Biomechanics of the Shoulder and Throwing
Shoulder Anatomy

- Most mobile joint in the body
  - Ball-and-socket joint
- 3 bones connected by muscles, ligaments & tendons
  - Clavicle
  - Humerus
  - Scapula
Range of Motion

- 6 degrees of freedom
- Flexion
  - Elevation in the sagittal plane
- Abduction
  - Elevation in the coronal plane
- Rotation
  - Internal / external: Forearm moving in transverse plane
3 Articulations

- Acromioclavicular
- Glenohumeral
- Scapulothoracic

AC: Restrains both rotation and posterior translation of clavicle

Cocco-acromial, coraco-clavicular and acromio-clavicular ligaments

http://www.upperlimbcentre.com/ligaments.htm
Sternoclavicular

• Links upper extremity directly to thorax
  – Fibrocartilage disc between the sternum and the clavicle
    • shock absorber
• Held together by strong ligaments
Glenohumeral

- 4 glenohumeral ligaments, connect the humerus to the glenoid
  - superior, middle, inferior and posterior
- Inferior glenohumeral ligament splits into a front and a back half.
  - These act like a hammock to support the humeral head
- Dislocation inferiorly & anterior most common in young people

http://www.upperlimbcentre.com/ligaments.htm
Scapulothoracic

• Bone-muscle-bone articulation between the scapula and thorax
• Involves gliding of the scapula on the posterior aspect of the thorax
• The subscapularis and the serratus anterior glide along one another
• No osseous connection with the axial skeleton
  – Allows for a wide range of scapular motion, including protraction, retraction, elevation, depression, and rotation
Subacromial Bursa

• Fluid filled sac that decreases the friction between bone & tendon
• Bursa covers the rotator cuff tendons and protects them from the overlying acromion
• Shock absorber

http://www.performancephysicaltherapy.com/images/image006.jpg
Labrum

- A ring of cartilage surrounding the shoulder joint socket
- Acts like a curved bumper to increase the depth of the glenoid fossa
- Keeps the humeral head in the glenoid fossa and helps to prevent dislocations
- Adds depth
- “Break stop” or centers humeral head
Rotator Cuff

- Four small muscles
  - subscapularis, supraspinatus, infraspinatus and teres minor
- Responsible for the stability of the shoulder joint.
- Holds the humeral head in the glenoid socket during early abduction

Throwing Motion

• Kinetic chain concept
  – Sequence of body segment motions
  – Legs and trunk act as force generation
  – Shoulder is force regulation
  – Arm is force delivery
Biomechanics of Throwing
Phase 1 – Wind up

• Preparation of kinetic chain
• Lead foot off ground
• Building potential energy package
• Raises center of gravity
• Minimal stress to shoulder
Phase 2 – Early Cocking

- Positions arm in 90° abduction
- Arm posterior to plane of body
- Initiates external rotation
- Stride initiates
- EMG; Early Deltoid, Late Cuff
Phase 3 – Late Cocking

• Foot contact
• Maximum abduction, external rotation (40 ° to 170°)
• Trapezius and Serratus Anterior force couple stabilizes scapula
• Peak Rotator Cuff activity
• Deltoid and supraspinatus function together to elevate humerus to greater than 90° of abduction
Late Cocking Cont’d

• Flexion to 90°
• Flexors and extensors work in coordination to control motion
• Moderate valgus force exists
• Problems
  – Anterior instability leading to internal impingement
  – Hyperangulation
  – Scapula Dyskinesis
Phase 4 - Acceleration

- Humerus IR 100 deg / 0.5 sec
- Rotates shoulder to ball release point of 90º rotation
- Velocity near 7000 deg/sec
- Eccentric to concentric conversion
Phase 5 - Deceleration

• Most violent
• Ball release to 0º rotation
• Eccentric contraction to slow arm
• Posterior capsule stress
• Joint loads
  – Posterior shear = 400N
  – Inferior shear = 300N
  – Compressive > 1000N
Phase 6 – Follow-through

- Ball release, adduction internal rotation, deceleration
- Rebalancing
- Muscles to resting levels
- Timing of Phases
  - Total 2 seconds
  - Wind-up to late cocking 1.5 seconds
  - Acceleration 0.5 seconds
  - Deceleration to end 0.5 seconds
Common Shoulder Injuries

- Dislocation
  - Subluxation
- Impingement
- Rotator Cuff Tear
- Dead Arm
The End
Clavicle

- Acts as a strut connecting the thorax to the upper extremity
- Protects underlying brachial plexus & vascular structures
- Attachment site for many of the muscles that act on the shoulder
Humerus

- The head of the humerus has 2 projections, the greater and lesser tuberosities.
  - It is at these points that the rotator cuff tendons attach.
Hyperangulation
Hyperangulation

• The abduction – external rotation position of the cocked baseball shoulder places a physiologic compression on the posterior labrum and posterior rotator cuff
• Leads to the common problem of internal impingement
• Cause
  – Muscular weakness (loss of dynamic stabilization)
  – Anterior Capsular stretch
Scapula Dyskinesia

- Lack of full retraction with cocking
- Scapula receives load from the trunk and transfers them to the arm
- Must retract and protract around thoracic wall for cocking/acceleration to deceleration
- Association with tight pec. major and minor; weak trapezius, serratus anterior, and rhomboids
Dislocation

http://www.zadeh.co.uk/shouldersurgery/shouldersurgery.htm
Dislocation Cont’d

• Shoulder ball and socket joint twisted apart
• Occurs after a significant injury in young, active people usually under 30 years old
• Older patients: accompanies other injuries such as fractures or rotator cuff tears
• Subluxation occurs if the head only partially slips out and then slips back in
• 3 major groups:
  – Traumatic
  – Atraumatic
  – Habitual
Traumatic (anterior) Instability

• Sporting injuries, major accidents/falls are the most frequent causes

• Associated with structural abnormalities such as a Bankart lesion or a Hill-Sachs defect
Atraumatic Instability

- Caused by repeated micro trauma to the shoulder as seen in throwing athletes
- Associated with structural abnormalities such as articular surfaces damage, capsular laxity and rarely a Bankart lesion
- Arthroscopic examination of the shoulder is invaluable
- Treatment in 2 stages:
  - Physical Therapy & Injections
  - Surgery
Habitual Instability

- Caused by inappropriate action or balance between various shoulder muscles
- Diagnosed by arthroscopic examination
- Treatment
  - Physical Therapy
Impingement

• Results from abnormal contact between the greater tuberosity and the under surface of the acromion during shoulder abduction

• Classically this contact occurs at 60°-120° of shoulder abduction resulting in a painful arc in mid abduction

http://www.zadeh.co.uk/shouldersurgery/shouldersurgery.htm
**Cause**

- Rotator cuff dysfunction (weakness)
  - Due to degenerative changes within the rotator cuff muscles & is an age related phenomenon
  - May follow a painful injury or traumatic tear

**Symptoms**

- Pain and weakness during activity, especially while elevating the arm sideways
- Pain localized around the deltoide muscle and may interrupt sleep
Treatment

• Dependant on the severity of the symptoms, age and occupation of the patient as well as whether there is an associated rotator cuff tear

• If NOT associated with rotator cuff
  – Steroid injection into the subacromial bursa & physical therapy

• If associated with rotator cuff or injections fail
  – Arthroscopic subacromial decompression
    • 90% success rate
  – Surgery
    • Rotator cuff repair may be necessary

http://www.zadeh.co.uk/shouldersurgery/shouldersurgery.htm
Rotator Cuff Tear

- Rotator cuff muscles are known to undergo degenerative changes with age.
- In some cases this could lead to pain, weakness or instability necessitating treatment.
Treatment

• Steroid injections, pills & physical therapy
• Surgical repair of the rotator cuff in combination with subacromial decompression is best long-term outcome
• Arthroscopic or open surgical techniques
  – Depending on the size of the tear
• Postoperative recovery period is rather prolonged and may take up to 3-6 months
Treatment Cont’d

Arthroscopic Rotator Cuff Repair

Open Rotator Cuff Repair

http://www.zadeh.co.uk/shouldersurgery/shouldersurgery.htm
Arthroscopic RC Repair Video
Dead Arm

- Shoulder stiffness due to thickening and fibrosis of the capsule
- Posterior capsular repetitive micro-trauma during the follow-through phase of throwing
- Lack of glenohumeral internal rotation
Treatment

• Steroid and local anesthetic injections in glenohumeral joint & physical therapy

• For severe stiffness the most effective is manipulation under general anesthetic with a steroid and local anesthetic injection into the joint & intensive physical therapy
Planes

Coronal plane

Sagittal plane

Hill-Sachs defect

Depression fracture caused by contact between humeral head hitting the glenoid rim.

Treatment:
– reduction under sedation or general anesthetic followed by 4 weeks of immobilization in an external rotation brace

http://www.szote.u-szeged.hu/radio/trauma2/traum4b.gif
Bankart lesion

Detachment of the cartilaginous edge of the glenoid (shoulder socket)

– creates a pocket, which in the position of shoulder abduction and external rotation allows abnormal displacement of the humeral head on the glenoid

http://www.orthop.washington.edu/_Rainbow/Album/10357mcf6cf4dd-d50c-4144-b88f-9a922d8bf872.gif
Scapula

The glenoid articulates with the humerus;
The edge of the glenoid is deepened by a cartilaginous structure - the labrum.