New Concepts in the Management of Upper Extremity Injuries in the Adolescent Throwing Athlete

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Objectives

- Understand throwing mechanics
- Describe stresses that lead to injury
- Describe dysfunctions of the upper extremity
- Identify flaws in generation of arm speed
- Evidence based treatment strategies with a case report
Goals

• Why?
• Think
• Knowledge
• Tools to implement
What is a “sports medicine” specialist?

To become a specialist in sports medicine, one needs to understand, among other things:

- The game
- The mental demands of the game
- The biomechanics of that game
- Injuries common to that game
- Principles of basic rehabilitation
- The SAID principle and Wolf’s Law

“To understand dysfunctional movement patterns, it is necessary to have a good understanding of normal motion and the development of normal and abnormal movement patterns” Schlueter, M Ed, ATC
“Baseball was made for kids, and adults only screw it up”

Bob Lemon
Injuries in Baseball

- Played by over 4.8 million 6 – 17 year olds/yr
  Committee on Sports Medicine and Fitness, 2001

- 17% – 50% of all participants will c/o shoulder or elbow pain during the season.
  Klingel & Kocher 2002
  Lyman et al 2002

- Once an upper extremity injury is sustained there is increase risk of a cascade effect leading to more frequent and severe dysfunctions.
  Hayes et al 2002
Mechanism of Injury

• Self Imposed – 80%
  1. Overuse
  2. Poor Mechanics

• Trauma – 20%

Batt
Who is injured?

1. Pitchers – 70%
2. Infielders - < 20%
3. Outfielders - < 20%

MacFarland 1998

Pitchers have the highest incidence of shoulder c/o followed by infielders, catchers, and finally outfielders

Wasserlauf and Paletta 2003
Biomechanics of throwing

6 Phases
1. Wind up
2. Stride
3. Cocking
4. Acceleration
5. Deceleration
6. Follow through

Meister, 2000
Biomechanics of throwing

An additional phase - **transition phase** is not described for the overhead athlete but is for the golfing athlete.
Phase I - Wind up

Starts at initiation of movement ending when the lead foot is lifted from the ground and the throwing hand is removed from the glove.
Phase I – Wind up

Problem
A reading phase to raise the body’s center of gravity. Poor balance here can lead to compensations during the motion.
Phase II - Stride

Stride phase ends when the lead foot contacts the ground. At foot contact, the lead foot should be pointed toward the target.
Phase II - Stride

Problem

Often young and inexperienced throwers over rotate and place the foot on the first base side of the mound. This results in the pitcher opening up too soon – “over rotation” – leading to loss of velocity and increase strain to the anterior shoulder.

Whiteside, Andrews, Fleisig 1999
Meister 2000
Phase II - Stride

Why would someone over rotate?
Mentally one attempts to produce greater velocity but may be doing so inefficiently.

Study by Hosea et al (1994) found amateurs generated 50% more trunk and muscle activity and 50-80% greater spinal forces yet produced 34% less club head speed.
Phase III - Arm Cocking

Phase III begins at heel strike and ends when the arm reaches full external rotation.
Phase III - Arm Cocking

**Problem**

Limited range of motion especially in the shoulder may lead to compensations such as increased trunk extension in an effort to achieve greater distance to produce higher velocity
By the Numbers – Phase III

Forces across the anterior shoulder and medial elbow in highly skilled pitchers are at or near peak levels.

Fleisig et al 1995

ROM

• Elbow flexion - 95° ± 10°
• Shoulder external rotation - 165° ± 11°
• Shoulder abduction - 94° ± 21°
• Horizontal adduction - 11° ± 11°
By the Numbers – Phase III

**Elbow**

- Maximum Varus Torque - $64 \pm 12$ N-m
- Medial Force - $300 \pm 60$ N
- Anterior Force - $160 \pm 80$ N
- Compressive Force - $270 \pm 120$ N
By the Numbers – Phase III

**Shoulder**

- Internal Rotation Torque - 67 ± 11 N-m
- Anterior Force - 310 ± 100 N
- Superior Shear Force - 250 ± 80 N
- Horizontal Adduction Torque - 87 ± 23 N-m
- Abduction Torque - 44 ± 17 N-m
Phase IV - Acceleration

Phase IV begins at maximum external rotation and ends at ball release.
By the Numbers – Phase IV

Acceleration

Identified as the fastest movement in sports with internal rotation velocity reaching excess of \textbf{7000^\circ/sec}!

Fleisig et al 1995

Remarkably, shoulder loads are minimal with shear forces and torques decreasing from peak at the end of cocking.

Fleisig et al 1995
Transition

Phase between cocking and acceleration when the legs and hips are moving forward toward target while the arm is still moving backward.
Transition Phase

This zone was identified as one of two critical instances in the throwing motion by Fleisig et al (1995).

Overthrowing can lead to the arm moving or lagging behind the plane of the scapula which also increases anterior capsular strain.  

Wilk et al 2002

Consequence of trying to produce velocity in an inefficient or neuromuscularly incorrect manner “overthrowing” is manifested in the transition from late cocking (Phase III) into acceleration (phase IV).
Phase V - Deceleration

Starts at ball release and ends when the arm is at maximum internal rotation.
Responsible for dissipation of the remaining energy not imparted to the ball.
Phase V - Deceleration

• The second critical instant for the shoulder
• Recognized as the most violent phase of the throwing cycle

Fleisig et al 1995
Meister 2000
The arm is outstretched toward target
- Elbow Flexion - 20° – 35°
- Shoulder External Rotation - 64° ± 35°
- Shoulder Abduction - 93° ± 10°
- Shoulder Horizontal Adduction - 6° ± 8°
By the Numbers – Phase V

Shoulder Compressive Forces - 1090 ± 110 N

Compared to maximum shear forces and torques:

• Anterior Direction - 80 ± 180 N
• Posterior Direction - 400 ± 90 N
• Inferior Direction - 310 ± 80 N
• Adduction Torque - 83 ± 26 N-m
• Horizontal Abduction Torque - 97 ± 25 N-m
• External Rotation Torque - 7 ± 5 N-m
By the Numbers – Phase V

Elbow Compressive Forces - 900 ± 100 N

Compared to maximum shear forces and torques:
Medial Direction - ~100 N
Anterior Direction - 260 ± 70 N
Flexion Torque – 61 ± 11 N-m
Varus Torque - ~19.6 N-m
Acceleration - Deceleration

Acceleration is an action - Deceleration is a reaction

Therefore, if phase II – IV are performed efficiently, deceleration torques and forces should be minimized
Phase VI - Follow-through

Known as the rebalancing phase as the body moves forward with the arm until motion stops.
Phase VI - Follow-through

- Muscle firing returns to resting levels
- Joint loads decrease
- Compressive forces at shoulder start as high as 400 N
- Inferior Shear - 200 N
- Anterior Shear - 75 N

Meisner 2000
Shoulder Injuries

Primary Instability

Meister (2000) identified the phase between late cocking and early acceleration (transition) as a zone of risk for primary instability secondary to microtrauma.

Rotation of the torso after foot plant can generate an estimated 400 N of anterior shear across the shoulder.

Dillman et al 1993
Shoulder Injuries

**Adolescent**
Greater risk in adolescent to develop instability due to collagen make-up. The adolescent collagen is composed of greater amounts of the supple and elastic type III versus a more stable type I in adults.
Shoulder Injuries

**Consequence of Primary instability**

- Secondary subacromial impingement
- Internal impingement of the undersurface of the rotator cuff
- Detachment of the superior glenoid labrum (SLAP)
- Anterior labral fraying
- Posterior labral injury
- Rotator cuff tears

Meisner 2000
JOSPT, 10/02
Shoulder Injuries

- Supraspinatus
- Teres Minor
- Infraspinatus
- Posterior Deltoid
- Biceps
- Labrum

Used to resist glenohumeral distraction, horizontal adduction and internal rotation.

Also important to resist superior, anterior and posterior translation of humerus.

As a consequence of poor stability, forces cause translation of humerus leading to grinding of labrum, traction on biceps, impingement of SIT muscles and overuse of posterior deltoid.

Fleisig et al 1995
Adolescent Shoulder Injuries

In addition to the aforementioned:

- Little Leaguer’s Shoulder
- Humeral Retroversion
Elbow Injuries

- 85% of athletes experiencing pain was during the early acceleration phase.
- At 95° ± 14° elbow flexion which is during the early acceleration phase, maximum varus torque is needed to overcome maximum valgus force.
- A major structure that absorbs this force is the UCL producing an estimated 34.6 N-m.
- Studies show the UCL fails at 32.1 ± 9.6 N-m

Hutchinson, Wynn 2004
Fleisig et al 1995
Dillman et al 1991
Cain et al 2003
Elbow Injuries

Valgus overload can lead to:
- UCL injury (anterior band)
- Ulnar nerve damage
- Lateral compression between radius and capitellum
- Chip fractures
- Avascular necrosis or osteochondrosis of the capitellum
- Olecranon fossa osteophytes
- Olecranon chondromalacia
- Loose body formation
- Flexor/Pronator muscle tears

Cain et al 2003
Fleisig et al 1995
Hutchinson and Wynn 2004
Elbow Injuries

Valgus Extension Overload

- Olecranon tip osteophytes
- Loose bodies
- Chondromalacia on olecranon and posteromedial trochlea

Cain et al 2003
Adolescent Elbow Injuries

In addition to the aforementioned:

• Little Leaguer’s elbow – apophysis of the medial epicondyle

*In the skeletally immature athlete the apophysis will usually fail before the medial collateral ligament.

Hutchinson and Wynn 2004
Main difference in throwing mechanics from youth to professional pitchers was velocity.

Fleisig et al 1999
Biomechanics by Age

In the same study by Fleisig et al there were some interesting differences.

Pelvic Rotation

Youth - 650°/sec
High School - 640°/sec
College - 670°/sec
Professional - 620°/sec

All amateur pitchers rotated through hips faster than professionals yet velocity of ball is slower. Appears to be contradictory to traditional thought in that power comes form the legs and hips.
Pitch Types

Study of little league pitchers ages 9-10, 11-12, and 13-14.

- Frequency of shoulder and elbow pain highest in 13-14 y/o group
- With pitch types of curve, slider, and change up; other than slider, 13-14 y/o group had less pain than other groups
- Comparing number of pitches thrown in a game; in most all categories the 13-14 y/o group had greater odds of pain that the other groups.

Lyman et al 2001

Why is the 13-14 year old group having more pain in all categories except breaking pitches?
Pitch Types

When in the throwing motion are the highest forces and torques generated?
  Transition from Phase III – Phase IV

When in the throwing motion does the pitcher attempt to impart spin?
  Late Phase IV
Growth Plate Injuries

Open growth plates: epiphyseal plate and apophysis along with articular joint surfaces, are more susceptible to stress injuries during periods of growth.

Micheli 2005

Figure 1. An anteroposterior radiographic view of the right shoulder of a 15-year-old male pitcher who complained of right shoulder pain; it demonstrates separation of the right proximal humeral epiphysis (arrows).
Growth Plate Injuries

- The apophysis is the growth cartilage site where a major tendon inserts on the growing bone
- The epiphyseal plate (physis), located between the epiphysis and the metaphysis
Growth Plate Injuries

The growth plate is weaker than ligament, capsule and tendon during growth spurts and will usually fail before a ligament or tendon.

Micheli & Fehlandt 1992
Little Leaguer’s Shoulder

- On X-ray a uniform widening of the proximal humeral growth plate
- First described by Dotter in 1953
- Seen in throwers between ages 12 – 15
Little Leaguer’s Elbow

An apophysitis of the medial epicondyle
- On X-ray a widening of the medial epicondyle
- Seen in throwers between ages 10 – 15

Cervoni et al 1997
Humeral Adaptations

- Humeral Retroversion
- Occurs at a mean age of 13.6 years
- Due to stress on proximal humeral physis as it is active
- Will affect internal versus external range of motion
- Total range of motion will be the same

Carson & Gasser 1998
Review

• Biomechanics
  – Wind up
  – Stride
  – Cocking
  – “Transition”
  – Acceleration
  – Deceleration
  – Follow Through
Review

- Phase(s) of maximum strain
  - Stride – opening up too soon
  - Late Cocking “Transitioning” into Acceleration – Forces and torques
  - Deceleration – a reaction to an action
Review

• Injuries
  – Instabilities leading to a cascade of shoulder problems
  – Physeal injuries (little leaguer’s shoulder)
  – Apophyseal injuries (little leaguer’s elbow)
Which Pitch?
Why?
Therefore

Since the transition phase places the greatest forces and torques across the elbow and shoulder

AND

Since the transition phase appears to be the instant of greatest injury occurrence

AND

Since the main difference between elite and youth pitchers is velocity versus mechanics

We need to

Address HOW the athlete – especially the young athlete - tries to generate velocity as this may be at the genesis of injuries
Neuromuscular Principles of Throwing
Efficiency

Achieving desired result with the minimum of waste, energy, or expense.
Productive

Achieving desired results but at an expense.
Balance

Regulation of upright stance is fundamental to the safe and efficient performance of many of our voluntary movements.

J.S. Frank, M. Earl
Rotational Athletics

Rotational sports utilize centrifugal forces to manage the end segment (club, bat, racquet, ball etc.).
Balance

Main force to be managed in rotational athletics…

Centrifugal Force

The force which impels a thing, or parts of it, outward from the center of rotation.
Balance

Force used to counter centrifugal force:

**Centripetal force**

The component of force that is directed toward the center of curvature or axis of rotation
Balance

If too much centrifugal force is generated, throwing the body out of balance, excess centripetal force will be needed to regain balance. Therefore, energy is used inefficiently with a resultant loss of velocity on both the end segment and ball.

Brakeville et al 1998
Wilk et al 2002
Meister 2000

There will also be an increase load to the shoulder and elbow

Wilk et al 2002
Meister 2000
Efficiency

Amateurs produce 50% more trunk muscle activity and 50-80% greater spinal forces yet generated 34% less clubhead speed.

Hosea et al
Centrifugal force

When in the throwing motion is the greatest amount of centrifugal force generated?

TRANSITION!
Power

- Traditional teaching is to generate power from the legs.
- Kinetic chain of movements to transfer energy from the ground, up through the legs, trunk and into the arm.
THINK

An efficient motion uses the lower extremities, core, upper extremities and centrifugal force to produce maximum velocity.

The question is how we think we need to generate it?
Feedforward Control

Anticipatory postural adjustments consist of postural activity that begins IMMEDIATELY PRIOR to onset of voluntary movement and serves to prevent or minimize displacement of the body’s center of gravity associated with that movement.

Corso PJ, Nasher LM, Frank JS, Earl M
How Should We Transition?

It is AUTOMATIC!
Transition Thought

Move the arm faster!
Case

- 15 y/o male baseball pitcher/infielder
- Pain deep sup./post. R shoulder 6 mo- mild with baseball
- Pain increase past 2 months – moderate with throwing and hitting practice
- Pain with overhead activities – mild – moderate
- Has limited baseball due to pain
- Subjective Score – 80% due to limiting baseball from pain
Case

MD

X-ray – negative
D/x – rotator cuff strain
R/x – NSAIDS, PT, return to throw when pain free
Case

- Review of systems – negative
- PMHx – negative
- 5’ 4”, 85 lbs, mesomorph, body tone 4-/5
- Posture – negative gross abnormalities
- Neurovascular - negative
- AROM – full, - shoulder shrug sign, - painful arc
- Lateral Scapular Slide test – negative
Case

MMT

Supraspinatus: 4/5, - lag, - pain
Infraspinatus/teres minor: 4-/5, - lag, - pain mid range but mild pain end range of internal rotation
Subscapularis: 4/5, - lag, - pain
General shoulder strength: 4/5
Elbow strength: 4/5
Grip strength: 45% of body weight
Case

- Load and shift sitting and supine – grade I+ anterior movement (4/5 Paris)
- Anterior Impingement – Neer, Hawkins/Kennedy, Coracoid, Cross-over all negative
- Yergason’s test - negative
- Labrum tests:
  - Compression –
  - Ant/Post glide –
  - O’Brien +
  - Anterior slide –
  - Crank test +
  - Provocation –
  - Speeds –
  - Clunk –
Case

Jobes Subluxation/Relocation test - negative
Apprehension sign - negative
Jobes Subluxation - positive
Jerk test - negative
Posterior glide - negative
Problem List

1. Total shoulder weakness
2. Pain with throwing and batting progressing to pain with overhead activities
3. Specific External Rotation weakness
4. External rotation pain when tested end range internal rotation
5. Mild – Mod. instability anterior capsule
6. + Labrum tests
7. + Internal impingement sign
8. ? Of proper biomechanics with throwing
9. + Ability to reproduce symptoms
Assessment

Possible:
1. Internal impingement with infraspinatus involvement
   • pain posterior shoulder
   • + Jobes subluxation test posterior shoulder
   • muscular weakness (reflex inhibition) of E.R.
   • General U.E. weakness
   • Anterior laxity
   • Over rotation theory
   • Repetitive micro trauma
   • Deceleration stress

Davies, Fleisg, Andrews
Assessment

Instability versus hypermobility – pathologic condition that manifests as pain associated with excessive translation of the humeral head on the glenoid during active shoulder motion.

Davies
Tzannes et al

Anterior capsular laxity
Weakness
Positive labrum tests
Assessment

Labrum

Baseball throwing – biceps loading during deceleration

Positive labrum tests

Andrews

Davies

Huijbregts
Assessment

Poor mechanics
  Upper extremity weakness
  Over rotation theory
  Neuromuscular efficiency
  Scapulothoracic weakness

Brakeville
Fleisig
Davies
Huijbregts
Prognosis

Excellent: 6 – 12 weeks of rehabilitation

Areas of concern:

1. limited blood supply to articular side of infraspinatus (critical zone)
2. weakness through UE leading to compensations in throwing/hitting
3. biomechanical flaws in throwing/hitting

Rothman & Park
PNF
PNF
Scapular Mobility
External Rotation - Neutral
Internal Rotation - Neutral
External Rotation - 90°
Internal Rotation - 90°
PNF Patterns
Scapulo Thoracic Stability
Scapulo Thoracic Stability
Scapulo Thoracic Stability
Proprioception
Proprioception
Proprioception
Proprioception/Biomechanics
Punishment
Biomechanics
Biomechanics/Stability
Learning

Knowledge of Results

Feedback Frequency
Feedback Timing
Feedback Information

Swinnen 1990
Swinnen et al 1990
Wulf & Schmidt 1989
Traditional Feedback

- Video/Visual Devices
- Verbal Ques
- Kinematic/Balance Systems
- Outcome

- Frequency with each of these can be manipulated for best results. Often at first then decreasing to maximize learning.
- Results are provided seconds or minutes after the task when our neuromuscular system works in microseconds.
- Accuracy of information is in question.
The Coordinator
The Coordinator
Outcome

• At 6 weeks of sport specific physical therapy, clinical tests are all negative

• At 5 weeks, patient in throwing program described in manuscript by Brakeville et al, progressing to full baseball participation at 7 weeks.

• At 2 years follow up patient continues to participate in travel baseball without limitations or pain.
Additional Thoughts

Downward cycle of wanting to throw hard with weakness in UE:

• Increase LE drive resulting in open position and increase centrifugal force through body
• Stress increases through UE
• May try supplements to include steroids
• Throwing consistency continues to decrease