PART 2: BASIC PRINCIPLES OF BIOMECHANICS

INTERNATIONAL FEDERATION OF SPORTS CHIROPRACTIC

# Part 2 – Upper Limb

A simple guide to pick up on Normal and Abnormal biomechanical limb behaviour:

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**M-Tech Chiropractic (UJ) 2010**

**ICCSP (T 201602222193)**

*Main source of referencing acquired from:
- Hyde, T. E. and Gengenbach, M. S. (2007), Conservative Management of Sports Injuries, 2nd ed, Massechusetts, Jones and Bartlett.
- Levangie, P.K. and Norkin, C. C. (2005) Joint Structure a& Function: A Comprehensive Analysis, 4th ed, Philadelphia, F. A. Davis Company.

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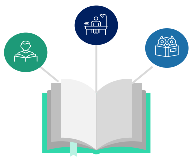
## Unit Content

- Shoulder
- Elbow and Forearm
- Wrist and Hand (Gripping)
- Complete integrated upper limb Biomechanics
- Biomechanics of throwing
- Pathomechanics in throwing





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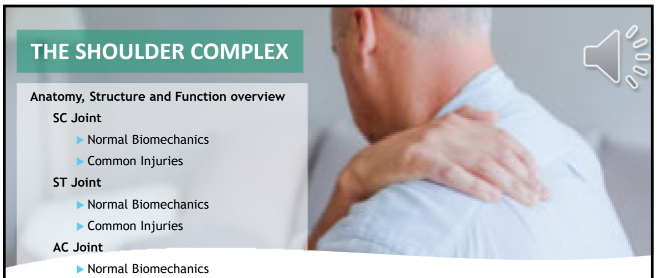

## THE SHOULDER COMPLEX

**Anatomy, Structure and Function overview**

- SC Joint
  - Normal Biomechanics
  - Common Injuries
- ST Joint
  - Normal Biomechanics
  - Common Injuries
- AC Joint
  - Normal Biomechanics
  - Common Injuries
- GH Joint
  - Normal Biomechanics
  - Common Injuries

**Stabilization of the shoulder joint**

**Rehab**



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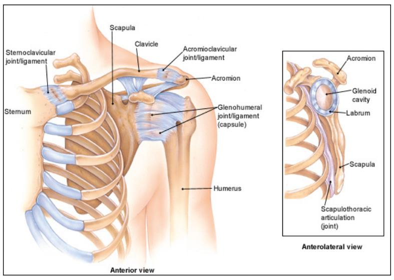
## Shoulder as a whole




**The shoulder complex is composed of:**

- AC
- SC
- GH
- ST (Pseudo joint)

The shoulder complex is the most mobile joint but because of the mobility there is a sacrifice in stability.

**3 Degrees of freedom with vast ranges of motion to allow for multiple tasks such as:**

- Upper limb manipulation for fine work
- Throwing
- Weight Bearing and Hanging (Anti-Gravity)

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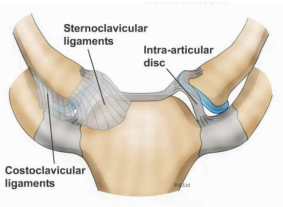
## Sternoclavicular joint (SC)




- The SC Joint is the direct link for the shoulder complex to the Axial Skeleton.
- Consists of 2 concave surfaces separated by an intra-articular joint disc.
- It is a planar type joint with 3 Degrees of freedom.
  - Elevation/Depression
  - Protraction/Retraction
  - Anterior/Posterior Rotation
- Supported and limited by very strong extrinsic ligaments:
  - Sternocalvicular
  - Costoclavicular
  - Intercalvicular

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## Common Injuries: SC Joint Separation/Subluxation

- Contact Sport / *Extreme Sport injury*
- Commonly Benign
  - Potential emergency as a Posterior Subluxation may cause Respiratory Distress.
  - Requires immediate intervention.
- Manipulation and reduction techniques need to be followed up with auscultation and or radiology to assess any mediastinal or lung damage.

Follow up with a figure 8 splint follow same protocol as un-displaced clavicle fracture.

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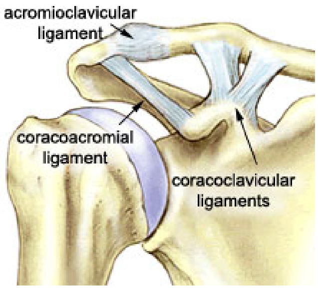
## Acromioclavicular Joint (AC)

- Plane synovial joint
- 3 degrees of freedom.
- Joint capsule.
- 2 major ligaments.
- Joint disc may/may not be present
- Primary motions at the AC joint:
  - Anterior/Posterior tipping of the scapula.
  - Medial/Lateral rotation of the scapula.
  - Superior/Inferior translation of clavicle on acromion or vice versa.
- ACJ susceptible to degeneration and trauma, due to the lack of muscle tissue and fat pads to protect the joint.

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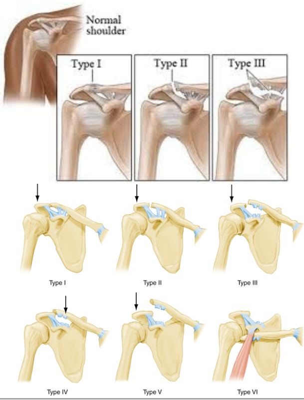
## Common Injuries: AC Joint Separation

- Commonly injured in contact and impact sports.
- Graded by direction and amount of displacement.
- 2 Main thoughts of Classification:
  - Grade 1 – 3
  - Rockwood's 6 types of classification
- Depending on the grade: treatments vary from conservative to radical.

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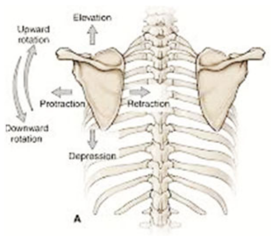
## Scapulothoracic Joint (ST)

- Pseudo-Joint (No synovial lining).
- Forms part of a true closed kinematic chain with AC and SC joints.
- Movements:
  - Elevation / Depression
  - Protraction / Retraction
  - Upward/downward Rotation

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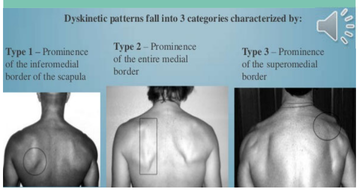
## Winging of the Scapula - Dyskinesis

Commonly caused by falls, impact and contact, or underlying connective tissue injuries.

**3 types:**

- True Winging
  - Due to weakness of Serratus anterior muscle (Long thoracic Nerve palsy)
- Rhomboid/Pseudo Winging
  - Rhomboid injury /Dorsal Scapular Nerve (C5) palsy
- Voluntary Winging
  - Common in Connective tissue disorders

To assess: Wall Push-Up Test

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## Glenohumeral Joint (GH)

- Ball and Socket Joint
- 3 Degrees of freedom
- Humeral:Glenoid ratio 1:3 therefore extremely mobile with Very little stability.
- Supported by strong ligaments but not able to support extremes of force.
- The Glenoid Labrum deepens the socket to increase congruency.

**Two Factors of Stabilization needed:**

- Static stabilization
- Dynamic stabilization

The two heads of the biceps brachii are crucial for maintaining the congruency of the articular surfaces of the shoulder. The short head prevents downward dislocation and the long head presses the humeral head against the glenoid and is also an abductor.

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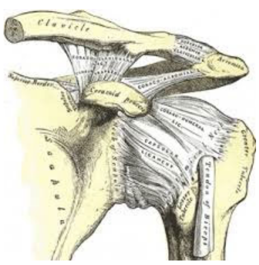

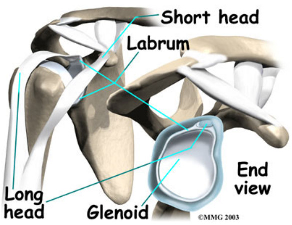


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## Glenohumeral

### Dislocation and Subluxation

- Most Common injury in high force Contact Sports such as Rugby and Football.
- Can also be due to instabilities caused by throwing or upper body training.
  - All GH Dislocations result in an inferior displacement of the humerus but have distinct patterns due to the Mechanism of Injury (MOI).

**Anterior:** The humerus is usually displaced in:
- Abduction
- Ext. Rotation
- Extension

**Posterior:** The humerus is usually displaced in:
- Adduction
- Int. Rotation
- Flexion



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## Glenohumeral Dislocation and Subluxation

Process of reduction and immobilization needs to be considered with the following factors:

- Reduce ASAP
- Hospital Availability and EMT Availability
- Follow on post reduction (XR, CT, MRI)
- Professional involvement
- Risk/ Potential RTP (Coach or Parent interference)



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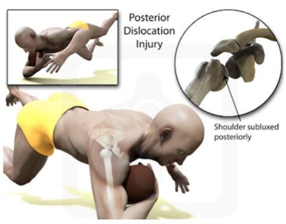
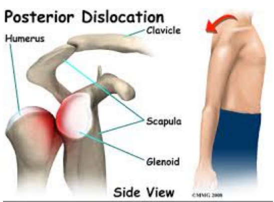
## Posterior Dislocation



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## Anterior Dislocation


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## Biomechanics of the shoulder as a whole

Static and Dynamic Stabilization and the importance of understanding it

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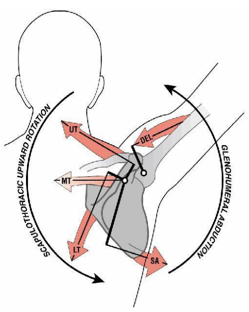
## Scapulohumeral Rhythm

- Overall contributions of movement from the Scapula and the humerus in the motion of abduction.
- When the arm is abducted in an arc of $0^0$ to $180^0$ the humerus and scapula move at a 2:1 ratio.
- The scapular movement allows for stability and increased congruency between the glenoid and the head of the humerus during abduction.
- Any pathology of the shoulder reverses the ratio to a 1:2 Ratio called **REVERSE-SCAPULOHUMERAL RHYTHM**

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## Shoulder Stabilization

- Shoulder complex (especially the GH joint) has sacrificed anatomical stabilizers in order to maximize on mobility and range of motion.
- Therefore the limb is not able to stabilize just by a ligamentous capsule and joint congruency.
- **2 types of stabilization** are adopted with resting muscle tone and active muscle counteraction in order to maintain stability:

**1. STATIC STABILIZATION**
Rotator interval capsule and resting muscle tone responsible for stabilization.

**2. DYNAMIC STABILIZATION**
Active muscle interaction creating a counterforce and a compression in the GH joint.



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## Static Stabilization of the GH Joint

- When the arm hangs at the side, the humeral head rests in glenoid fossa and labrum.
- Gravity pulls down parallel to the shaft of the humerus.
  - Equilibrium needs to be maintained.

NO MUSCLE CONTRACTION IS FOUND IN THIS MECHANISM

- Gravity acts on the humerus as a translatory force distant from the centre of rotation results in an adduction moment on the joint.
- The Adduction moment is counterbalanced by the tension of the **ROTATOR INTERVAL CAPSULE (RIC).**
- Only when the passive counter-force of the RIC is inadequate for static stabilization, will the supraspinatus be recruited.
- Although the supraspinatus and subscapularis are not active in the unloaded arm at side, if they are paralysed or dysfunctional, it can lead to gradual inferior subluxation of the GH joint.



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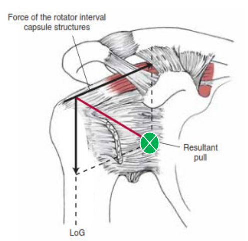
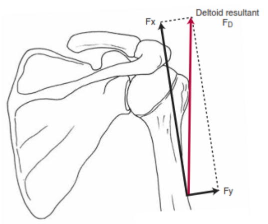
## STATIC STABILIZATION (VIZ)




▲ **Figure 7-34** ■ Mechanism for stabilization of the dependent arm. With the arm relaxed at the side, the downward pull of gravity on the arm (vector extended from the center of gravity of the upper extremity) is opposed by the passive tension in the rotator interval capsule. The resultant of these opposing forces stabilizes the humeral head on the glenoid fossa.




▲ **Figure 7-35** ■ The action line of all three segments of the deltoid follows the line of pull of the middle deltoid. The resultant ($F_D$) resolves into a very large translatory component (Fx) and a small rotatory component (Fy) so that an isolated contraction of the deltoid would cause the deltoid to produce more superior translation than does rotation of the humerus.



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## Dynamic Stabilization of the GH Joint

- The direction of action of the Deltoid muscle can be defined as two components:
  1. A large translatory force upwards
  2. a small compressive force or rotary component as an abduction moment.
- Abduction from the Deltoid can only be achieved when the humerus is abducted past 15⁰ which is initiated by the Supraspinatus.
- The translatory (upward) force of the deltoid if unopposed would cause the humeral head to impact against the coracoacromial arch.
- The inferior translatory pull of gravity is not enough to offset the resultant force of the deltoid because that force must exceed that of gravity before any rotation can occur.
- Therefore another force / set of forces must be introduced.
- The rotator cuff (RC) tendons blend with and reinforce the GH joint capsule. The component forces of the cuff muscles create some rotation of the humerus and also compresses the head of the humerus into the glenoid fossa.
- Combined contraction of the RC creates a downward translatory force that is strong enough to counteract the pull of the deltoid.
- The supraspinatus contraction has a rotatory component that generates a compressive force provides a stable force as it compresses the humeral head into fossa.



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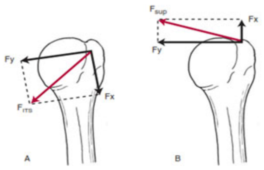
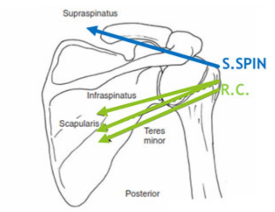
## DYNAMIC STABILIZATION (VIZ)




▲ **Figure 7-37** ■ **A.** The infraspinatus, teres minor, and subscapularis muscles individually or together have a similar line of pull. The rotatory component (Fy) compresses as well as rotates, and the translatory component (Fx) helps offset the superior translatory pull of the deltoid. **B.** The supraspinatus has a superiorly directed translatory component (Fx) and a rotatory component (Fy) that is more compressive than that of the other rotator cuff muscles and can independently abduct the humerus.




▲ **Figure 7-36** ■ The action line of the four segments of the rotator cuff: the supraspinatus, infraspinatus, teres minor, and subscapularis muscles.



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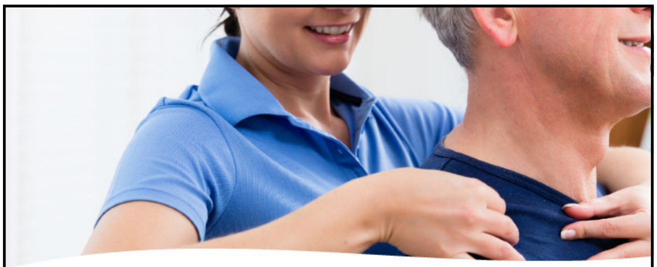

## Rehab Techniques

Refer to Conservative Management of Sports Injuries Text book for all methods and indications for rehabilitation techniques:

Hyde, T. E. and Gengenbach, M. S. (2007), Conservative Management of Sports Injuries, 2nd ed, Massechusetts, Jones and Bartlett.



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# THE ELBOW and FOREARM COMPLEX

**Anatomy, Structure and Function overview**
**ELBOW**
- Humero-Ulnar joint
- Radio-Ulnar Joint
- Ligaments
  - Ulnar Collateral Ligament (UCL)
  - Radial Collateral Ligament (RCL)
  - Annular Ligament
  - Interosseous membrane interactions

**Common Injuries**
- Lateral Epicondylitis
- Medial Epicondylitis
- Elbow Dislocations

**Rehab**



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## Anatomy of the elbow joint

Composed of 3 Bones forming 4 articular components that influence the movement of the hand:

**4 articulations:**
- Humero-Ulnar
- Humero-Radial
- Proximal Radio-Ulnar and Distal Radio-Ulnar (VIA IO MEMBRANE).
- Hinge type joint: Uniaxial ($1^0$ of motion)
  - Flexion and extension only

**3 Major Ligaments**
- Radial Collateral Ligament (RCL)
- Ulnar Collateral Ligament (UCL)
- Annular Ligament

**5 Major Muscles that directly work on the joint**
- 3 Flexors
- 2 Extensors
- The articulating surfaces are the most significant in the biomechanics of the elbow and dictate the tension on the RCL and UCL, Common Extensors and Flexors and the Epicondylar Apophyses.



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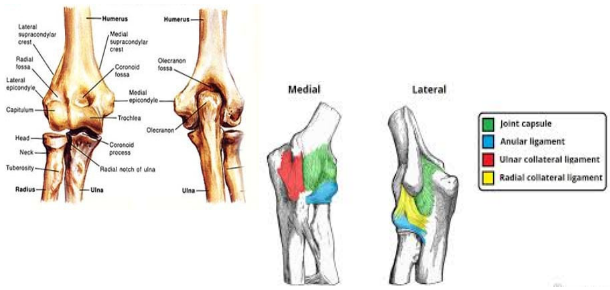
## Elbow Structure: Osteokinematics and Arthrokinematics



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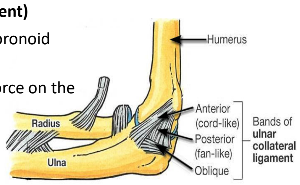
## ULNAR COLLATERAL LIGAMENT (UCL)

**Comprised of 3 parts:**

- **Anterior Bundle**
  - $1^0$ Stabilizer of valgus force from $20^0$ to $120^0$ of elbow Flexion
- **Posterior bundle**
  - Less involved in checking valgus force.
  - Guides interaction of Olecranon process and Trochlea
- **Transverse Bundle (Cooper's Ligament)**
  - Between Olecranon and Ulnar Coronoid process
  - Maintains a varus compressive force on the Humero-Ulnar articulation.

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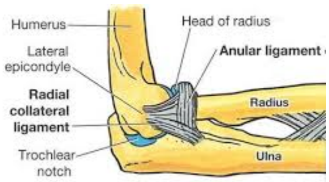
## RADIAL COLLATERAL LIGAMENT (RCL)

- Fan Shaped Ligament
- Small degree of Resistance against Varus stress
- Prevents joint distraction
- More elastic than UCL
- Fibres are taut at $110^0$ of elblow flexion.

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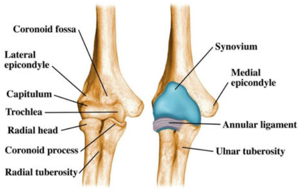
## ANNULAR LIGAMENT

- Strong ligament
- 4/5 ring encircling the radial head.
- Inner surface of ligament is covered with cartilage and therefore serves as a joint surface.
- Lateral aspect reinforced by fibers from LCL.
- Maintains Radial head interaction and allows pivoting in Pronation and supination.

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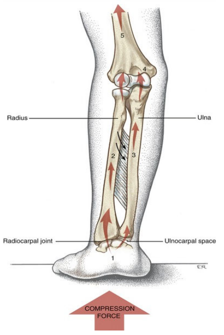
## INTEROSSEOUS MEMBRANE

- Broad, dense membrane rich in collagen which runs between the radius and ulna.
- Runs Distally and Medially
- Allows transmission of forces from hand and distal end of the radius to the ulna.
  - Indirectly acts as a locking mechanism for the elbow and wrist during weight bearing and gripping.



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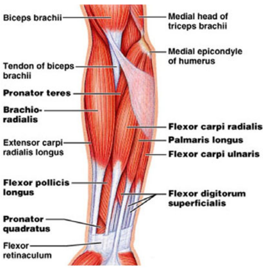
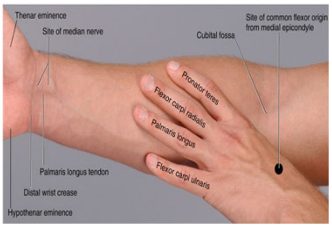
## Muscles of the forearm (Flexors)



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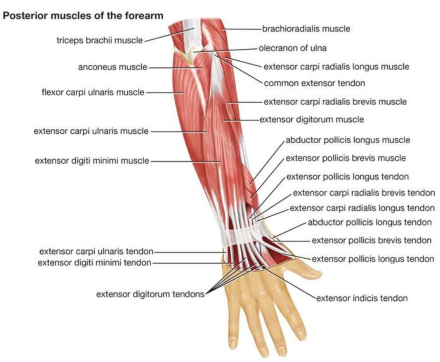
## Muscles of the forearm (Extensors)



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## Common Injuries:

**Lateral Epicondylitis**

**(TENNIS ELBOW)**

- Racquet increases the length of the forearm lever which increases stress on the elbow
- Caused by repeated forceful contractions of the wrist extensors
- Repeated tensile stress on the inelastic tendon can result in microscopic tears at the musculotendinous junction and result in tendonitis

**Medial Epicondylitis**

**(GOLFERS ELBOW)**

- Caused by forceful repetitive contractions of the pronator teres, flexor carpi radialis and flexor carpi ulnaris
- The injury usually involves elbow extension, pronation and wrist flexion

Treatment can include a brace around the forearm just distal to the muscle insertion site in order to move the point of leverage. This allows the muscles to work over a different length and rests the insertion site.



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## GOLFERS vs TENNIS ELBOW




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## Elbow Dislocations




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## Elbow Dislocations

- Common contact sport injury:
  - Football
  - Ice Hockey
  - Rugby
  - Wrestling
- Common Posterior displacement
- Uncommon Anterior displacement without associated Supracondylar fracture.
- Send to ER:
  - Reduction may result in laceration of the Brachial Artery and result in Volkmann's Ischaemic Contracture

- Process of reduction and immobilization needs to be considered with the following factors:
  - Reduce ASAP
  - Hospital Availability and EMT Availability
  - Follow on post reduction (XR, CT, MRI)
  - Professional involvement
  - Risk/ Potential RTP (Coach or Parent interference)

RED FLAG:
POTENTIAL SUPRACONDYLAR FRACTURE

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## Forearm Fractures


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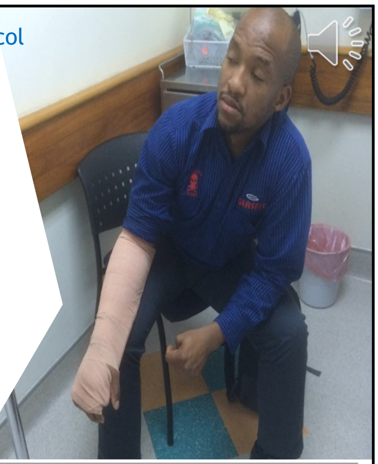
## Forearm Fracture Protocol

**26 Male Rugby Player.**

- Fractured Forearm in a tackle
- Missed by EMT's and was allowed RTP
  - Arm was locked in pronation
  - Unable to supinate actively

**Protocol**

- Splint
- Immobilise
- XR



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## WRIST AND HAND (prehension)

**Anatomy, Structure and Function overview**

- **Wrist**
  - The Carpal Rows
  - Intercalated Segment
  - Common Injuries
    - Carpal Tunnel Syndrome
- **Hand**
  - Flexor/Extensor force couples
  - Grip (Prehension)
  - Types of Grip



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## Structure and function of the Wrist

**The most complex joint in the body, both anatomically and physiologically.**

- Also known as the carpus: consists of 2 compound joints:
  - The Radiocarpal joint
  - Midcarpal joint
- Function of the wrist is to control to allow fine adjustments of grip.
- Secondary function is placement of the hand in space.


**Bi-axial:**

- flexion/extension around a coronal axis
- radial/ulnar deviation (abduction /adduction) around an AP axis.

**Variations in movement are due to:**

- ligament laxity
- shape of articular surfaces
- constraining effects of muscles



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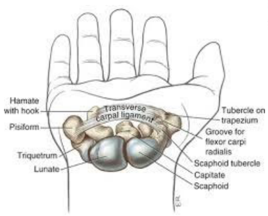
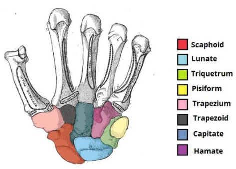
## The Carpal Rows

There is a **2-joint system** at the wrist in order to facilitate:

- Large ROM
- Prevention of structural pinch at extremes of ranges.
- flatter multi-joint surfaces more capable of withstanding pressure.



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## Intercalated Segment

**How does an intercalated segment work?**
- When compressive forces are applied across an intercalated segment:

**The middle segment** tends to collapse and move in the **opposite direction** from the segments above and below.
- Ex: compressive extensor forces across the wrist complex results in the proximal row of carpals flexing and the distal row extending.

- **HOWEVER**, some stabilization is required in order to prevent **complete collapse** of the middle segment.

- This mechanism involves the **scaphoid** and its attachments to the lunate and to the distal carpal row.
- The scaphoid tends to flex while the lunate and triquetrum tend to extend. These counter-rotations within the proximal row are prevented by the ligaments of the wrist.
- These linkages will cause **the proximal carpals** to "collapse synchronously" into flexion and pronation while **the distal carpals** move into extension and supination.
- This counter-rotation between the rows increases ligamentous tension and thereby **increases stability**.

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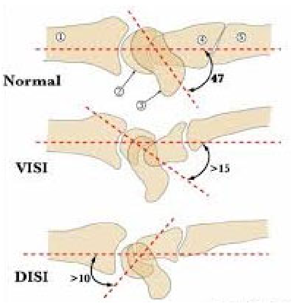
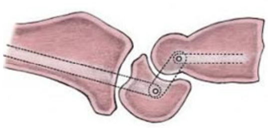
## Intercalated Segment



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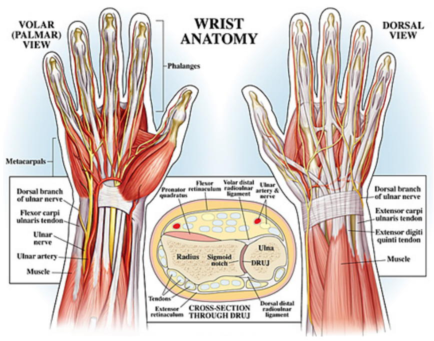
## Anatomy of the Hand

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## Prehension

- Grasping or taking hold of an object between any 2 surfaces in the hand.
- Fingers usually function to hold object into palm.
- They sustain flexion position which varies with size, shape and weight of object. Palm contours to object as the palmar arches form around it.
- The thumb creates an additional surface area for contact ie: adducts to clamp object.

**Prehension divided into:**

- **Power grip**
  - Forceful act resulting in flexion at all finger joints, objects held between thumb & palm
  - *Phases of power grip*: open hand, position fingers, approach object, maintain static phase of grip so that the object can be moved through space by the more proximal joints.
- **Precision handling**
  - Skillful placement of an object between fingers or finger and thumb; the palm is not involved.
  - *Phases of precision:* open hand, position fingers, approach object, fingers and thumb grasp object with intention of manipulating it within the hand.



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## Power Grip: Cylindrical Grip

- **Uses flexors to carry fingers** around and maintain the grasp on the object – mainly FDP.
- **Interossei flex MCP** with some abduction / adduction.
- **Thumb** usually flexes and adducts to close the grip.
- **Wrist** usually neutral between flexion/extension with slight ulnar deviation (puts thumb in line with forearm and positions object better to be able to be moved by pronation / supination by forearm and maintains long finger flexor's optimum length-tension).
- **The more ulnar deviation by FCU**, the more tension on the flexor retinaculum, which gives hypothenar muscles a more stable base on which to contract.




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## Power Grip: Spherical Grip

- Similar to cylindrical
- Fingers more spread out to encompass the object, therefore more interosseous activity.
- MCP's don't all deviate ulnarly, but tend to abduct.




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## Power Grip: Hook Grip

- Primarily involves fingers, may include palm, BUT never the thumb.
- Can be sustained for long periods of time.




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## Power Grip: Lateral Prehension

- Contact between 2 adjacent fingers
- Not coventional power grip, but similar in that position is maintained so that object can be moved by more proximal joints.
- MCP and IP joints generally extended, and MCP can abduct / adduct. Extensor muscles play part in maintaining position.




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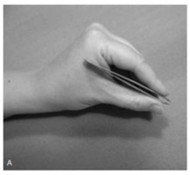
## Precision Grips

Pad to Pad




Tip to Tip


Pad to Side

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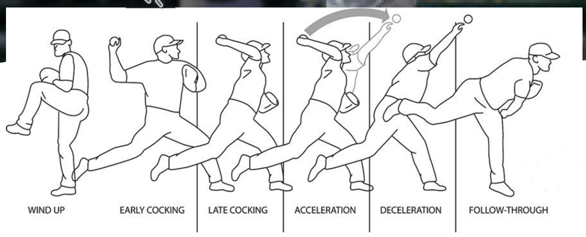
## Biomechanics of throwing

Phases of throwing



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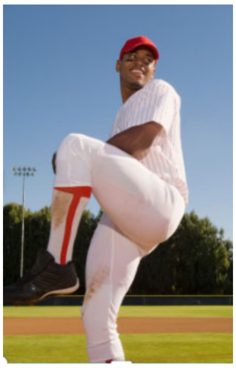
## 1 - Wind-up Phase

- Preparatory phase
- Two-legged stance
- Arm begins movement towards cocking
- There is little strain on the shoulder
- Any loss of control, balance or stability will cause an increased demand on the shoulder.





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## 2 + 3 - Cocking Phases

**Early:**

- Arm moves towards full external rotation at 90º abduction
- The external rotators (infraspinatus and teres minor) are active and thus store elastic energy.

**Late:**

- There is strong activity of the internal rotators (subscapularis and lat. dorsi) to decelerate the externally rotating arm.
- The GH joint capsule is stretched anteriorly and rotation wrings the capsule posteriorly compromising the vascularity of the upper rotator cuff tendons.
- The trunk begins to rotate.
- Medial motion of the humerus signifies the onset of the acceleration phase.



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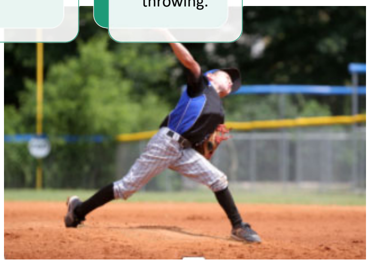
## 4 - Acceleration Phase

Medial rotation and forward translation of the arm takes place ending with the release of the object being thrown.

Shoulder remains at 90º abduction.

Lateral trunk flexion gives the appearance of side-arm throwing.



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## 5 - Release Phase

Arm is parallel to the line of the shoulders.

External rotators undergo eccentric loading in order to decelerate the arm – which leads to injuries.

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## 6 – Follow Through Phase

- External rotators and posterior fibres of the deltoid contract eccentrically to decelerate the arm.
- The serratus anterior and trapezius stabilize the scapula.
- The forward movement of the arm, medial rotation of the shoulder and protraction of the scapula are decelerated
- **Long deep follow-through:**
  - The arm passes down and across the body so that the hand finishes lateral to the contralateral knee.
- **Shallow follow-through:**
  - Increases contribution of smaller muscles therefore requires flexibility
- The trunk flexes and rotates
- Weight transferred to the leading leg.
- The hip and knee flex in order to lower the centre of gravity which allows larger muscles to assist in deceleration.

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## Pathomechanics in throwing

**Pathomechanical Cocking Patterns**

- Externally rotating the shoulder too early causes increased stress on the anterior shoulder as the trunk rotates and the shoulders remain ‘open’.
- Overextension of the elbow in early cocking causes the arm to arrive late in the late cocking position and the acceleration stresses the cuff muscles.
- Bringing the arm too far back across the midline due to excessive trunk rotation requires rapid acceleration for the arm to catch up with the trunk and thus stresses both the shoulder and the elbow.



## Pathomechanics in throwing

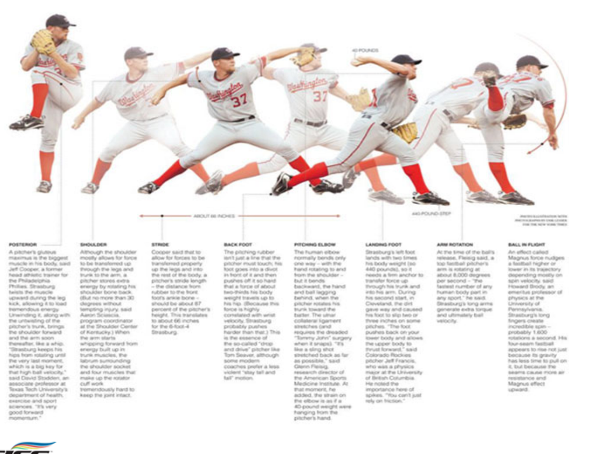
**Pathomechanical Follow Through**

**Shallow follow-through:**

- Increased contribution of smaller muscles therefore requires flexibility.

- The trunk flexes and rotates putting strain on core musculature.
- Weight transferred to the leading leg.
- The hip and knee flex in order to lower the centre of gravity which allows larger muscles to assist in deceleration.







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