

## The Science of Understanding and Preventing Baseball Injuries

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## Technology is changing the way we analyze athletes



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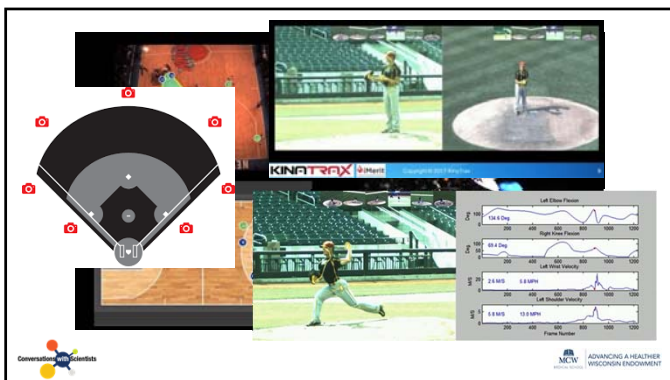
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Sports biomechanics uses tools to assess athletes to improve performance and prevent injuries

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## The Science of Understanding and Preventing Baseball Injuries

1. Injury epidemic in baseball
2. Biomechanical tools
3. Applying tools to prevent injury and increase performance




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## Injury Epidemic in Baseball

- Throwing elbow injuries common at all levels of baseball
- **Ulnar Collateral Ligament Injury**
  - "Tommy John" injury




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## Injury Epidemic in Baseball

- What is the UCL?
  - Ligaments are strong bands of tissue
    - hold bones together
    - help control the movement of joints
  - When torn, the tether is too long and the bones move too much
  - UCL complex located on inside of elbow
  - Pitchers UCL larger from throwing




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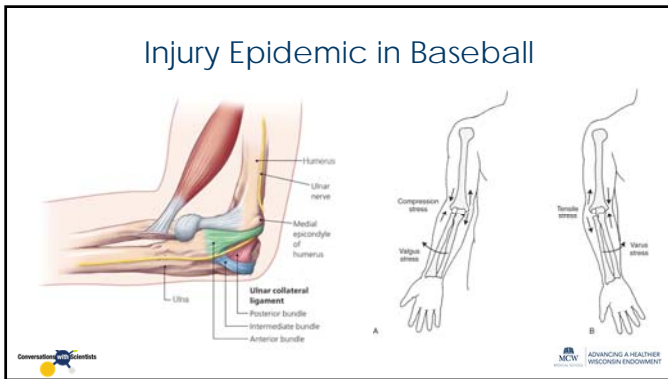
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### Injury Epidemic in Baseball

– What are the risk factors for UCL injury?(1-5)

- Age
- Pitch velocity
- Pitch type
- High pitch counts
- Pitching year round
- Pitching consecutive days
- Pitching when fatigued
- Geography
- Sports Specialization
- Poor mechanics

1. Fortenbaugh D, Fleisig GS, Andrews JR. Sports Health. 2009 07;1(4):314-20.  
 2. Anz AW, Bushnell BD, Griffin LP, Noonan TJ, Torry MR, Hawkins RJ. Am J Sports Med. 2010 July 01;38(7):1368-74.  
 3. Wilk KE, Macrina LC, Fleisig GS, June KT, et al. Am J Sports Med. 2014 September 01;42(9):2075-81.  
 4. Lyman S, Fleisig GS, Andrews JR, Oshinski ED. Am J Sports Med. 2002 July 01;30(4):463-8.  
 5. Olsen SJ, Fleisig GS, Dun S, Loftice J, Andrews JR. Am J Sports Med. 2006 June 01;34(6):905-12.

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### Injury Epidemic in Baseball

– How is the UCL repaired?

- UCL Reconstruction = Tommy John surgery
- Named after first player to undergo procedure, performed in 1974 by Dr. Frank Jobe
- Tendon taken from somewhere else in body, or from a donor, to serve as new UCL

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## Injury Epidemic in Baseball

### - Injury rates

- Injury trends in MLB over 18 seasons: 1998 – 2015 (6)

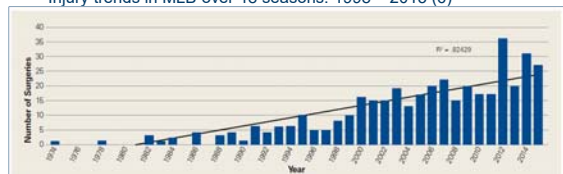


Figure 7 The first medial ulnar collateral ligament reconstruction was performed on a Major League Baseball player in 1974. Since that time, the rate of surgery has increased to a significant degree ( $P < .001$ ).

6. Conte SA, Camp CL, Dines JS. Am J Ortho. 2016;45(3):116-23.




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## Injury Epidemic in Baseball

### • Return to Play rates

- Performance and Return to competition after Tommy John (7)
  - 80% returned to pitch at least 1 MLB game
  - 67% of established pitchers (>10 games) returned to same level of competition
  - 57% returned to DL due to throwing arm injury
- Prevalence of UCL surgery in professional baseball players (8)
  - 25% of MLB pitchers have history of UCL reconstruction
  - 15% of MiLB pitchers

7. Makhlif EC, Lee RW, Morrow ZS, et al. Am J Sports Med. 2014;06(01):2019(03:42(6)):1323-32.

8. Conte SA, Pfaig CS, Dines JS, et al. Am J Sports Med. 2015;July 01:43(7):1764-9.




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## Injury Epidemic in Baseball

### • Injury rates and Return to Play rates

- MLB pitchers make up a small percentage of the overall patient population undergoing Tommy John surgery(9)
  - 5% of high school baseball players play in college
  - 0.5% of high school baseball players play in MLB
  - 15 to 19-year-old age group account for significantly more Tommy John procedures than any other age group (58% of all procedures)
  - Incidence of procedures increased at rate of 9% per year
  - Pitchers age 20 to 24 account for 22% of all procedures

9. Erickson BJ, Neuchukwu BJ, Roosa S, et al. Am J Sports Med. 2015;07(01):2019(03:43(7)):1770-4.




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## Injury Epidemic in Baseball

- Public Perception of Tommy John (10)
  - 30 - 51% coaches and players believe Tommy John should be performed **without elbow injury** to enhance performance
  - 28 - 31% coaches and players did **not** believe number of pitches thrown to be a risk factor
  - 20 - 28% coaches and players believe performance would be **enhanced** beyond pre-injury level
  - Alarming misconceptions about Tommy John surgery



10. Ahmad CS, Grantham WJ, Greive RM. Physic Sports Med. 2012;05(1):40(2):64-72.



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## Injury Epidemic in Baseball

- **Injury epidemic is very concerning**
- What is being done about it?
  - Sports biomechanists are working to understand how we can reduce/predict injuries



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## Biomechanical Tools

- What is Biomechanics?
  - Study of movement (**kinematics**) and the effects of forces (**kinetics**) on living bodies



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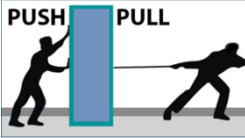
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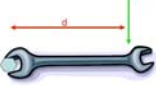
### Biomechanical Tools



- Kinetics: Forces and Moments



**PUSH**     **PULL**

Moment = Force x Distance ( $T = R \times F$ )



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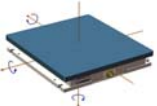

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### Biomechanical Tools

– How do we measure forces and moments?

- Force plates
- Motion analysis systems

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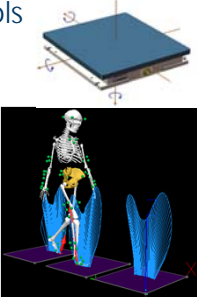
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### Biomechanical Tools

– Force Plates

- Have force transducers that determine force
- Forces measured:

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## Biomechanical Tools

- Motion Analysis Systems
  - Used to capture 3D movements in digital form
  - Considered gold standard
  - Body modeled as system of rigid links connected at joints
  - Used in clinical gait, sport analysis, entertainment industry




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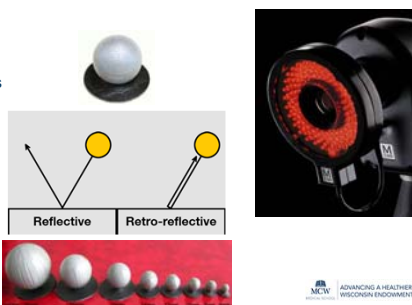
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## Biomechanical Tools

- Equipment
  - Infrared cameras
  - Markers
  - Software




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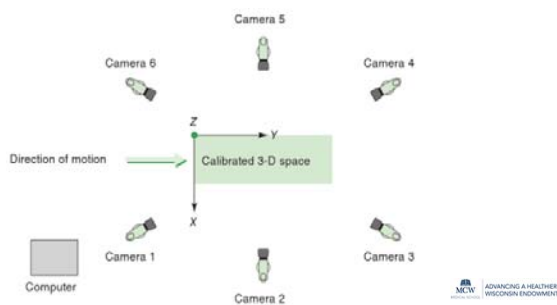
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## Biomechanical Tools




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### Biomechanical Tools

- Calibration
  - Enables image coordinates of each camera to be converted to real world 3D coordinates of each marker
  - 2 step process:
    - Static Calibration (L-frame)
    - Dynamic Calibration (wand)



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### Biomechanical Tools

- Marker Sets
  - Minimum of 3 markers required per segment
  - Each marker must be seen by 2 cameras
  - Marker set selection



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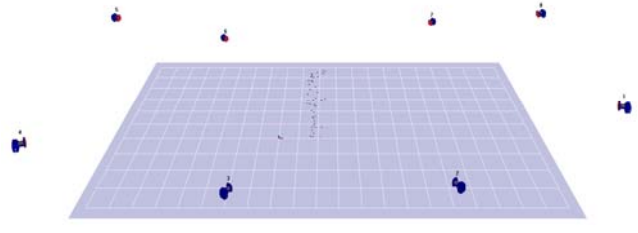
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### Biomechanical Tools



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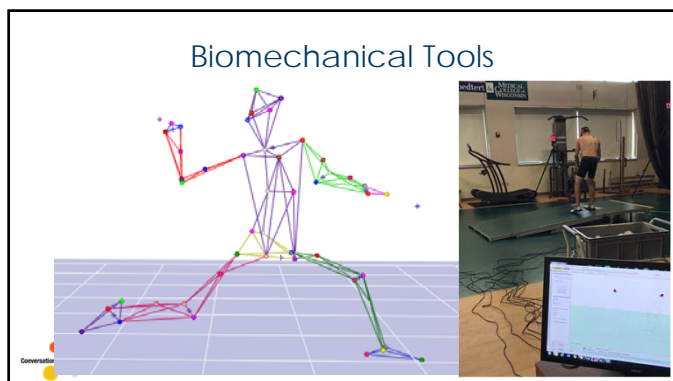
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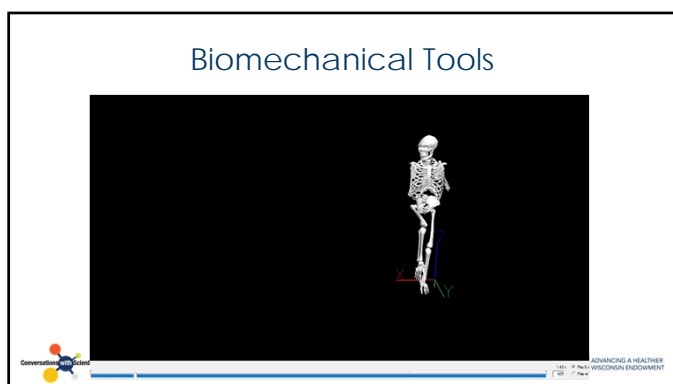
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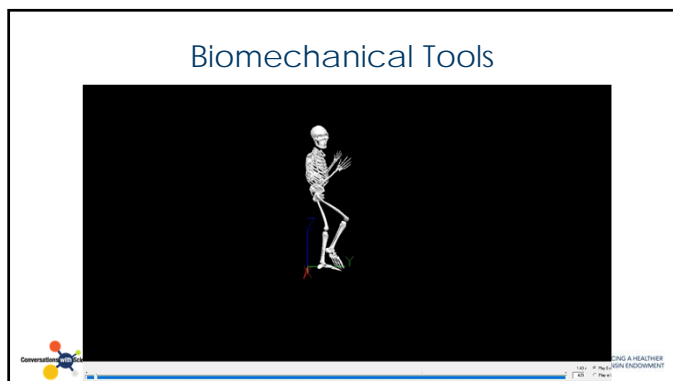
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## Biomechanical Tools

- Data Analysis
  - Going from marker trajectories to kinematics
  - Biomechanical Model: mathematical model that describes motion

ADVANCING A HEALTHIER WISCONSIN ENDOWMENT

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## Biomechanical Tools

- Biomechanical Model
  - Markers used to define segments
  - Define each segment LCS
  - Kinematics calculated
  - Motion analysis measures position, calculations to determine joint angles, velocity, acceleration

$$x \rightarrow \dot{x} = \frac{dx}{dt} = v \rightarrow \ddot{x} = \frac{d^2x}{dt^2} = a$$

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## Biomechanical Tools

- How do we calculate forces?
  - Mass of body segment calculated as % of total body mass
  - Newton's 2nd law: acceleration of object dependent on force and mass
    - Force = mass x acceleration  $\rightarrow F = m \cdot a$



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## Biomechanical Tools

- Using biomechanical tools, we can analyze pitching mechanics
  - Able to quantify joint angles, velocity, acceleration and forces
- Apply these methods to assess injury risk in pitchers

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## Applying Tools

– First 3D kinematic and kinetic analysis of pitchers was conducted in 1989 by Feltner and Dapena

### Biomechanics of Pitching with Emphasis upon Shoulder Kinematics

Charles J. Dillman, PhD  
Glenn S. Fiebig, MD  
James R. Andrews, MD



The three-year (1986-1989) research project was aimed at better understanding of mechanics involved in upper extremity motion in throwing athletes. The paper presents a number of kinematic and dynamic parameters of arm motion about the shoulder during the high velocity activity. These kinematic and dynamic parameters are presented in 3D motion. The paper reports on the kinematics in three-dimensional motion in shoulder and glenohumeral mechanics as well as in arm motion in sagittal plane at 170°.

**Key Words:** shoulder kinematics, shoulder motion, pitch, throwing.

### Kinetics of Baseball Pitching with Implications About Injury Mechanisms

Glenn S. Fiebig,\* PhD, James R. Andrews, MD, Charles J. Dillman, PhD, and Rafael F. Escamilla, MS, CSCS

*From the American Sports Medicine Institute, Birmingham, Alabama*

**ABSTRACT**

Elbow and shoulder kinetics for 28 highly skilled, healthy male pitchers were compared using high-speed motion analysis. Two critical moments were (1) shortly before the arm reached maximum external rotation, when 57% of shoulder internal rotation torque and 54% of elbow varus torque were generated, and (2) shortly after ball release, when 100% of shoulder compression force was produced. In addition, 50% of total elbow varus torque and 20% of total shoulder lateral compression or posteromedial impingement injury. At the glenohumeral joint, compressive forces, joint torques, and 500 N of anterior force during arm cocking can lead to anterior glenoid labrum tear. Rapid external rotation in combination with these forces can produce a grinding injury factor on the labrum. After ball release, 500 N of posterior force, 1000 N of compression force,

**MATERIALS AND METHODS**

Twenty-one healthy, highly skilled adult male pitchers with a mean age of 25 ± 2.2 years, were used for this study. These athletes were a selected group of pitchers chosen

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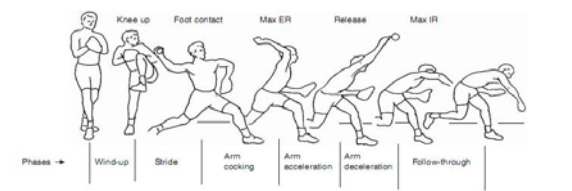
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## Applying Tools



Pitching phases and key events. ER = external rotation; IR = internal rotation (11)

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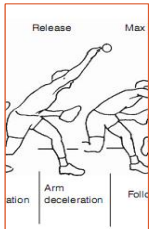
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## Applying Tools

- Fleisig examined elbow and shoulder kinetics of mound pitching on 26 highly skilled, healthy adult pitchers (12)

- Found 2 critical instants during pitch
- 1. Just prior to maximum external rotation (MER)
  - 67 Nm of shoulder torque generated
  - 64 Nm of elbow torque generated
- 2. Just after ball release (BR)
  - 1090 N of shoulder force produced



12. Fleisig GS, Andrews JR, Dilman CJ, Escamilla RF. Am J Sports Med. 1995 March 01;23(2):233-9.

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## Applying Tools

- Critical Instant #1
- During arm cocking phase, just prior to MER
  - Shoulder 165° external rotation
    - Large Shoulder Torque
  - Elbow: 95° flex
    - Large Elbow Torque
  - UCL load near maximum capacity



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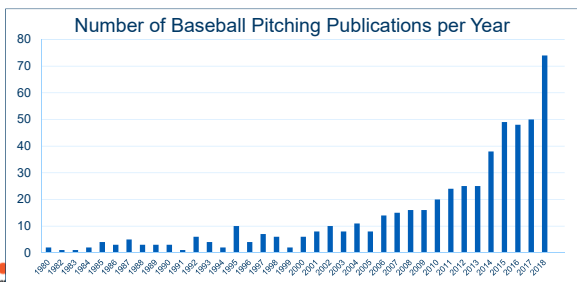
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## Applying Tools

Number of Baseball Pitching Publications per Year



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## Applying Tools



Pitch Count Limits and Required Rest Recommendations							
Age	Daily Max (Pitches in Game)	0 Days Rest	1 Days Rest	2 Days Rest	3 Days Rest	4 Days Rest	5 Days Rest
7-8	50	1-20	21-35	36-50	N/A	N/A	N/A
9-10	75	1-20	21-35	36-50	51-65	66+	N/A
11-12	85	1-20	21-35	36-50	51-65	66+	N/A

<https://www.mlb.com/pitch-smart>

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## Applying Tools



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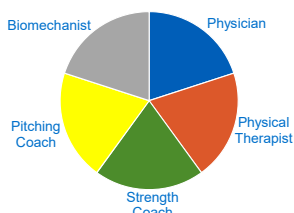
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## Applying Tools

- Use Motion Analysis to assess pitcher's mechanics
  - Player with high torques or forces, look in depth at mechanics



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