
# Problem #1 (1-D)

- ΣM=0



# Problem #2 (2-D)

- ΣFx=0
- ΣFy=0
- ΣM=0



# Problem #3 (3-D)

- $\Sigma Fx=0$
- $\Sigma Fy=0$
- $\Sigma Fz=0$
- $\Sigma M=0$