Biomechanics of shoulder

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Shoulder complex

- Sternoclavicular
- Acromioclavicular
- Glenohumeral
- Scapulothorcic

1. Sternoclavicular joint

- **Ligamentous constraints**
  - Interclavicular lig: superior
  - Sternoclavicular lig: anterior > posterior
  - Costoclavicular lig: inferior
- **Motion and constraint**
  - 6 actions occur
    - elevation
    - depression
    - protrusion
    - retraction
    - upward rotation
    - downward rotation
  - approximately 35 of upward rotation
  - a similar 35 of anterior and posterior rotation
  - up to 45 to 50 axial rotation
  - the costo-clavicular ligament is believed to be the most important single constraint in limiting motion

2. AC joint

- **Articualr surface**
  - Not perfectly congruent
  - Presence of a meniscus
  - Acromial surface is flat or slightly convex
- **Ligamentous structure**
  - Conoid ligament:

- the biomechanical data have explained that the conoid ligament must be intact to prevent even slight displacement.
- Trapezoid ligament:larger, longer, and stronger
- AC capsule

· **Motion and constraint**
- 3 axes of rotation
  - AP rotation of clavicle; 3time than SI rotation
    - Conoid lig
    - Trapezoid lig.
    - Ant and post AC lig
  - SI rotation
    - Medial conoid lig; superior constraint
    - Ant and post AC lig. And trapezoid
  - AP(inferior-superior) axial rotation
    - Conoid lig. Constraint both motion
    - Anterior rotation is greater than posterior rotation
    - 5~8° motion is possible
    - slight displacement is limited by the AC lig, but large displacements are resisted by CC lig

Motion of the clavicle

During arm elevation
- 30° clavicle elevation
  - 10° forward rotation during first 40°
  - 15~20° rotation at terminal arc
- axial rotation; 40°
- by Rockwood and green
  - less than 10° rotation of clavicle
  - 30° axial rotation on SC joint
  - clinically
    - SC joint ankylosis; 90° elevation of arm
    - Clavicle fixation; minimum loss of arm elevation

3. Gelenohumeral and scapulothoracic joint motion

Description of joint motion
- Sliding; pure translation of moving segment
- Spinning;opposite of sliding
- Rolling; moving and fixed segment
- ICR (instantaneous center of rotation)

1) Shoulder motion

· Resting posture
- Scapular
  - Anteriorly 30° rotated
  - Upward 3°
  - Tiled forward 20°
- Humerus
  - 30° retroversion

· Articular surface and orientation
- Humerus
  - Upward tilt 45°
  - Retroverted 30°
- Glenoid
  - Slight upward tilt 5°
  - Retroverted a mean of 7°
  - In coronal plane, articular surface arc: 75°
  - 1/3 of humeral head surface is in contact with the glenoid:
    - glenohumeral ratio -0.8~0.6
    - surface ration of G and H: 1:4.3 without labrum
    - surface ration of G and H: 1:2.8 with labrum

Arm elevation
- Early descriptions
  - GH motion as first 90°, followed by ST rotation
- Poppen and Walker
  - 4:1 GH: ST ration during first 25°, after that 5:4 rotation
  - average overall 2:1
- Doody: linearity
  - ST: GH ration 7:1 during first 30°, after that 1:1 from 90 to 150° elevation
- Bergmann
  - During the first 30° ; variable greater motion at GH joint
  - Last 60° ;equal GH and ST motion
- Harryman
  - Total arc of elevation GH: ST is 2:1

· Scapular anterior rotation
- about 15° AP rotation of an arc occur
  - 6° anterior rotation during first 90° elevation
  - 6° posterior rotation occur next elevation

- 20° of forward tilt referable during elevation
· after total shoulder arthroplasty; ratio change 2:1 to 1:2

External rotation of the humerus

· Obligatory external rotation of humerus is necessary
  - Tuberosity impingement with CA arch is cleared by external rotation
  - Inferior lig. Of GH joint loosened by external rotation
· The plane of maximum arm elevation was shown to occur 23° anterior to the plane of the scapula
· Elevation in any plane anterior to the scapular plane required external rotation of humerus, and maximum elevation was associated with 35° external rotation
· Pearl et al.
  - In vivo measurements
  - Maximum elevation was achieved with the humerus just behind the scapular plane
· Combining the motion of elevation sequence
  1. GH motion
  2. SC and AC rotation with elevation of scapula
  3. Scapula pivots upward around the AC joint

Center of rotation

· Center of GH rotation defined as a locus of points situated within 6±2 mm of the geometric center of head
· Center lie 8 mm behind and 6 mm below the intersection of the shaft and head axes
· Multiple center theory

} Cause of Spinning and translation

  - Example
    - 3 mm upward translation during first 30° abduction
    - 1 mm additional translation after 30° elevation

Clinical Relevance

· True AP radiograph of GH joint is taken 30° oblique
· External rotation with maximum arm elevation-frozen shoulder
· Flexion is accomplished by internal rotation
· Potential for ST motion- arthrodesis, frozen shoulder
· Understanding the axis of rotation- prosthetic replacement
· Shoulder abduction force direction- prosthetic design
· Superior translation of humeral head in RC deficient shoulder
  - Directed resultant vector with initiation of abduction by deltoid

- Lack of soft tissue interposition
- Dislocation of LHB
- Degeneration of infraspinatus muscle

2) Constraints

Static constraints
Dynamic stabilizer

1. Static constraints

· **Articular contribution to glenohumeral stability**

- The glenoid articulation 7° retroverted
- Dimentional relationship:
  - 0.75 in sagittal plane
  - 0.6 in transverse plane
  - 25~30% of humeral head is covered by glenoid surface
- Glenoid labrum increases the area and depth of glenoid
  - 1/3 of humeral articular surface
  - 40% of radius of a typical 44 mm humeral prosthesis
  - translation force to dislocation humeral head decreased 20% after removal of labrum
- The joint contact area and position change
  - Contact point moves forward and inferior during internal R
  - Contact point moves superior during elevation
  - Contact point moves posteroinferior during external R
  - The maximum contact area is obtained at 120° elevation
  - With arm elevation: contact surface move superocentral and posterior
- The slight 5° superior tilt of glenoid surface prevent inferior subluxation
- Intra articular pressure

· **Capsular and ligamentous contributions to static shoulder stability**

- Force of dislocation: 2000 N
- The tensile strength of anterior capsule (30~40years): 56.5 kg
- The anterior shear force has been calculated to be 42 kg
- Coracohumeral lig
  - The function of lig. :very controversial
  - Rotator interval?
  - It stablize the shoulder indirectly through maintaining the intraarticular pressure

- Superior glenohumeral lig
  - Passive resistance to inferior subluxation or dislocation
  - Important inferior stabilizer
  - SGHL and ant.CHL strain: Adduction and external rotation
  - SGHL seems to have similar function with CHL
- Middle
  - Major constraint to anterior humeral dislocation:
    - Adduction and neutral R-Debski et al
    - Abduction and neutral R with ant. of IGHL - Debski et al
  - Taut with position of abduction and external R
  - Lax with neutral and internal R; regardless of abduction
  - Maximum strain with external R with lower angle abduction
- Inferior
  - Posterior band and anterior band
    - Anterior band most tight; abduction and external R
    - Posterior band most tight; abduction and internal R
  - The most important anterior stabilizer in 90° of abduction and external R
  - Abduction and neutral R: SGHL+MGHL=IGHL
  - External R: SGHL+MGHL=2×IGHL
  - The major static stabilizer of the shoulder joint consists of the capsular-ligamentous complex, with the IGHL being the most essential component of the complex

2. Dynamic stabilizer

· Mechanism of stabilization by muscle

1. Passive muscle tension
2. Compression of the articular surface
3. Dynamic elements causing secondary tightening of static constraints
4. Barrier effect

· Rotator cuff

- Passive muscle tension
  - Subscapularis is important as an anterior barrier to anterior dislocation
    - 0 to 45° abduction; Primary anterior stabilizer-subscapularis
    - 90°abduction; IGHL
- Dynamic contraction
  - Importance of muscle balance
  - Supraspinatus: