Shoulder Biomechanics

Lecture originally developed by Bryan Morrison, Ph.D. candidate
Arizona State University
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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 ________)
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
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.
Protraction and Rotation

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

Opinions on Movement

<table>
<thead>
<tr>
<th></th>
<th>Glenohumeral/ Shoulder Girdle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innman (1944) Flexion/Abduction</td>
<td>2/1 after 60°/30° - 120°/60° Total Motion</td>
</tr>
<tr>
<td>Freedman (Scapular Plane)</td>
<td></td>
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<tr>
<td>Doody (Scapular Plane)</td>
<td></td>
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<tr>
<td>Saha (Scapular Plane)</td>
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<tr>
<td>Poppen (Scapular Plane)</td>
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</tbody>
</table>
Codman’s Paradox

- Flex
- Horizontally Abduct
- Adduct
- Rotation without 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

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Movements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ant. Deltoid</td>
<td>Flex, Add &lt;90, Abd &gt;90, __________ Rotation, Horiz. __________</td>
</tr>
<tr>
<td>Middle Deltoid</td>
<td></td>
</tr>
<tr>
<td>Pos. Deltoid</td>
<td>Extend, Add &lt;90, Abd &gt;90, Ext. Rotation, Horiz. Abd</td>
</tr>
<tr>
<td>Supraspinatus</td>
<td>Abduct, Int. Rotation</td>
</tr>
<tr>
<td>Infraspinatus</td>
<td></td>
</tr>
<tr>
<td>Teres Minor</td>
<td></td>
</tr>
<tr>
<td>Subscapularis</td>
<td>Int. Rotation</td>
</tr>
<tr>
<td>Teres Major</td>
<td>Extend, Int. Rotation, Add, Horiz. Abd</td>
</tr>
<tr>
<td>Coracobrachialis</td>
<td>Flex, Horiz. Add</td>
</tr>
</tbody>
</table>
### Muscular Motions Scapulothoracic

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Movement Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trapezius</td>
<td>Add, Downward Rotation, Elevation</td>
</tr>
<tr>
<td>Levator Scapulae</td>
<td></td>
</tr>
<tr>
<td>Serratus Anterior</td>
<td></td>
</tr>
<tr>
<td>Pectoralis Minor</td>
<td>Abd, Inf-Upward Rotation, Depression, Sup-Downward Rotation, Elevation</td>
</tr>
</tbody>
</table>

### Muscular Motions of Multiple Joint Muscles

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Movement Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pectoralis Major</td>
<td>Extend, Int. Rotation, Add, Horiz. Abd</td>
</tr>
<tr>
<td>Biceps Brachii</td>
<td></td>
</tr>
</tbody>
</table>
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
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
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

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**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 ____ %
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

Reference Line from Anthropometric Data

Average Limb Weight (BW)

Average Center of Mass Distance

F*d = Moment

Moment (Hinrichs, 1981)
Outline

- Anatomy
- Biomechanics
- Problems

Problem #1 (1-D)

- $\Sigma M=0$
Problem #2 (2-D)

- $\Sigma F_x = 0$
- $\Sigma F_y = 0$
- $\Sigma M = 0$

Problem #3 (3-D)

- $\Sigma F_x = 0$
- $\Sigma F_y = 0$
- $\Sigma F_z = 0$
- $\Sigma M = 0$