BIOMECHANICS OF BASEBALL PITCHING

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Biology 438
• Extremely explosive and unnatural motion

• Several factors go into a good pitch – e.g. Velocity, Movement, and Position

• Velocity pitch – fastball

• Movement pitch - curveball

• Many different pitching styles, but all follow a similar basic concept
SIX PHASES OF MOTION

- Wind-up
- Stride
- Arm Cocking
- Arm Acceleration
- Arm Deceleration
- Follow-through
1. WIND-UP

- Leg raise and straight posture do work against gravity and store potential energy for upcoming lateral motion
- Arms remain stationary and at front
2. **STRIDE**

- Beginning of the conversion of potential energy into mechanical energy
- Abduction of the shoulder (Deltoid) muscles raises the elbows to prepare for cocking motion
- Ends with foot plant
3. COCKING PHASE

- Maximal external rotation of the shoulder (Infraspinitus and teres minor muscles stabilize humerus rotation)
- Foot plant begins action of the ‘kinetic chain’
4. ACCELERATION

- Kinetic Chain: Foot plant → Trunk Rotation → Shoulder Rotation → Elbow translation → Wrist Translation
- Extensor (tricep) muscles allow for rapid forearm extension
- Internal angular velocity at the shoulder: ~7600 deg/sec
- Internal angular velocity at the elbow: ~2500 deg/sec
- Force on the Ulnar Collateral Ligament can reach 60N
Arm Deceleration

- Post-release deceleration of arm, supraspinitus muscle contracts to decelerate internal rotation
- Pitching muscles begin to relax
FOLLOW THROUGH

- Natural momentum-guided motion
- Back leg raises to stabilize position
IMPORTANT PITCHING MUSCLES

Muscles of the Rotator Cuff

- Subscapularis
- Supraspinatus
- Infraspinatus
- Teres Minor

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Pitch Comparison

- **Fastball**: Thrown for speed, the fastball is the most common pitch and sacrifices lateral motion for precision and speed.

- **Curveball**: A generally slower pitch that sacrifices speed for a drastic change in position. Typical curveball pitching motion involves wrist flexion immediately prior to ball release.

- **Task**: Using the kinetic chain paradigm, analyze the differences in velocity between the shoulder, elbow, and wrist in both the fastball and curveball.
FASTBALL ARM VELOCITIES

Fastball Arm Velocity

- Shoulder Velocity (m/s)
- Elbow Velocity (m/s)
- Wrist Velocity (m/s)

Time (s)
• Force of chain on ball = ma = (4.96kg+.149kg)(36m/s^2) = 185.5N

• KE = 1/2mv^2 = 1/2(.149kg+4.96kg)(14.6m/s)^2 = 545 Joules

• U = mgh = (.149kg)(9.8m/s^2)(1.62m) = 2.4 Joules

• Work = ΔKE + ΔU = (545J) + (2.4J) = 547.4 Joules

• Momentum prior to release = mv = (4.96kg+.149kg)(14.6m/s) = 74.6 N•s

• Momentum of ball after release = mv = (.149kg)(36.1m/s) = 5.4 N•s

• Conservation of momentum states that Ben should be moving at around .84m/s after throw. Logger Pro calculated 1.13m/s so, not far off
FASTBALL
ACCELERATION
• Assume: Force is always acting perpendicular to the moment arm (which it is not)

• Arm length: ~.7m

• Arm mass: ~6% of body weight, so, (82.6kg)(.06) = 4.96kg

• Acceleration from cocking to release: 36 m/s²

• \[ T = F \times r = (4.96\text{kg})(36\text{m/s}^2)(.53\text{m}) = 94.6 \text{ N} \cdot \text{m} \]
Curveball Arm Velocities

Curveball Arm Speeds

Shoulder Velocity (m/s)
Elbow Velocity
Wrist Velocity

Time (s)

Graph showing the velocities over time for shoulder, elbow, and wrist movements in curveball arm.
• Force of chain on ball = (4.96+.149kg)(68.4m/s²) = 352.5N
• KE = \( \frac{1}{2} \) mv² = (1/2)(4.96kg.149kg)(12.1m/s)² = 374 Joules
• U = 2.4 Joules
• Work = ΔKE + ΔU = (374J) + (2.4J) = 376.4 Joules
• Momentum prior to release = mv = (4.96kg+.149kg)(12.1m/s) = 61.8 N·s
• Momentum of ball after release = mv = (.149kg)(25m/s) = 3.7 N·s
• So: Ben’s velocity after should be .70m/s, Logger Pro calculated .86m/s, so again pretty close
CURVEBALL ACCELERATION

Linear Fit for: VideoAnalysis | X Velocity 3
Vx = mt+b
m (Slope): 68.40
b (Y-Intercept): -167.9
Correlation: 0.8788
RMSE: 0.9397
• Same assumption as before; force is always perpendicular to the moment arm

• Acceleration from cocking to release in curve: 68.4 m/s²

• \( T = F \times r = (4.96 \text{kg})(68.4 \text{m/s}^2)(0.6 \text{m}) = 203.6 \text{ N\cdot m} \)

• Moment-arm assumption really comes into play in this case
Common Injuries: UCL

- Due to the unnatural motion of pitching, injury is exceedingly common.
- A very common injury involves damage to the UCL, which can reach its ultimate tensile strength.
- Over many throws, the UCL can become frayed or torn.
- Tommy John surgery.
COMMON INJURIES: ROTATOR CUFF

- During cocking and deceleration, extreme stress is placed on the muscles of the rotator cuff.

- Rotator cuff injury usually involves injuries in the tendons of the supraspinitus or infraspinitus muscles, which stabilize the glenohumeral joint during deceleration.
LIMITATIONS

• The majority of the momentum that goes into a pitch comes from the rotation of the trunk

• By studying the linear movement of the shoulder, elbow and wrist, only the final portion of the kinetic chain is analyzed

• 2D analysis is limiting

• Future analysis might use motion capture to look at the rotational kinematics of the trunk during pitching, as well as analyzing the rotation of the arm in more depth
Future Goals

- The biomechanics of pitching has been studied in depth, however pitching injuries remain extremely common.
- There is a dichotomy within pitching biomechanics between altering mechanics to improve output and altering mechanics to lessen the occurrence of injury.
- Future studies might look to elucidate changes in form that can lessen the stress of the pitching motion on commonly injured structures, while maintaining peak performance.