The Biomechanics of Baseball Pitching

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- Established American Sports Medicine Institute (ASMI) in 1987
- PhD dissertation in 1994
- Keynote presentation at ISBS 2001 – Pitching Biomechanics Injury Mechanisms
- Keynote presentation at ISBS 2010
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)

1200 Baseball Pitchers
Pitching Biomechanics

90 Elite Pitchers

- Threw 85+ mph during testing
- 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

$4 \pm 7$ degrees

Throwing Arm Position

Throwing Shoulder Abduction

$93 \pm 11$ 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

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**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

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**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

**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

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**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

**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
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.
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.
• Injuries in Baseball Course
  – January 2011
  – Tampa, FL
  – MD
  – PT
  – ATC
  – CSCS
  – Biomechanists
  – Coaches
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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