Biomechanical Analysis of Motion of Professional Baseball Pitchers

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Theory of pitching motion

Roger Clemens
MLB career in 1984-2007
“The Rocket”

“Three stage rocket system” mechanism
Background

- Many baseball players in Japan

Population aged 10 years and over

Under 19 years: 2.97 million

Baseball contestant: 9.7 million (8.6%)

The Census in 2005, Japan
Background

- Necessity to keep long baseball careers

- Healthcare and growth in daily life
- Development of baseball player resources
- Stimulation of social activity
- Increase in purchasing power for baseball equipment

Problem: Many pitchers are injured.
Aim

- To clarify how to keep playing baseball for pitchers during their long lives

1. Biomechanical analysis of a professional baseball pitcher who has long career

2. Quantification of the pitching motion using biomechanical energetics

3. Comparisons between the veteran pitcher and a rookie pitcher
Subjects and trials

- Two active professional pitchers

**Subject A (lefty)**
- 27 years career
- 1.76 m / 84.6 kg
- Ball speed 121 km/h

**Subject B (righty)**
- 2 years career
- 1.82 m / 84.1 kg
- Ball speed 133 km/h
Model Analysis

15 segments
14 joints

Head
Torso
Upper arm
Forearm
Hand
Pelvis
Thigh
Shank
Foot

Whole body rigid link model

Visual3D (c-motion Inc.)

57 markers

Floor plate

Measurement using MOCAP

Center of gravity

Foot reaction force
Phase of pitching motion

1. Wind-up
2. Early cocking
3. Late cocking
4. Acceleration
5. Follow-through
6. Foot contact
7. Maximum flexion of hip of swing leg
8. Maximum lateral rotation of shoulder

Target phases
Mechanism of pitching motion

- Extension of leg joints
- Hip abduction
- Hip medial rotation
- Waist twist and lateral bending, as shoulder moves forward and upward
- Shoulder adduction and medial rotation
- Elbow extension
- Forearm medial rotation
- Ball release

Three stage rocket system mechanism
Relative velocity of each joints

**Definition**
- Upper joint velocity relative to lower joint velocity
- Parallel to ground

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- Upper joint velocity relative to lower joint velocity
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**Subject A**

- Ball release
- Torso twist speed increased
- Pivot leg push foreword body
Aim

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Mechanical modeling of muscle activity

- Isotonic muscle activity modeling
  - Concentric contraction
    • Muscle activity shortening
  - Eccentric contraction
    • Muscle activity lengthening

Joint power
= Joint moment × Joint angular velocity

Joint moment
Leverage of muscle tension for joint rotation

Horsepower = Torque × Engine revolution
Biomechanical energetics

- Joint energy consumption
  - e.g. Joint power of axial rotation of pitching arm

Positive:
- Energy emission for accelerating motion

Negative:
- Energy absorption for decelerating motion

No regeneration = No contribution for ball speed
Aim

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Quantification of pitching mechanism

- Distribution ratio of joint concentric energy
- Sum of joint concentric energy of each part
- Sum of joint concentric energy of whole body

Index of muscle activity for accelerating motion

Subject A protected his arm from overuse.
Pitching Efficiency

- Evaluation of ball speed and whole body energy consumption

- Kinetic energy of ball
  
  \[
  \frac{\text{Kinetic energy of ball}}{\text{Energy consumption of whole body}}
  \]

Short term: Capability of complete games

Long term: Capability of long career of pitcher

<table>
<thead>
<tr>
<th></th>
<th>Subject A</th>
<th>Subject B</th>
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</thead>
<tbody>
<tr>
<td>Ball Speed</td>
<td>33.6 m/s 121 km/h</td>
<td>36.9 m/s 132 km/h</td>
</tr>
<tr>
<td>Kinetic energy of ball</td>
<td>79.1 J</td>
<td>95.5 J</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>918.0 J</td>
<td>1237.1 J</td>
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<tr>
<td>Pitching Efficiency</td>
<td>0.086</td>
<td>0.077</td>
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<tr>
<td>Innings pitched / Years</td>
<td>3336.2/29=115</td>
<td>295.0/4=74</td>
</tr>
</tbody>
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Subject A had high capability of long career.
Conclusion

To clarify how to keep playing baseball for pitchers during their long lives

1. Pitching mechanism is like “3-stage rocket system”
2. Two energetic indices are defined
3. Using pivot leg and waist contribute to pitch effectively from results of 2 energetic indices
Acknowledge

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Thank you for your kind attention!
How to improve the motion of subject B?

- Back to the motion data...
  - e.g. ball release

Training or equipment to support hip inner rotation muscle