Shoulder and Elbow Biomechanics and Pathology in Pitching

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Purpose of Studying Throwing Shoulder Biomechanics

MECHANICAL EFFICIENCY

Prevention of Injury
- Decreased Fatigue, Increased Stamina
- Decreased Energy Expenditure

Performance Enhancement
- Decreased Force & Torque on Joints
- Increased Control
- Increased Velocity
- Decrease in Tissue Stress
ASMI Throwing Tests: 1989-present
1600+ Pitchers Tested

- >300 High School
- >300 Youth
- >50 Recreation
- >200 Major League
- >300 Minor League
- >500 College

1993 Cy Young
2002 Cy Young
2006 Cy Young
2009 Cy Young
2007 Cy Young
2008 Cy Young
2003, 2010 Cy Young
Qualitative Analysis of Pitching Mechanics

Research grant by International Olympic Committee Subcommission on Biomechanics and Physiology to study pitching biomechanics in 1996 and 2000 Olympic Baseball Pitchers from Australia, Italy, Japan, Korea, Netherlands, US, Cuba, & Nicaragua
Quantitative Analysis of Pitching Mechanics

- **Kinematics** - Describes How Motion Occurs
  - Quantifies Shoulder Angles, Velocities, & Accelerations

- **Kinetics** – Explains Why Motion Occurs
  - Quantifies Shoulder Forces & Torques

- **Electromyography**
  - Quantifies Shoulder Muscle Activity
Quantitative Analysis of Pitching Mechanics

Motion Analysis System
- Eight high-speed cameras
- Automatic 3-D digitizing

100 x 50 x 25 ft. Indoor Laboratory
100 x 50 x 25 ft. Indoor Laboratory

Quantitative Analysis of Pitching Mechanics
Phases of Pitching

1. Wind-Up
2. Stride
3. Arm Cocking
4. Arm Acceleration
5. Arm Deceleration
6. Follow-Through
Wide-up and Stride

- Low to moderate shoulder and elbow muscle activity (approx 10-50% MVC)
  
  (DiGiovine et al., J Shou Elb Surg, 1992)

- Note: Even though shoulder and elbow stress is low, poor pitching mechanics in these 2 phases could lead to increased shoulder and elbow stress in subsequent phases
Kinematics at Lead Foot Contact

(Escamilla et al., 1998; Fleisig et al., 1999)

90-90 Position at Shoulder and Elbow

Shoulder Abduction

Elbow Flexion
Inadequate ER (eg, late in rotating the arm up) at FC can result in increased shoulder compressive force during arm cocking.
Arm Cocking
*(Lead Foot Contact to Max Shoulder External Rotation)*

Note: Shoulder and Elbow Stress is Highest During the Arm Cocking and Arm Deceleration Phases
Shoulder Biomechanics During the Arm Cocking Phase
Kinematics During Arm Cocking

(Escamilla et al, 1998; Fleisig et al, 1999; Matsuo et al, 2001)

Max Shoulder External Rotation (ER)

Inadequate ER correlates with a ↓ in throwing velocity
Excessive ER correlates with ↑ Injury Risk (eg, SLAP, Impingment)
Arm Cocking Shoulder Girdle EMG

Scapular Muscles
(moderate to high activity)

- Upper Trapezius – 37% MVC
- Middle Trapezius – 51% MVC
- Lower Trapezius – 38% MVC
- Serratus Anterior – 106% MVC
- Rhomboids – 41% MVC
- Levator Scapula – 72% MVC

(DiGiovine et al., J Shou Elb Surg, 1992)

Poor position of the scapula can increase the risk of impingement and reduce the optimal length-tension relationship of both scapular and glenohumeral musculature (Myers et al, AJSM, 2005)
Arm Cocking Shoulder Kinetics

(Escamilla et al., 2002; Fleisig et al., 1996)

- Shoulder Compressive Force
  660 N (70-80% BW)
Arm Cocking Shoulder EMG

Glenohumeral (GH) Compressors
(Rotator Cuff)
(high activity)

- Infraspinatus – 74% MVC
- Teres Minor – 71% MVC
- Supraspinatus – 49% MVC
- Subscapularis – 99% MVC

Biceps Brachii (26% MVC) may also contribute to GH compression
(DiGiovine et al, J Shou Elb Surg, 1992)
Arm Cocking Shoulder Pathomechanics

Pathology in the Thrower’s Shoulder is Often Complex and Multifaceted

- Rotator cuff articular surface partial thickness tears (full thickness tears uncommon)
- Labral/biceps pathology (SLAP lesions)
- Internal/external impingement
- Capsule injuries
- Microinstability
  - Anteroposterior
Subacromial Impingement

Classic External Impingement (Neer, JBJS, 1972)

View of subacromion space and bursa. A bursectomy may be performed on an abnormally thickened bursa.
Internal Impingement
(Walsch et al, JSES, 1992)

- Under (articular) surface of infraspinatus or supraspinatus tendons impinge on posterosuperior glenoid labrum
- Much more Common injury in overhead throwing than external impingement
- Torn margins separate due to shear and abrasion
- Articular surface slow to heal due to hypovascularity
Internal Impingement
Contributing Factors
(Myers et al, AJSM, 2006)

- Excessive ER
- Anterior capsule/labral injuries
- IR Deficit
  - Posterior Shoulder Tightness (tight posterior cuff and/or capsule)
- Excessive Hor Abd
- Muscle Weakness
- Scapular Dyskinesia
Anterior Instability (Secondary Impingement)

- During External Rotation Anterior Capsule and Anterior Band of Inferior Glenohumeral Ligament are Stretched and Helps Resist Humeral Head Anterior Translation

- With Capsular Injury Internal Impingement May Result Secondary to Excessive Anterior Humeral Head Translation
SLAP Lesions in Throwers (Andrews et al, AJSM, 1985)

Tension in Long Biceps helps control ER (Rodosky et al, AJSM, 1994),
Known as the “Peel Back Phenomenon” and may be exacerbated by excessive ER (Burkhart & Morgan, Arthroscopy 1998),

Type II most common - Detachment of Superior Labrum and Long Biceps Tendon from Glenoid
Elbow Biomechanics During the Arm Cocking Phase
Arm Cocking Elbow EMG

(DiGiovine et al., J Shou Elb Surg, 1992)

- **Elbow Flexors** (low activity)
  - Biceps Brachii – 26% MVC
  - Brachialis – 18% MVC
  - Brachioradialis – 31% MVC

- **Elbow Extensors** (moderate activity)
  - Triceps – 37% MVC
Arm Cocking Forearm EMG

(DiGiovine et al., J Shou Elb Surg, 1992)

- **Flexor/Pronator Mass** *(moderate activity)*
  - Pronator Teres – 39% MVC
  - Flexor Carpi Radialis – 47% MVC
  - Flexor Carpi Ulnaris – 41% MVC
  - Flexor Digitorum Superficialis – 47% MVC

- **Supinator/Extensor Mass** *(moderate to high activity)*
  - Supinator – 54% MVC
  - Extensor Carpi Radialis Longus – 72% MVC
  - Extensor Carpi Radialis Brevis – 75% MVC
  - Extensor Digitorum Communis – 59% MVC
Arm Cocking Elbow Pathomechanics

Mediolateral Elbow Injuries

- Medial Tensile Injuries
  - Ulnar Collateral Ligament (UCL)

- Lateral Compression Injuries
  - Osteochondritis Dissecans

Cain et al, AJSM, 2003
Azar et al, AJSM, 2000
Arm Cocking Elbow Pathomechanics

- **UCL Injuries**
  - Excessive throwing (overuse injury), throwing high stress pitches such as the curveball and slider, and poor pitching mechanics can all increase stress on the UCL.
Arm Cocking Elbow Kinetics

(Escamilla et al., 2002; Fleisig et al., 1995)

- Elbow
  - Varus Torque = 64 Nm
    - Peak Varus Torque Occurs at Max Shoulder ER to Resist Valgus Stress
  - Shoulder Internal Rotation Torque (67 Nm) Needed to Control ER by high eccentric activity from Shoulder IR Muscles (Lats, Pecs, Subscap)
Valgus Loading Counterbalanced by Varus Torque

- **Static Contributions to Varus Torque**
  (Morrey & An, 1983) - *in vitro*, so no muscle contribution
  - UCL: 54%
  - Osseous: 33%
  - Soft tissue/capsule: 13%

- **Dynamic Contributions to Varus Torque**
  (Buchanan et al., 1998) - simulation
  - Pronator Teres: 15%
  - FCR + FCU: 7%
Arm Cocking Elbow Pathomechanics

- It appears the UCL is loaded maximally with every pitch. However, in-vitro cadaveric strength is likely less than in-vivo strength.
- The flexor/pronator mass generates a varus torque that resists valgus, thus unloading the UCL. However, weak or fatigued muscles may result in increased UCL strain, increasing injury risk.
Shoulder Abduction and Lateral Trunk Tilt,
(Escamilla et al., 1998; Fleisig et al., 1999)

Shoulder Abduction & Lateral Trunk Tilt

- Mean shoulder abduction was approximately 90° (85-105° ± 1 SD)
- Mean Contralateral Trunk Tilt was approximately 25° (15-35° ± 1 SD)
Influence of Shoulder Abduction and Lateral Trunk Tilt on Peak Elbow Varus Torque for College Baseball Pitchers During Simulated Pitching

(Matsuo et al., J Appl Biomech, 2006)

- At 40° lateral trunk tilt and at 70° or 120° abd, 125 Nm was generated – approx twice the varus torque generated at 10-30° lateral trunk tilt & 90-100° abd)
Case 1. A twenty-nine-year-old baseball pitcher for a major-league team complained of pain about the medial aspect of the elbow of three months’ duration when he was first examined by us in June 1972. Tenderness was present over the ulnar collateral ligament. Roentgenograms showed a small focus of ossification just medial to the elbow joint, and this was thought to represent an old partial avulsion of the epicondyle. The area had been injected with steroids approximately twenty-five times over eight years. The elbow had initially been painful when the patient was twelve years old and was pitching in the Little League, but after two years of rest it became asymptomatic and he began to pitch again.
Tommy John

- pitched 1973 season with one episode of pain
- pitching well in 1974 (13-3) when severe pain after slider
- felt elbow “give way”
- Had UCLR surgery in 1974, rehabbed in 1975, then went on to pitch effectively another 13 years in MLB
Tommy John  
PITCHER

6'3" 200 lb.  THROWS: LEFT  BATS: RIGHT  SIGN: INDIANS-1961, PRIOR TO DRAFT  
ACQ: FREE AGENT, 5-2-86  BORN: 5-22-43, TERRE HAUTE, INDIANA  HOME: CRESSKILL, N.J.

COMPLETE MAJOR LEAGUE PITCHING RECORD  (LEAGUE LEADER IN ITALICS, TIE ○)

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UCL Surgeries in Professional Baseball

www.BaseballHeatMaps.com
Prevalence of UCL Reconstruction in Professional Baseball Pitchers

Conte et al (2015)

Major League (n=382)
- UCLr (25%)
- No UCLr (75%)

Minor League (n=2324)
- UCLr (15%)
- No UCL reconstruction (85%)
Biomechanical Performance of Baseball Pitchers With a History of Ulnar Collateral Ligament Reconstruction

Glenn S. Fleisig,*† PhD, Charles E. Leddon,‡ PhD, Walter A. Laughlin,‡ MS, Michael G. Ciccotti,§ MD, Bert R. Mandelbaum,‖ MD, Kyle T. Aune,† MPH, Rafael F. Escamilla,¶# PhD, PT, Toran D. MacLeod,¶ PhD, PT, and James R. Andrews,†‡ MD

Investigation performed at the American Sports Medicine Institute, Birmingham, Alabama, USA

Background: A relatively high number of active professional baseball pitchers have a history of ulnar collateral ligament reconstruction (UCLr) on their throwing elbow. Controversy exists in the literature about whether professional baseball pitchers regain optimal performance after return from UCLr. It has been suggested that pitchers may have different biomechanics after UCLr, but this has not been previously tested.

Hypothesis: It was hypothesized that, compared with a control group without a history of UCLr, professional pitchers with a history of UCLr would have (1) significantly different throwing elbow and shoulder biomechanics; (2) a shortened stride, insufficient trunk forward tilt, and excessive shoulder horizontal adduction, characteristics associated with “holding back” or being tentative; (3) late shoulder rotation; and (4) improper shoulder abduction and trunk lateral tilt.

Study Design: Controlled laboratory study.

Methods: A total of 80 active minor league baseball pitchers (and their 8 Major League Baseball organizations) agreed to participate in this study. Participants included 40 pitchers with a history of UCLr and a matched control group of 40 pitchers with no history of elbow or shoulder surgery. Passive ranges of motion were measured for each pitcher’s elbows and shoulders, and then 23 reflective markers were attached to his body. The pitcher took as many warm-up pitches as desired and then threw 10 full-effort fastballs for...
Biomechanics with/without UCLr

- Received Research Grant from MLB
- Collected data during 2014 spring training at AZ & FL

- Outdoor data collection
  - 10 camera Motion Analysis system collected 240 Hz data
  - 10 fastballs per pitcher
Biomechanics with/without UCLr

- Collected data during 2014 spring training at Arizona and Florida
  
  - 40 professional league pitchers with UCLr 1 to 4 years ago
  - 40 matched pitchers
    - 1-to-1 match with UCLr pitcher
      - Same organization
      - Same projected level
    - No history of any arm surgery
      - UCL, elbow, shoulder
      - Pro ball, amateur, U.S., abroad
## Results

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<th>UCLr (n=39)</th>
<th>Control (n=38)</th>
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<td>Elbow flexion (°)</td>
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<td>External rotation (°)</td>
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<td>Varus torque (N·m)</td>
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<td>99 ± 16</td>
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• About 20% don’t make it back to previous level
  – Prospective research to determine why

• Those who make it
  – Same mechanics as others
  – Same performance as others
Age

They are getting younger!
## Competition Level

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<tr>
<td>165</td>
<td>165</td>
<td>155</td>
<td>10</td>
<td>4</td>
<td>7</td>
<td>2</td>
<td>6</td>
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</tbody>
</table>
Trends in Medial Ulnar Collateral Ligament Reconstruction in the United States: A Retrospective Review of a Large Private-Payer Database From 2007 to 2011
DOI: 10.1177/0363546515580304
Factors Related to Pain in Adolescent Baseball Pitchers


- The incidence of elbow pain increased with the number of pitches thrown in a game.
- The incidence of elbow pain increased with the number of pitches thrown in a season.
- Pitchers who threw curveballs or sliders had greater incidence of elbow pain than those who didn’t.
When a pitcher regularly threw with arm fatigue, he was 36 times more likely to be in an elbow surgery group as opposed to the non-surgery group.

When a pitcher engaged in more than 8 months of competitive pitching during a year, he was 5 times more likely to be in an elbow surgery group.

When a pitcher threw more than 80 pitches in a game/appearance, he was 4 times more likely to be in an elbow surgery group.

When a pitcher self-reported that he threw more than 85 mph, he was 2.5 times more likely to be in an elbow surgery group.
## Can We Prevent UCL Injuries?

### Pitch Counts

<table>
<thead>
<tr>
<th>Age</th>
<th>2006 USA Baseball Guidelines</th>
<th>2010 Little League Baseball Regulations</th>
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<tbody>
<tr>
<td><strong>Daily Limits</strong></td>
<td></td>
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<tr>
<td>17-18</td>
<td>N/A</td>
<td>105/day</td>
</tr>
<tr>
<td>15-16</td>
<td>N/A</td>
<td>95/day</td>
</tr>
<tr>
<td>13-14</td>
<td>75/game</td>
<td>95/day</td>
</tr>
<tr>
<td>11-12</td>
<td>75/game</td>
<td>85/day</td>
</tr>
<tr>
<td>9-10</td>
<td>50/game</td>
<td>75/day</td>
</tr>
<tr>
<td>7-8</td>
<td>N/A</td>
<td>50/day</td>
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<tr>
<td><strong>Weekly Limits</strong></td>
<td></td>
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<tr>
<td>15-18</td>
<td>N/A</td>
<td>31-45 pitches = 1 day rest</td>
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<td></td>
<td></td>
<td>46-60 pitches = 2 days rest</td>
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<td>61-75 pitches = 3 days rest</td>
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<td></td>
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<td>76+ pitches = 4 days rest</td>
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<tr>
<td>13-14</td>
<td>125/week; 1000/season; 3000/year</td>
<td>21-35 pitches = 1 day rest</td>
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<td>36-50 pitches = 2 days rest</td>
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<td></td>
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<td>51-65 pitches = 3 days rest</td>
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<tr>
<td></td>
<td></td>
<td>66+ pitches = 4 days rest</td>
</tr>
<tr>
<td>11-12</td>
<td>100/week; 1000/season; 3000/year</td>
<td></td>
</tr>
<tr>
<td>9-10</td>
<td>75/week; 1000/season; 2000/year</td>
<td></td>
</tr>
<tr>
<td>7-8</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>
• 500+ pitchers in past 10 years pitched in the little league world series (LLWS), but only 8 ever made it to MLB
• Why so few?
• Where are they now?
Arm Cocking Elbow Pathomechanics
(Cain et al, AJSM, 2003; Azar et al, AJSM, 2000)

- Lateral Compression Injury of Radiocapitellar Joint
  - Osteochondritis Dissecans
Arm Cocking Elbow Pathomechanics

(Cain et al, AJSM, 2003; Azar et al, AJSM, 2000)

Lateral Compression Injury of Radiocapitellar Joint
- Osteochondritis Dissecans

(Morrey & An, AJSM, 1983)
Arm Cocking Elbow Pathomechanics
(Cain et al, AJSM, 2003; Azar et al, AJSM, 2000)

- Lateral Elbow Injury –
  Osteochondritis Dissecans of Capitellum with Secondary Degenerative Changes in Radial Head
  - High radiocapitellar compressive forces adversely affect subchondral blood supply in capitellum, resulting in osteochondral injuries and loose bodies.
Arm Acceleration
(Max Shoulder External Rotation to Ball Release)
Kinematics During Arm Acceleration

(Escamilla et al., 1998; Fleisig et al., 1999)

Max Shoulder Internal Rotation Angular Velocity

6,260 – 8,540 °/sec

Fastest joint motion in sport

How fast is 7500 °/sec?

If the arm maintained that peak speed for 1 second, it would make about 20 full revolutions!
Kinematics at Ball Release

(Escamilla et al., 1998; Fleisig et al., 1999)

Shoulder Abduction

105°

85°
Kinematics During Arm Acceleration

(Escamilla et al., 1998; Fleisig et al., 1999)

Elbow

• Max Extension Ang Vel
  • 2,120 – 2,730 °/sec
Arm Deceleration & Follow-Through
(Ball Release to End of Throwing Motion)
Shoulder Biomechanics During the Arm Deceleration Phase
Arm Deceleration Shoulder Kinetics
(Escamilla et al., 2002; Fleisig et al., 1996)

(Body Weight = 900 N, or approx 200 lbs)

• Shoulder
  – Compressive Force = 1100 N
  – Posterior Shear Force = 400 N
  – Hor Abd Torque = 100 Nm

These kinetic measurements are influenced by the integrity of the rotator cuff and posterior shoulder musculature, which contract eccentrically to slow down the rapidly moving arm across the body
Glenohumeral Compressors
(Rotator Cuff)
(moderate to high activity)

- Infraspinatus – 37% MVC
- Teres Minor – 84% MVC
- Supraspinatus – 39% MVC
- Subscapularis – 60% MVC
Arm Deceleration Shoulder Pathomechanics
Tensile Overload Articular Surface
(Undersurface) Rotator Cuff Tears

EMG
- Teres Minor–84% MVC
- Infraspinatus–34% MVC
- Supraspinatus–39% MVC
(DiGiovine et al., J Shou Elb Surg, 1992)

Posterior cuff fires eccentrically to decelerate arm hor add and IR, while the entire cuff is active to resist glenohumeral distraction.
Arm Deceleration Shoulder EMG

(DiGiovine et al., J Shou Elb Surg, 1992)

• Posterior Glenohumeral Muscles
  (moderate to high activity)
  - Posterior Deltoid – 60% MVC
  - Latissimus Dorsi – 59% MVC
  - Infraspinatus – 37% MVC
  - Teres Minor – 84% MVC
Arm Deceleration Shoulder EMG

(DiGiovine et al., J Shou Elb Surg, 1992)

- Scapular Muscles (moderate to high activity)
  - Upper Trapezius – 53% MVC
  - Middle Trapezius – 35% MVC
  - Lower Trapezius – 78% MVC
  - Serratus Anterior – 51% MVC
  - Rhomboids – 45% MVC
  - Levator Scapula – 33% MVC

There is evidence of scapular kinematic alterations associated with shoulder impingement, rotator cuff tendinopathy and tears, glenohumeral instability, and decreased shoulder ROM.

(Ludewig & Reynolds, JOSPT, 2009)
Arm Deceleration Shoulder Pathomechanics

**SLAP Lesion** (Andrews et al, AJSM, 1985)

- Increased and excessive biceps activity results in increased stress to long biceps anchor at the superior labrum, which over time may result in a SLAP lesion
**SLAP Lesion** (Andrews et al, AJSM, 1985)

- **EMG**
  - Biceps Brachii Have Their Greatest Activity During Arm Deceleration
    - 44% of MVC

*(DiGiovine et al., J Shou Elb Surg, 1992)*
Arm Deceleration Shoulder Pathomechanics
What is the Role of the Long Biceps at the Shoulder?

- With shoulder IR the long biceps tendon is re-positioned anteriorly at the shoulder, providing a compressive and posterior force to the humeral head, both which enhance anterior stability and control (resist) IR (Rodosky et al, AJSM, 1994)

- Throwers with chronic anterior instability activate their biceps to a greater extent (32% vs 12% MVC), as well as their supraspinatus and infraspinatus (37% vs 13% MVC), compared to asymptomatic throwers (Glousman et al, JBJS, 1988)
SLAP Surgical Treatment Options: Which is Best?

- Biceps Tenodesis (cut & re-attach lower)
- Biceps Tenotomy (cut)
- Type II SLAP Repair

![SLAP Surgical Treatment Options Diagram](image)
Elbow Biomechanics During the Arm Deceleration Phase
Arm Deceleration Elbow Kinetics

(Escamilla et al., 2002; Fleisig et al., 1995)

(Body Weight = 900 N, or approx 200 lbs)

- Elbow
  - Compressive Force = 900 N
  - Flexor Torque = 60 Nm
Arm Deceleration Elbow EMG
(DiGiovine et al., J Shou Elb Surg, 1992)

• Elbow Flexors
  (highest activity occurred during arm deceleration)
  – Biceps Brachii – 44% MVC
  – Brachialis – 49% MVC
  – Brachioradialis – 46% MVC

• Elbow Extensors (moderate activity)
  – Triceps – 54% MVC
Arm Deceleration Forearm EMG
(DiGiovine et al., J Shou Elb Surg, 1992)

- **Flexor/Pronator Mass** (moderate to high activity)
  - Pronator Teres – 51% MVC
  - Flexor Carpi Radialis – 79% MVC
  - Flexor Carpi Ulnaris – 77% MVC
  - Flexor Digitorum Superficialis – 71% MVC

- **Supinator/Extensor Mass** (moderate to high activity)
  - Supinator – 59% MVC
  - Extensor Carpi Radialis Longus – 43% MVC
  - Extensor Carpi Radialis Brevis – 43% MVC
  - Extensor Digitorum Communis – 47% MVC
Elbow Pathomechanics
Posteromedial Injuries – Valgus Extension Overload
(Andrews et al, 1983; Cain et al, 2003)

• Impingement of Posteromedial Olecranon with Posteromedial Trochlear Groove and Olecranon Fossa
Valgus Extension Overload

(Andrews et al, 1983; Cain et al, 2003)

- May result in posteromedial olecranon osteophytes & loose bodies
- May be exacerbated by UCL insufficiency/tear or pronator/flexor weakness or fatigue
- May result in osteochondroses of capitellum or radial head
Recommendations by USA Baseball Medical and Safety Advisory Committee – Yearly Competition

• Competitive baseball pitching should be limited to 8 months in any given year
  – A periodization regime should be followed, including active rest, in order to provide sufficient rest and recovery
  – At least 4 months/year a pitcher should not compete in baseball or participate in other overall throwing activities that may be stressful on the arm
    • e.g., javelin throwing, football passing, competitive swimming, etc…}
ASMI Position Statement for Injury Prevention

1. Watch and respond to signs of fatigue.

2. No overhead throwing of any kind for at least 2-3 months per year (4 months is preferred). No competitive baseball pitching for at least 4 months per year.

3. Follow limits for pitch counts and days rest.
4. Avoid pitching on multiple teams with overlapping seasons.

5. Learn good throwing mechanics as soon as possible. Learn, in order:
   - basic throwing
   - fastball pitching
   - change-up pitching

6. Avoid using radar guns.
7. Avoid pitcher-catcher combination.

8. If elbow or shoulder pain, see a sports medicine physician.

9. Inspire youth pitchers to have fun playing baseball and other sports. Participation and enjoyment of various physical activities will increase the youth's athleticism and interest.
Conclusion

- Poor pitching mechanics or muscle weakness or fatigue can result in increased shoulder force and torque, with a subsequent increase in shoulder injury risk.
- Both excessive shoulder ER and deficits in shoulder IR can lead to pathologies such as SLAP lesions and anterior instability.
- The Role of the long biceps brachii in pitching is becoming a bigger issue.
Conclusions

- Poor pitching mechanics or muscle weakness or fatigue can result in increased elbow force and torque, with a subsequent increase in elbow injury risk.
- UCL insufficiency or flexor/pronator muscle weakness or fatigue may result in UCL injuries.
Sample of Throwing Biomechanics Publications

- Escamilla, Barrentine et al., American Journal Sports Medicine, 2007
- Escamilla, Fleisig et al., American Journal of Sports Medicine, 2006
- Fleisig, Kingsley, et al., American Journal of Sports Medicine, 2005
- Fleisig, Nicholls, et al., Sport Biomechanics, 2003
- Escamilla, Fleisig et al., Sports Biomechanics, 2002
- Matsuo, Escamilla et al., Journal of Applied Biomechanics, 2001
- Escamilla, Fleisig et al., Sports Medicine, 2000
- Fleisig, Barrentine, et al., Journal of Biomechanics, 1999
- Escamilla, Fleisig et al., Journal of Applied Biomechanics, 1998
- Fleisig, Escamilla et al., in Injuries in Baseball (Lippincott Raven), 1998
- Fleisig, Escamilla et al., Journal of Applied Biomechanics, 1996
Thank You!

American Sports Medicine Institute

California State University, Sacramento

RESULT
Physical Therapy and Training Center

Andrews Institute
Pitch Mechanics Related to Injury

Gary J Calabrese PT, DPT
Senior Director
Rehabilitation and Sports Therapy
Cleveland Clinic
INVITED CLINICAL COMMENTARY
PITCHING MECHANICS, REVISITED
Gary J. Calabrese, PT, DPT

The International Journal of Sports Physical Therapy | Volume 8, Number 5 | October 2013 | Page 652
Cleveland Clinic Biomechanics Lab

What Our Eyes Think They See

Good balance
Tall then fall
Stop at the top
Stay back
Stay over the rubber
Rushed motion
Drop and drive
Push off the rubber
Stride across the body
Thumb to sky, ball to sky
Throwing side-arm
Open stride
Point toe to home plate

Land on ball of foot
Hand break towards second base
Hands move down and up
Get on top of the ball
Short/long stride
Reaches back
Short arming
Kinematics/Kinetics of Pitching
Pitching is a Kinetic Chain Event

- Kinetic Chain
  - Coordinated activation of body segments
  - Requires neuromuscular coordination
  - Demanding on soft tissue
  - Produces tremendous forces on shoulder/elbow
Pitching Kinetic Chain

- Stride
- Pelvis Rotation
- Upper Torso Rotation
- Shoulder ER
- Elbow Extension
- Shoulder IR Rotation
- Wrist Flexion/Pronation

Summation of speed concept
Comprehensive Components

Pitching Motion

Phases of Motion

Efficient Delivery

Pitching Signature Variables
Pitching Biomechanics - Pitching Phases

- Wind up
- Stride
- Arm Cocking
- Arm Acceleration
- Arm Deceleration
- Follow Through

Biomechanical breakdown at any phase increases risk of injury
7 Pitching Signature Variables

- Good balance and posture
  - Balanced lead leg lift
- Directional body thrust
  - Stride and momentum
- UE tracking opposite and equal
- Hip and Shoulder relationship
- Stack and Track to plate
- Rotate and stabilize
- Release and follow through
Wind-Up
Balance/Posture
Wind-Up Balance/Posture

First Movement to Peak Lead Leg Height

- Balance point (BP)
  - 2 leg to 1 leg stance
- Sets tone for pitch

Clinical Pearl:
Assess hip and ankle mobility
Ability to hip hinge
Balance deficits
Wind-Up Balance/Posture

Historical
- Ball in Glove
- Glove at chest height
- Shoulders between home and second
- Lead leg hip/knee at 90

Pearl: Signature Variables
- Balance
- Posture
Wind-Up Balance/Posture

Signature Variables

- Good balance – head over trunk and between balls of feet to start
- Athletic position
- Good posture – spine to hip angle that stabilizes head during delivery (TILT)
Lateral side bend at balance point – weak glut medius stance leg  
Thoracic spine – passive insufficiency of lower trap (weak)  
Closed stride – tight lead leg ER  

YES  
YES  
YES
Wind-Up Balance/Posture

Poor stability at Balance Point _ weak glut medius, poor core stability
Hip and Shoulders rotate to plate together – poor core dissociation
Program: Proximal stability

YES
YES
Stride

Shoulder - Pelvis Rotation
Direction
Upper Extremity Tracking
Length
**Stride**

- From Max lead leg height to first hand break to stride foot contact

**Affected by:**
- Leg lift
- **Stride direction**
- Foot contact
- Lead knee angle
- Stride length

**Affects:**
- UE opposite and equal movement
- Hip/shoulder separation
Stride Kinematics

Biomechanics - Lower Quarter Requirements
- Lead leg hip ER/abduction
- Trail leg hip IR
- Trail leg to lead leg stride angle (>135 deg.)

Biomechanics – Upper Quarter Requirements
- Stride trunk position must maintain proper scapular/body plane position between 30-40 degrees

Clinical Pearl:
Assess hip ROM
Glut Med strength
Load While Moving Forward

- Quads are excellent for pushing and jumping forward, NOT good for sitting, riding or rotating.

Clinical Pearl:
Determine Quad vs Glut Med dominance
Glut Med > Quad work
Assess Hamstring and adductor flexibility
Trunk

- Trunk orientation rotation and tilt

Produced a higher ball speed (by 3.3 mph) but also had 10% greater shoulder and elbow joint loading.

Stride Hip and Shoulder Separation

- Optimal angle difference between lead hip and back shoulder
  - 40 – 60°
  - < 40° look for tissue restriction
  - > 40° hypermobile
Poor Shoulder Pelvis Dissociation

Glute dominant pitcher tends to project themselves toward home plate. Quad dominant tend to land toward their arm side, or they exhibit some sort of disconnected directional correction.
Stride Direction

- Towards target or slightly closed

Closed – Increased lead leg hip IR torque
  Posterior shoulder eccentric overload
Open – Increased trail leg hip ER torque
  Poor UE timing sequence with increased anterior shoulder strain at max ER and ball release.
Stride Length

- **Debatable (77-95% height)**
  - **Younger (65-80% height)**

Trunk is main contributor to linear and angular momentum

- Longer strides (longer generation phase) better regulates transverse trunk momentum in double support prior to acceleration.

- Shorter strides Conversely, increased transverse trunk momentum prior to throwing arm acceleration may elicit undesirable momentum exchanges between the trunk and throwing shoulder

Short Stride

2 sports athlete
BB and basketball

Short stride based off lead leg ankle stability – weak ankle Eversion
Tight hamstrings L>R (right handed)
Stride – UE Opposite and Equal Movement

- Mirror image of glove and ball hand in late cocking phase of stride
- Same image in early cocking phase
- Arm Path – smooth “down and up”

Biomechanics – UE Requirements

- Shoulder ER
- Elbow height
- Elbow Flexion
UE Position at Foot Contact

- From Stride Foot Contact to Max. Shoulder ER → Arm Cocking

Scapula functions to align the humerus with the spine of the scapula so as to maximize glenohumeral joint configuration within the “safe zone” at the MER.

Complication factors:
- Poor Scapular upward mobility
- Poor total arc of shoulder motion (GIRD)
- Short stride
- T-Spine extension restriction

Faults
- Arm path
  - Long arming
- Shoulder/Elbow height
- Wrist hooking
Summary

- Balance tissues – stretch Pec Minor, mobilize restricted joints, strengthen scapular retractors
- Balance Point issues – assess hip and ankle mobility
- Stride issues – hip mobility, ham/adductor flexibility
- Determine Quad vs Glut dominant stride
- Shoulder / Pelvis dissociation – T-spine mobility
- Stride direction – Open vs Closed or “just right”
- Stride length – progress slowly after direction issues
Thank You

Gary J. Calabrese, PT, DPT
calabrg@ccf.org
Video Throwing Analysis: Biomechanics and Prevention for the Baseball Pitcher

Drew Jenk PT, DPT
Regional Clinical Director
Sports Physical Therapy of NY
CSM 2017
San Antonio, TX

Disclosures
Nothing to Disclose and no financial considerations

Objectives
• Outline Video Analysis for the Private Practitioner
  – The Lecture
  – The Exam
    • UE
    • LE
  – The Video Analysis
• Cases
• Coaching knowledge
• Take home

Goals – Video Analysis for the Private Practitioner
• Educate the clients on the muscles, forces, and stresses involved in the throwing motion
  – Lecture
• Create an individualized exercise program
  – Physical exam
    • Thrower’s 10; Ballistic 6; Interval Throwing Program
    • Individual program based on exam
• Identify and correct aspects of the throwing motion that may predispose athletes to injury
  – Video analysis

The Lecture
- Group format
Functional Return to Throwing

Drew Jenk DPT
Regional Clinical Director
Sports Physical Therapy of New York

Challenges
- Minimizing effects of microtrauma
- Controlling acute inflammation
- Maintaining total arm flexibility
- Improving arm power and endurance
- Maintaining cardiovascular, lower extremity & core conditioning
- Communication

Presentation Goals
- Biomechanics
  - Phases of throwing / pitching
  - Muscles, motion & force
- Back to Basics: Functional Progression of Rehab / Training
- Seasonal exercise considerations
- The return to throwing
  - Interval throwing programs
  - Common throwing flaws
  - Common questions

Why?
- 1998: AJSM
  - 349 players on the disabled list
  - 49% pitchers
- 2006: Rick Wilton’s Baseball Injury Report
  - 347 players on the disabled list
  - 69% pitchers

Pitch 22
- Could Tommy John be the end of the shoulder injury epidemic?
- Is the elbow the new weakest link?
  - Shoulder injuries (Days on the DL)
    - 2008: 7,000
    - 2014: 3,000
  - Elbow injuries (Days on the DL)
    - 2008: 5,000
    - 2014: 8,000
The Stages of Throwing

- Wind-up
- Arm cocking
- Arm acceleration
- Arm deceleration
- Follow-through

Biomechanics of Pitching

- The stages of pitching
- 23 youths, 33 HS, 115 college, 60 professionals
- Kinematic, kinetic, temporal data averaged for 3 pitches
- Mechanics are the same, forces are different

Max Forces at Shoulder

- **Cocking phase**
  - Max ER = 165 - 185°
  - Ant shear = 380 N
  - IR torque = 64 N

- **Acceleration phase**
  - Minimal loads
  - > 7000 deg/sec @ shldr
  - > 2500 deg/sec @ elbow

- **Deceleration phase**
  - Horizontal abd = 97 N
  - Compressive = 1090 N

Valgus torque 64 Nm

- Fleisig AJSM 2007

Phases of Injuries

- Injuries most likely to occur at cocking, acceleration, and deceleration phases.
- Follow-through ???
- 0.5 seconds to complete throw from wind-up to ball release

Back to Basics: Functional Progression of Rehab

- 1) Warm-up
- 2) Tissue Preparation
- 3) Relaxation
- 4) Tissue Mobility
- 5) ROM / Flexibility
- 6) Strength
- 7) Coordination / Proprioception / Balance
- 8) Speed / Agility / Power
- 9) Functional Skills
- 10) Endurance
- 11) Cool Down
Seasonal Exercise Considerations

- Postseason – Active Rest and Recovery
- Off-Season – Fitness Training
- Preseason I – Training to Compete
- Preseason II – Training to Play
- In-Season – Training to Win

Interval Throwing Program

- Considerations:
  - Level of play
  - Pro/college
  - Little league
  - Softball (Windmill)
  - Injury rehab
  - Field Position
  - Proper warm up

Common Questions & Concerns

Q: What do I look for as a coach or parent?
A: Uncontrollable pitches
    - Velocity losses
    - Ineffective outings
    - Increasing time between outings
    - Stiffness and/or pain
    - Elbow dropping
    - Lateral trunk lean
    - Front shoulder flying open

The Return to Throwing

Common Questions & Concerns

- Pitch Count
- Rest
- Type of Pitch

Research
The Physical Exam

Upper Extremity
- Inspection
  - Posture
  - Movement – Shirt off
- ROM
- Flexibility
- Joint Mobility
- Strength

Lower Extremity
- ROM
- Flexibility
- Strength
- Y-balance
- FMS

Education
- KJOC
- Interval Throwing Program
- Thrower’s 10
- Ballistic 6
- Risk Factors
- Individualized HEP
  - All based on Periodization

The Video Analysis

Biomechanical Video Throwing Analysis
- One Simple Question:
  - What mechanics may make this athlete more susceptible to injury?
- Views
  - Anterior
  - Posterior
  - Right and Left
What do you need?

- Getting started
  - Brochures
  - Video camera
  - DVD recorder
  - Open space

- Finished Product
  - DVD
  - Analysis
  - Individualized HEP
  - Thrower’s 10
  - Interval throwing program
  - Equipment
    - Theraband soft wt
    - Tubing
    - Flexbar

Marketing

- Patients
- Physicians
- ATC’s
- CSCS
- Coaches
- Little League / Travel League
  - Parents
  - Players

Cases

Analysis

- Hand position at initiation of motion demonstrate increased elbow elevation compared to (L). This potentially affects the range and duration of the arm path into the cocking phase.
- During wind-up, he rotates his body away from home plate potentially throwing off his timing.
- Trunk collapse which shortens his anterior core musculature and may contribute to a shorter stride. A shorter stride will lead to the arm having to accelerate to get to ball release point in the proper timing pattern of the throw.
- Short break; early lead foot contact causes arm to lag behind and excessive IR at foot contact.
- Initial hand break appears to be in a hyper-flexed wrist position which can cause excessive muscular tension and increased pronation. Wrist hooking often leads to flavor pronator type arm and does not allow the pitcher to get their hand tall and up at the late cocking position. The arm is always playing catch-up and thus stress is realized in the elbow.
- At late cocking he moves from a wrist hyper-flexed pronated position to a position of excessive extension in a very short period of time in the throwing cycle.
- Just after stride foot contact, he is not achieving adequate hip and shoulder separation. His hips and shoulders seem to rotate together prior to maximal external rotation. He could be losing the necessary transfer of energy from his lower legs through his trunk to his arm during this phase.
Analysis

- Large rocker step
- Trunk and leg collapse
- Front side flies open
- Energy transfer lateral instead of toward home plate
- Arm playing constant catch-up

Coaches Knowledge


Joseph K. Pamias-Velázquez, Michele M. Figueroa-Negrón, Jesús Tirado-Crespo, and Ana L. Mulero-Portela

The purpose of this study was to determine the compliance of pitching coaches of 9- to 14-year-old Little League teams in Puerto Rico with the Administrative Order 2006-01 and the USA Baseball guidelines.

RESULTS:

Thirty-five coaches (response rate, 78%) participated in the study. On average, the coaches complied with 70% of the Administrative Order and with 73% of the USA Baseball guidelines. No significant correlations were found.

Research


James J. Fazarale, Ronald A. Magnussen, Anthony D. Pedroza, Chad C. Kaeding, and Todd M. Best

Conclusion: This subset of youth baseball coaches is deficient with regard to knowledge of the USA Baseball Medical and Safety Advisory Committee pitching guidelines. This situation may put youth baseball pitchers at increased risk for upper extremity pain and injuries.

Take Home

What to Look For – Sometimes a “Baseball Thing”

- Loss of pelvic control at wind-up
- Pelvis closed at foot strike
- Strike foot planted away from home plate
- Elbow dropping below shoulder height
- Excessive lateral trunk lean
- Supination of the forearm at foot strike
- Excessive shoulder IR at foot strike
- Poor finish
5 Things to Remember

- Dynamic Balance
- Posture
- Opposite and Equal
- Glove in a box
- Late Rotation

Thank You

djenk@sptny.com