The Biomechanics of Baseball Pitching

Glenn S. Fleisig, Ph.D.

ASMI
American Sports Medicine Institute

The Biomechanics of Baseball Pitching

- Established American Sports Medicine Institute (ASMI) in 1987
- PhD dissertatio
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Pitching Biomechanics

- ISBS 2001
  - Proper mechanics
  - Injury mechanisms

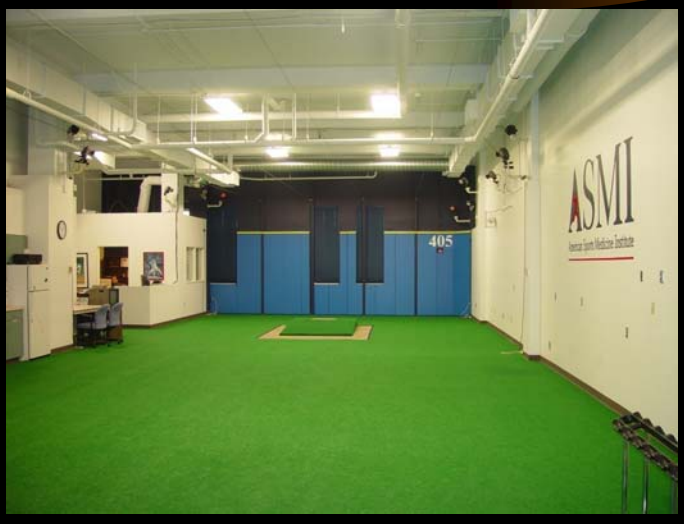
- Since 2001
  - Prevention of injuries
  - Quantity and quality of data
  - Equipment upgrade
  - Numerous publications
  - Individual athletes and coaches (ISBS mission)

Pitching Biomechanics

- ISBS 2010
  - Proper mechanics
  - Understanding of injury mechanisms
  - Changes correlated to
    - Increased velocity
    - Increased joint loads
  - Comparison among levels
  - Pitch types
  - "Big picture" of injury risk

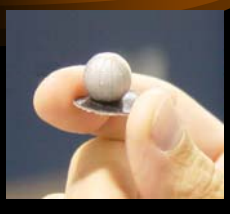
James Andrews Biomechanics Lab

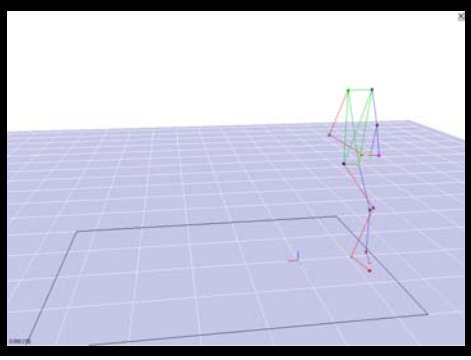
- 85 x 30 x 17 ft. Indoor Laboratory



Biomechanics Laboratory Equipment

- **Motion Analysis System (Motion Analysis Corp.)**
  - **8 high-speed cameras (240 Hz)**
  - **Reflective markers**
  - **Automatic 3D digitizing**





Marker placement

- **Reflective markers**

Acromion

Lateral Epicondyle

Greater Trochanter

Distal Ulna

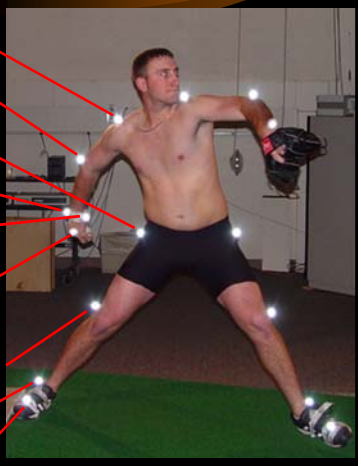
Distal Radius
(only on pitching hand)

Distal 3rd Metacarpal
(only on pitching hand)

2 in. Superior to Proximal Fibula

Lateral Malleolus

Distal 3rd Metatarsal

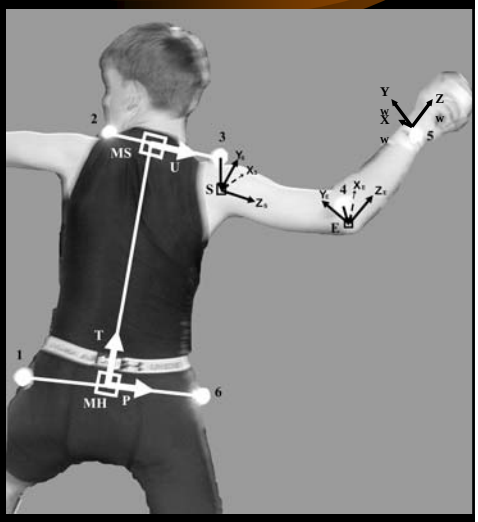


Biomechanics Laboratory Equipment

- **High-Speed Video (Vision Research Inc.)**
  - **450 frames/second**

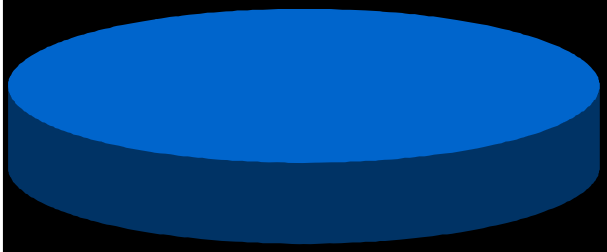
Pitching Biomechanics

- 46 Kinematic parameters (joint angles, joint velocities, timing)
- 19 Kinetic parameters (joint forces and torques)



Pitching Biomechanics

1200 Baseball Pitchers



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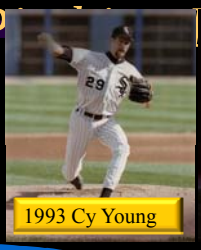
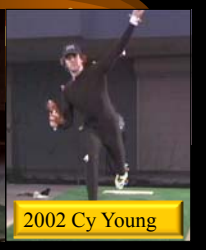
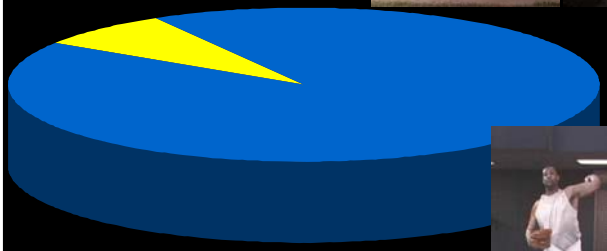
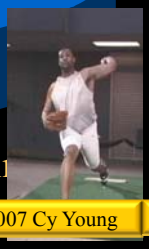
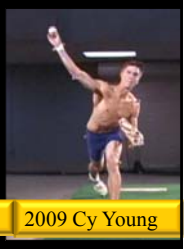
90 Elite Pitchers







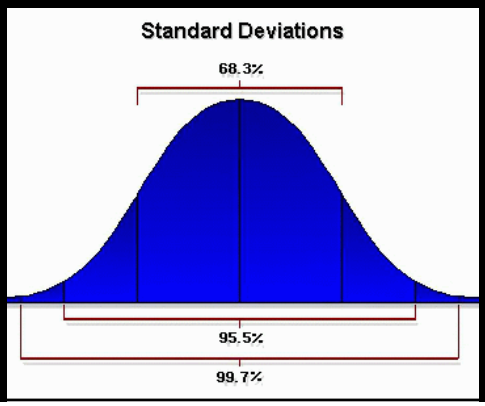




- Threw 85^{+} mph during testi
- Healthy for 1^{+} year

Elite Pitching

- "Elite Range" calculated as mean ± standard deviation for each parameter.



Throwing Motion

Six Phases

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

Balance Point

Pelvic Drift

20 ± 5 cm

Balance Point

Hands in Front of Chest

Stride

Hands break when knee moves towards plate

Both Arms Swing Down, Apart, Up

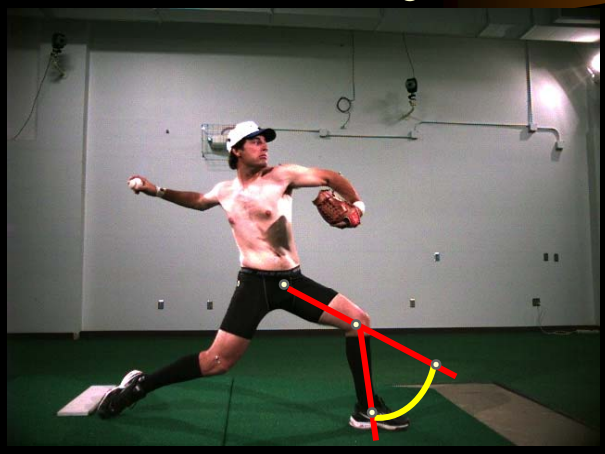
Stride Length

Stride Length Ratio

77 to 87% of height

Lead Knee Angle

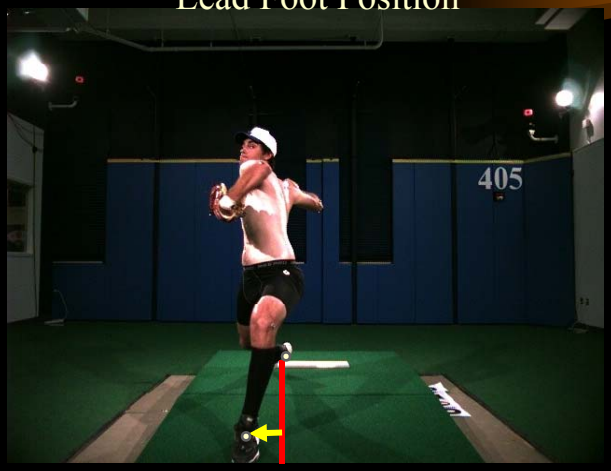
Lead Knee Angle



43 ± 10 degrees

Lead Foot Position

Lead Foot Position



25 ± 10 cm

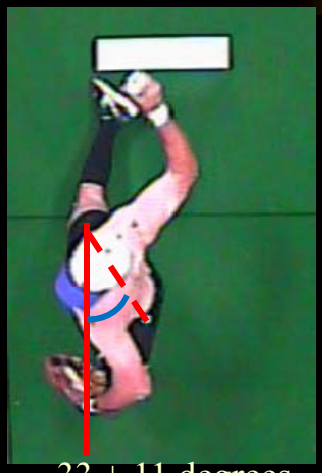
Lead Foot Position

Lead Foot Angle

17 ± 9 degrees

Pelvic and trunk position

Pelvic Rotation



33 ± 11 degrees

Pelvic and trunk position

Trunk Separation

45 ± 14 degrees

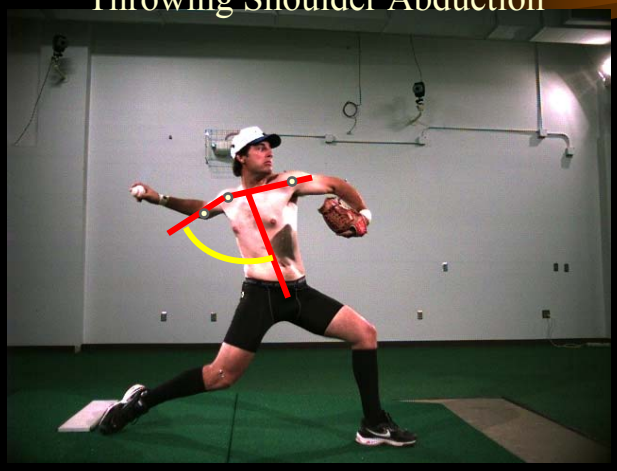
Pelvis and Trunk Position

Trunk Tilt

4 ± 7 degrees

Throwing Arm Position

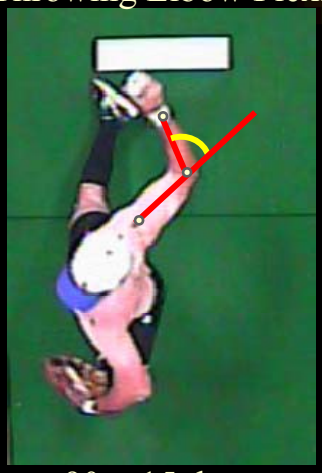
Throwing Shoulder Abduction



93 ± 11 degrees

Throwing Arm Position

Throwing Elbow Flexion



90 ± 15 degrees

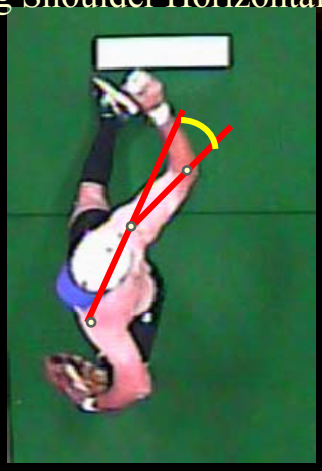
Throwing Arm Position

Throwing Shoulder External Rotation

57 ± 21 degrees

Throwing Arm Position

Throwing Shoulder Horizontal Abduction



24 ± 10 degrees

Pelvic Rotation

Maximum Pelvic Rotation Velocity

590 ± 80 deg/sec

27 ± 10 % time

Upper Trunk Rotation

Maximum Upper Trunk Rotation Velocity

1150 ± 80 deg/sec
48 ± 9 % time

Throwing Arm Position

Maximum External Rotation

182 ± 8 degrees

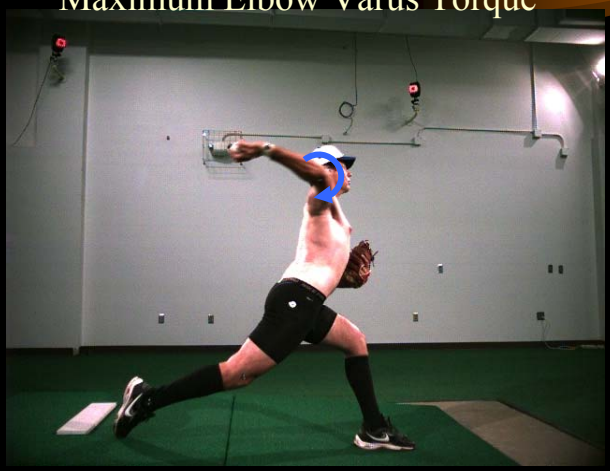
Throwing Arm Position

Maximum Shoulder Internal Rotation Torque

101 ± 17 Newton-Meters

Throwing Arm Position

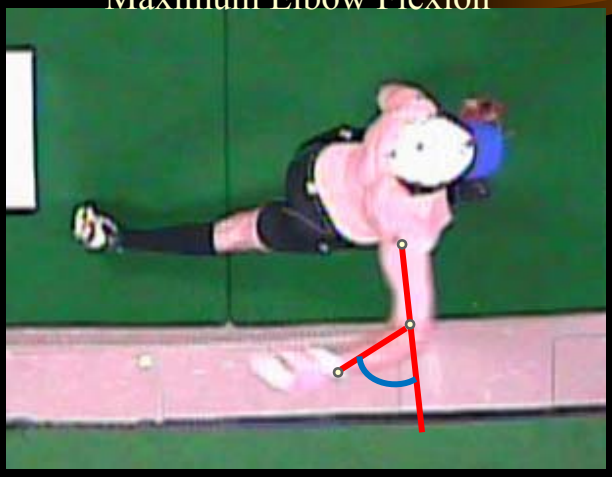
Maximum Elbow Varus Torque



99 ± 17 Newton-Meters

Throwing Arm Position

Maximum Elbow Flexion



102 ± 11 degrees

Throwing Arm Position

Maximum Horizontal Adduction

21 ± 2 degrees

Throwing Arm Position

Maximum Horizontal Adduction Torque

112 ± 22 Newton-Meters

Shoulder Rotation

Maximum Shoulder Internal Rotation Velocity

7510 ± 850 deg/sec

Shoulder Rotation

Maximum Shoulder Proximal Force

1270 ± 170 Newtons

Elbow Extension

Maximum Elbow Extension Angular Velocity

2350 ± 330 deg/sec

Elbow Extension

Maximum Elbow Flexion Torque

52 ± 11 Newton-Meters

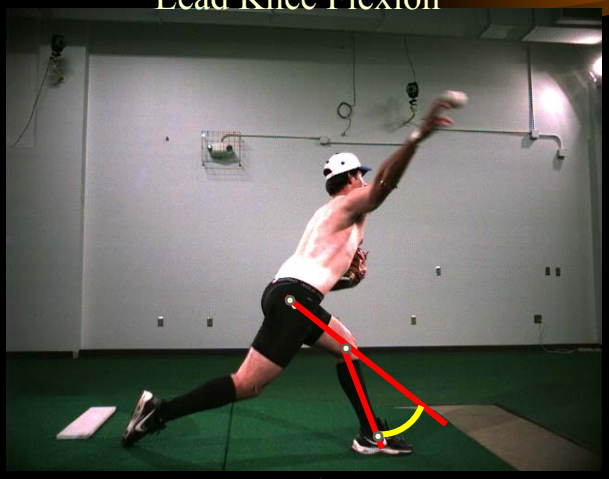
Pelvic Deceleration

Maximum Pelvic Deceleration

31 ± 8 m/sec²

Front Leg Position

Lead Knee Flexion



35 ± 13 degrees

Front Leg Position

Lead Knee Flexion at FC - BR

12 ± 9 degree change

Front Leg Position

Shank Angle (Relative to Vertical)

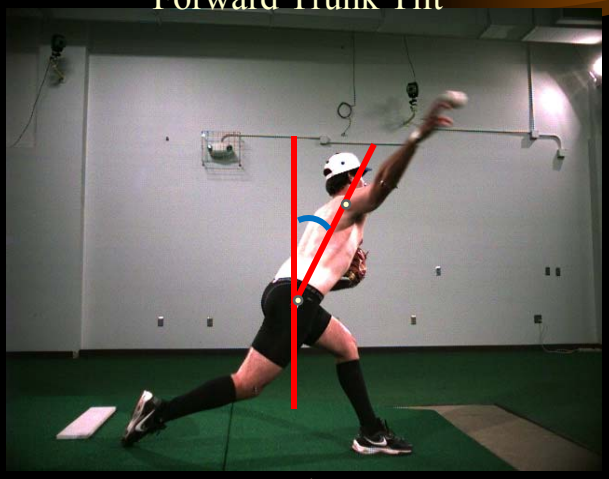
17 ± 7 degrees

Front Leg Position

Glove Tucked at Release

Trunk Position

Forward Trunk Tilt



36 ± 7 degrees

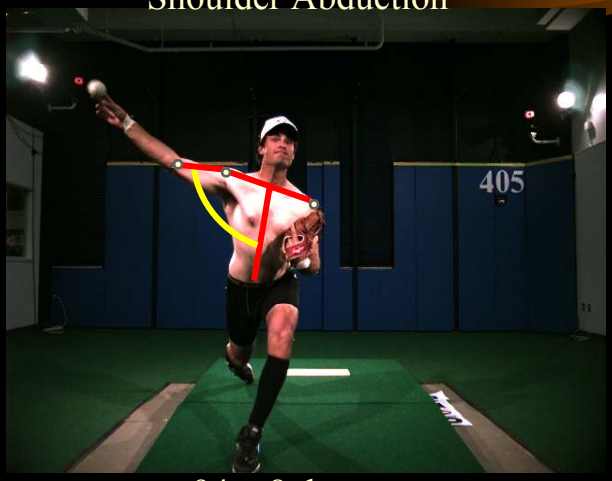
Trunk Position

Side Trunk Tilt

23 ± 10 degrees

Arm Position

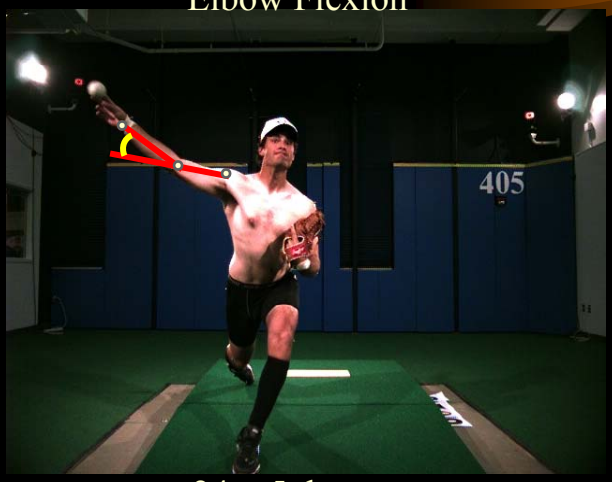
Shoulder Abduction



94 ± 8 degrees

Arm Position

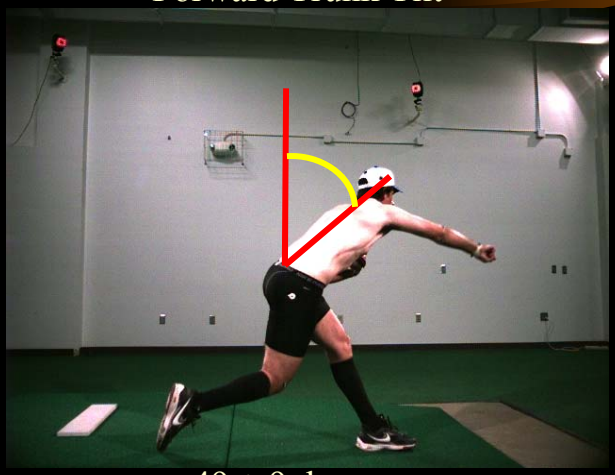
Elbow Flexion



24 ± 5 degrees

Follow Through Position

Forward Trunk Tilt



49 ± 9 degrees

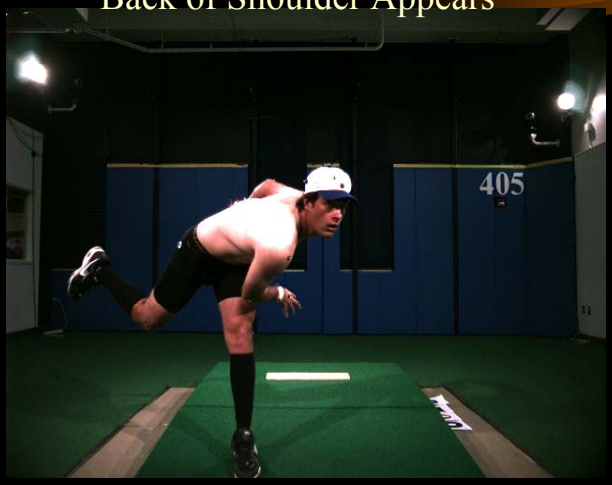
Follow Through Position

Lead Knee Flexion

22 ± 12 degrees

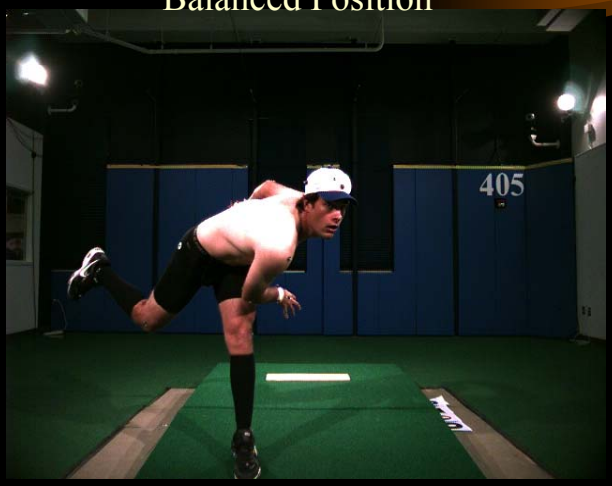
Follow Through Position

Back of Shoulder Appears



Follow Through Position

Balanced Position



Biomechanics of injury

- Observation from orthopaedic surgery clearly shows that pitching injuries are from repetition.

- Biomechanics
  - Motion studies
    - Joint position
    - Joint velocity
    - Joint force/torque
  - Cadaveric studies
    - Tissue strength

Pathomechanics

Two critical instants

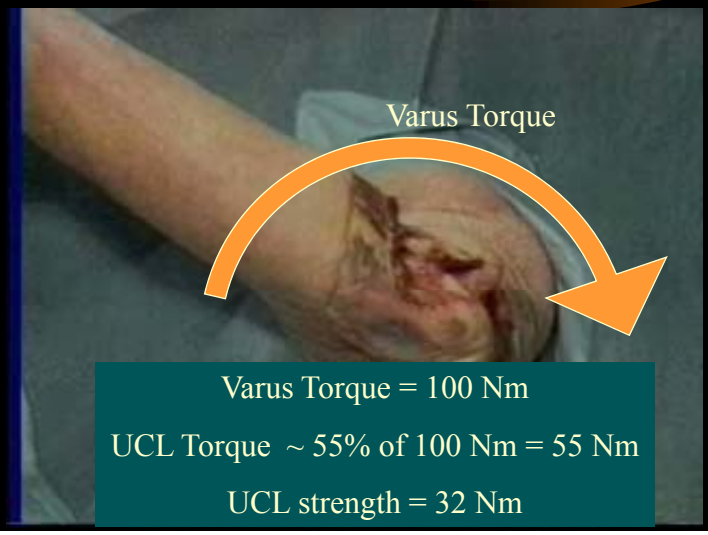
Max. ER

Ball Release

Pathomechanics

- Maximum external rotation
- Shoulder
  - Anterior Force = 340 N
  - Int Rot Torque = 100 Nm
- Elbow
  - Varus Torque = 100 Nm
    (equivalent to 25 kg mass hanging down from the hand)

Ulnar collateral ligament injury

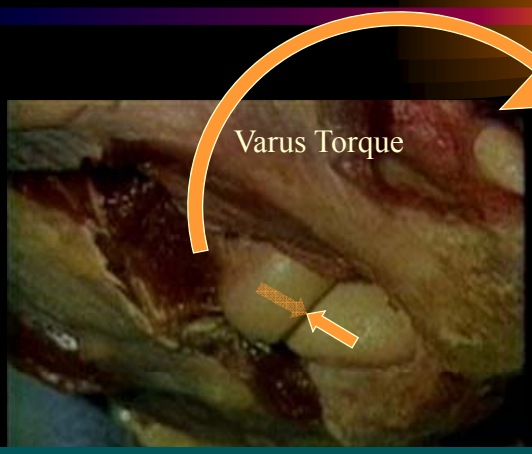


Varus Torque = 100 Nm

UCL Torque ~ 55% of 100 Nm = 55 Nm

UCL strength = 32 Nm

Lateral Elbow



Varus Torque = 100 Nm

Radiocapitellar ~ 33% of 100 Nm = 33 Nm

33 Nm / 0.04 m = 800 N

Valgus Extension Overload

Pathomechanics

- Elbow Varus Torque = 100 Nm
- Elbow Extension = 2300°/s

Pathomechanics

- Shoulder
  - Proximal Force = 1270 N (resist distraction)

(Avg. Pitcher's Body Weight = 920 N)

Ball Release

SLAP Lesion

SLAP Lesion

SLAP Lesion

Arm Deceleration

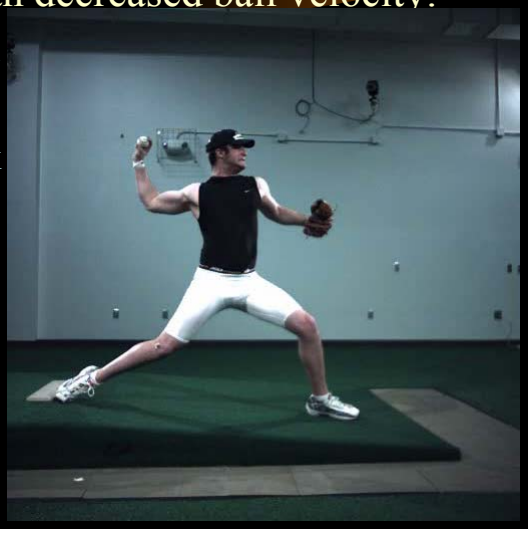
- Tension in Posterior Rotator Cuff Muscles

Ball Velocity

- Flaws correlated with decreased ball velocity:
  - ↓ Push off rubber
  - ↓ Stride length
  - Excessive ER at FC
  - ↓ Horizontal ABD

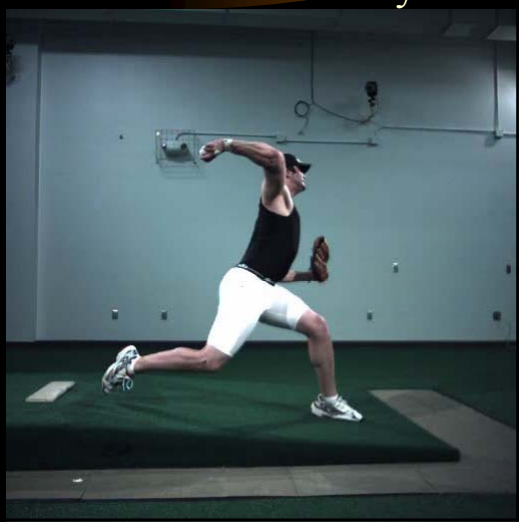
Ball Velocity

- Flaws correlated with decreased ball velocity:
  - Early pelvis rotation
  - ↓ Pelvis velocity
  - Poor timing of trunk
  - ↓ ER



Ball Velocity

- Flaws correlated with decreased ball velocity:
  - ↓ knee extension vel
  - Improper ABD
  - Upright trunk



Joint Loads

- Correlated with ↑ shoulder/elbow force or torque
  - Front foot open
  - Improper ER

Joint Loads

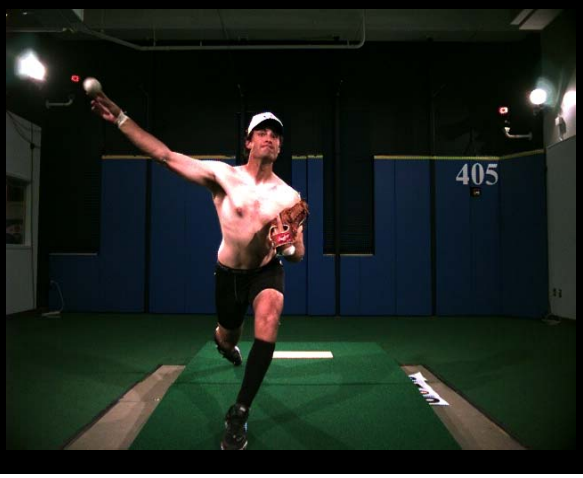
- Correlated with ↑ shoulder/elbow force or torque
  - Late pelvis rotation
  - Poor trunk timing

Joint Loads

- Correlated with ↑ shoulder/elbow force or torque
  - ↑ Hor ADD and Elbow flexion

Joint Loads

- Correlated with ↑ shoulder/elbow force or torque
  - Improper ABD



Age Levels

- Compared to adults, young pitchers have
  - Similar angles, timing
  - More variability in angles
  - Less angular velocity, ball velocity
  - Much less force & torque

Pitch Types

- Compared to the fastball,
  - Change up has slower motions
  - Change up has less force and torque
  - Curveball has different motions
  - Curveball has similar or less force & torque

Injury factors

Injury factors

- Pitching Mechanics
- Pitch Type
- Pitch Volume
  - Epidemiology studies
- Physical Attributes
  - Genetics (height, anatomy)
  - Physical conditioning
  - Nutrition and supplements

ASMI Position Statement

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.

ASMI Position Statement

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.

ASMI Position Statement

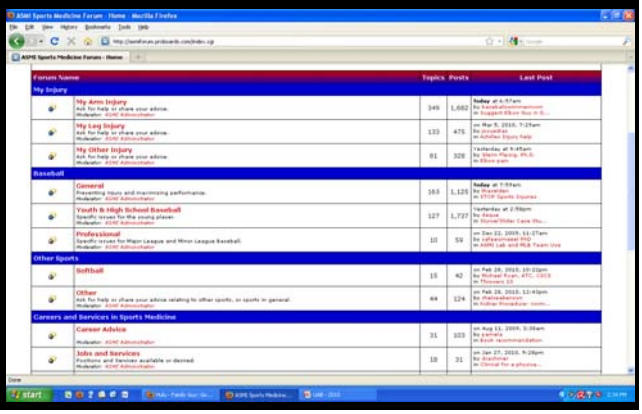
7. Avoid pitcher-catcher combination.

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 .

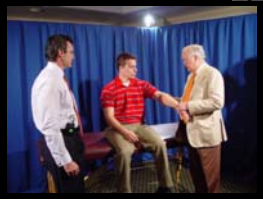
American Sports Medicine Institute

- www.asmi.org
  - Research summaries
  - Publications
  - Forum



American Sports Medicine Institute

- Injuries in Baseball Course
  - January 2011
  - Tampa, FL
  - MD
  - PT
  - ATC
  - CSCS
  - Biomechanists
  - Coaches



ASMI
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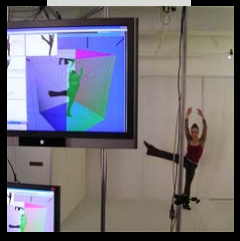
Future

- More usage by coaches and individuals
  (ISBS Mission)




Future

- More usage by coaches and individuals
- Markerless automatic 3D (real-time game data)

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