Upper Limb Biomechanics
Phases of throwing motion

1. Wind-up
2. Early cocking
3. Late cocking
4. Acceleration
5. Deceleration
6. Follow-through

Start
Hands apart
Foot down
Maximum external rotation
Ball release
Finish
1. Wind up

**Starts:** initiate first movement

**Ends:** lead leg is lifted & throwing hand removed from glove

COG raised
2. Early Cocking

**Start:** lead leg is lifted & throwing hand removed from glove

**End:** front foot contacted the ground

Moves 90° shoulder & 15 ° horizontal abduction

Early activation deltoïd & late activation of supraspinatus, infraspinatus & teres minor
3. Late Cocking

**Start:** front foot contacted the ground

**End:** throwing arm reaches maximum external rotation (170-180°)

Scapula retracts to aid this position & form stable base for humeral head

Should abduction stays 90-100° but horizontal shoulder ⇒ 15° adduction

Abduction & external rotation ⇒ posterior translation of humeral head on glenoid

Rotation torso ⇒ anterior shear force & rotator cuff muscle generate 650 N compressive force
3. Late Cocking

1. Critical Point

• Just before maximum external rotation
• 165° arm external rotation
• 95° elbow flexion
• 67 Nm internal moment
• 64 Nm varus elbow moment
  • Valgus moment ⇒ medial elbow injury
  • Varus moment generated prevent it
  • Ulnar collateral ligament generates 54% varus moment required but its at its maximum before failure is around 35 Nm
• 310 N anterior shoulder force

4. Acceleration

**Start:** throwing arm reaches maximum external rotation

**End:** ball release

Scapula protract $\Rightarrow$ stable base for humeral head as body moves forward, allows conversion muscle function (ecc-conc/conc-ecc)
5. Decceleration

Start: ball release

End: arm reaches maximum internal rotation

Dissipation of energy not imparted on ball

Reversal of first 3 phases

Eccentric contraction to slow down arm rotation

Joint loads at maximum
5. Deceleration

2. Critical Point

• Just before maximum external rotation
• 64° arm external rotation
• 25° elbow flexion
• 1090 N shoulder compressive force
• Inability generate 310 N maximum inferior force $\Rightarrow$ superior translation of humerus
• $\Rightarrow$ impingement of greater tuberosity, rotator cuff muscles or biceps against inferior surface of acromion or coracoacromial ligament

6. Follow-Through

**Start:** arm reaches maximum internal rotation

**End:** person reached balance position
Throwing

Sequence of co-ordinated linked events
- optimal performance
- minimal injury

Look for:
• Compensations
• Early opening up/ hyperang
• Lack of drive/ rotation
• Imbalances IR/ER
• Core/ shoulder instabilities
• Elbow over external/ valgus
Throwing injuries

Shoulder:
  • Impingement
  • Subluxation/ scapular instability
  • Cuff/labral pathology
  • Stress #

Elbow:
  • Medial strains
  • Olecranon fossa
  • Biceps tendon

Trunk/ spine:
  • Stabilises
  • Muscle strain

Groin/ glut / hamstrings
Pitching in Children

Table 1  Maximum number of pitches recommended

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Maximum pitches/game</th>
<th>Maximum games/week</th>
</tr>
</thead>
<tbody>
<tr>
<td>8–10</td>
<td>52±15</td>
<td>2±0.6</td>
</tr>
<tr>
<td>11–12</td>
<td>68±18</td>
<td>2±0.5</td>
</tr>
<tr>
<td>13–14</td>
<td>76±16</td>
<td>2±0.4</td>
</tr>
<tr>
<td>15–16</td>
<td>91±16</td>
<td>2±0.4</td>
</tr>
<tr>
<td>17–18</td>
<td>106±16</td>
<td>2±0.6</td>
</tr>
</tbody>
</table>

Table 2  Minimum number of pitches thrown that requires a rest

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>1-Day rest</th>
<th>2-Day rest</th>
<th>3-Day rest</th>
<th>4-Day rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>8–10</td>
<td>21±18</td>
<td>34±16</td>
<td>43±16</td>
<td>51±19</td>
</tr>
<tr>
<td>11–12</td>
<td>27±20</td>
<td>35±20</td>
<td>55±23</td>
<td>58±18</td>
</tr>
<tr>
<td>13–14</td>
<td>30±22</td>
<td>36±21</td>
<td>56±20</td>
<td>70±20</td>
</tr>
<tr>
<td>15–16</td>
<td>25±20</td>
<td>38±23</td>
<td>62±23</td>
<td>77±20</td>
</tr>
<tr>
<td>17–18</td>
<td>27±22</td>
<td>45±25</td>
<td>62±21</td>
<td>89±22</td>
</tr>
</tbody>
</table>

Table 3  Age recommended for learning pitches

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Pitch type</th>
</tr>
</thead>
<tbody>
<tr>
<td>8±2</td>
<td>Fastball</td>
</tr>
<tr>
<td>10±3</td>
<td>Change-up</td>
</tr>
<tr>
<td>14±2</td>
<td>Curveball</td>
</tr>
<tr>
<td>17±2</td>
<td>Screwball</td>
</tr>
<tr>
<td>16±2</td>
<td>Slider</td>
</tr>
<tr>
<td>16±2</td>
<td>Forkball</td>
</tr>
<tr>
<td>15±3</td>
<td>Knuckleball</td>
</tr>
</tbody>
</table>

Remember what a torque is

\[ T = F d \]

\[ \text{force} \times d_{\perp} = T \]

\[ 10 \text{ N} \times 2 \text{ m} = 20 \text{ Nm} \]
Thinking about torques........
when does peak joint reaction force occur during shoulder abduction?

\[ T = Fd_\perp \]

Peak joint reaction force
- Weight remains constant
- Abduction changes moment arm
- Maximum = 90° abduction
- Abductor muscle force greatest to generate a moment to counteract the adduction moment created by arm weight

Maximum shear force
- 60° abduction
Now based on this information, how would you use this information in prescribing exercise?
Elbow muscles

1. Brachioradialis
2. Biceps brachii
3. Brachialis
4. Pronator teres
Effect on the elbow joint in using axillary crutches
**Muscular Strength**: Ability of given muscle group to generate torque at particular joint

- **Rotary Component**: Parallel to bone component
- **Parallel to bone component**

2 orthogonal components

- **Amount of tension muscle can generate**
- **Moment arms of contributing muscle with respect to joint center**
Based on this information & tissue biomechanics, explain the typical mechanism of a distal dislocation of the superior radioulnar?

Radial head is pulled through the ring of the annular ligaments

Tissue biomechanics

• <6-7 years
• Weaker ligament?

More narrow lateral aspect of the radial head slips out when elbow extended & forearm pronated
Wrist Forces

Cane

• During support phase, can pushes up on cane
• \( \Rightarrow \) wrist extension moment
• Total flexor force must balance wrist extension moment
• Location of reaction force of cane (changes moment arm) \( \Rightarrow \) \( \uparrow \)/\( \downarrow \) muscle & joint reaction force
Why is the cane used on the contralateral hand?

Aim: ↓ load at the joint ⇒ ↓ pain

↑ Base of support ⇒ ↑ stability ⇒ ↑ COM motion without loss of stability

Contralateral to the affected limb or in the dominant hand if there is no discernible affected limb.

Hip load influenced by hip abductor muscle activity, which is dependent on cane side

- Ispilateral: ↑ force
- Contralateral: 60% ↓ force
  (↑ moment arm & opposite direction)
Why is the cane used on the contralateral hand?

Hip osteoarthritis

- Contralateral hand: hip abduction moment ↓ 26% affected hip but ↑ 28% contralateral (Ajemian et al. 2004)

Knee osteoarthritis (Chan et al, 1993)

- Contralateral: smallest knee flexion & abduction joint moment
- ⇒ no cane ⇒ ipsilateral

Aid propulsion via ↑ horizontal ground reaction force
Why is the cane used on the contralateral hand?

Cane length/correct hand is not associated with greater confidence, improved functional ability, or \( \downarrow \) falling (Dean & Ross, 1993)

Destabilising effect

- Lifting arm/device \( \Rightarrow \) reaction forces & moments at shoulder that may perturb COM
- Environment obstacles

\( \uparrow \) upper limb demands
Wrist Forces

Why are there different types of crutches?

Assistive devices place large loads wrist

Issue rheumatoid arthritis

Supports allow weight bearing on forearm rather than hand & wrist