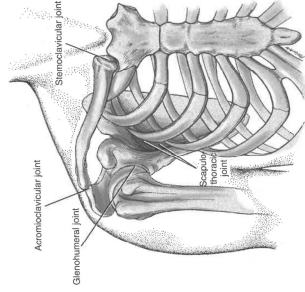


SHOULDER BIOMECHANICS

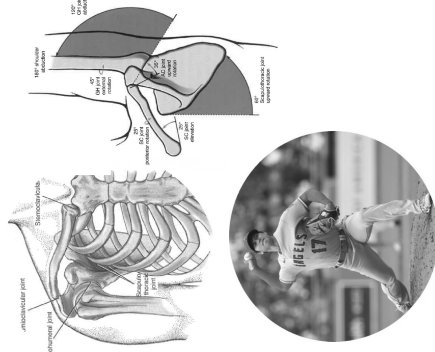
Sakiko Oyama, ATC, PhD
Associate Professor
University of Texas at San Antonio (UTSA)



Shoulder Biomechanics

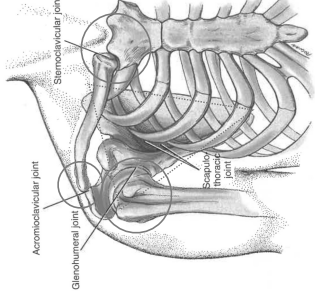
Overview (9:00-10:30am)

- Review of anatomy
- Biomechanics of arm elevation
- Shoulder biomechanics in overhead sports
- My research



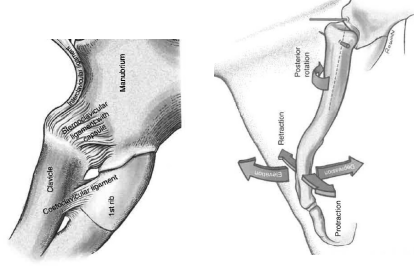
Shoulder Complex

- Sternoclavicular joint
- Acromioclavicular joint
- Scapulothoracic articulation
- Glenohumeral joint



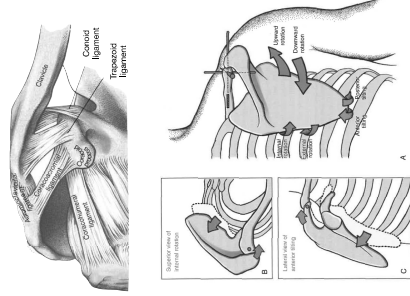
Sternoclavicular (SC) Joint

- Supported by extensive ligaments for stability while allowing considerable range of motion.
- Saddle joint with movements in 3 planes.
 - Elevation (45°) / depression (10°)
 - Protraction / retraction (15-30°)
 - Axial rotation (20-35°)
- Movement guides the general path of the scapula.



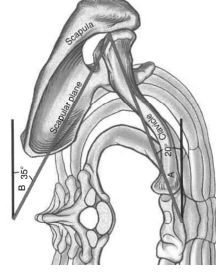
Acromioclavicular (AC) Joint

- Supported by joint capsule and reinforced by ligaments.
- Gliding joint with movements permitted in 3 planes.
 - Upward / downward rotation (30°)
 - "Horizontal adjustment" (IR/ER)
 - "Sagittal adjustment" (AT/PT)



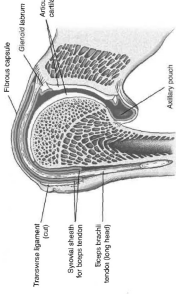
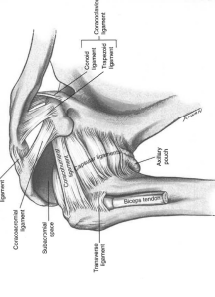
Scapulothoracic (ST) Articulation

- Not a true joint
- Scapular motion = SC motion + AC motion.
 - Elevation / depression
 - Protraction / retraction
 - Upward / downward rotation
 - Internal / external rotation
 - Anterior / posterior tilt



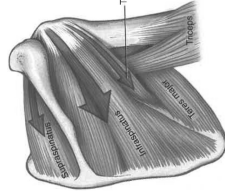
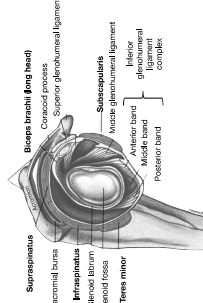
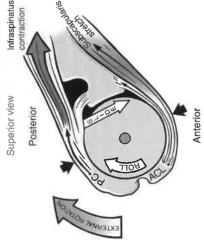
Glenohumeral (GH) Joint

- Thin *loose-fitting* joint capsule reinforced by ligaments provides passive stability.
- Passive tension is produced only when elongated or “twisted”.
- Negative intra-articular pressure.
- “Socket” is deepened by the glenoid labrum.



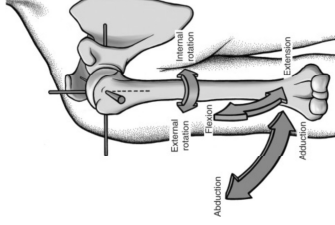
Glenohumeral (GH) Joint

- Dynamic stabilizers produce *active* stabilizing tension at any joint position.
- Rotator cuff
- Long head of the biceps

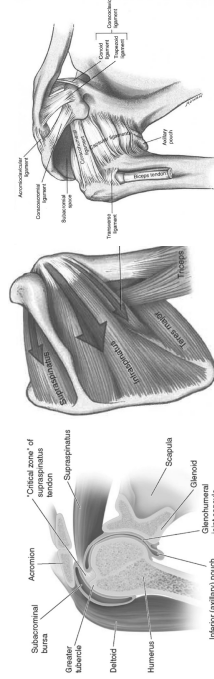


Glenohumeral (GH) Joint

- Glenohumeral joint motion
- Flexion / extension
- Abduction / adduction
- Internal / external rotation
- Horizontal abduction / adduction
- Joint stability must be maintained throughout the large range of motion.



Importance of ST motion in GH function

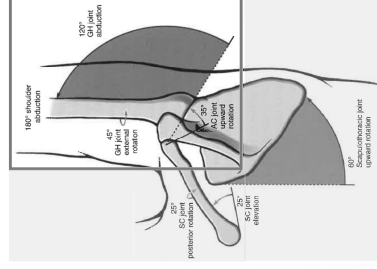


Preservation of subacromial space (i.e., the space between humeral head and coracoacromial arch).

Avoiding excess tension on the GH ligaments and joint capsule.

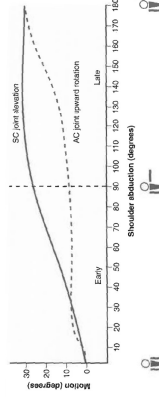
Biomechanics of arm elevation

- GH abduction produces 120° of the shoulder abduction.
- Shoulder externally rotates 45° so that the greater tubercle moves posteriorly to the acromion process.



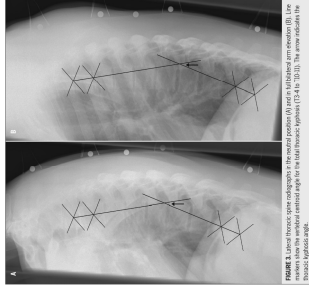
Biomechanics of arm elevation

- The rest of the shoulder abduction (60°) is produced by the simultaneous elevation at the SC joint and upward rotation of the AC joint.



Biomechanics of arm elevation

- Importance of thoracic extension in sagittal plane arm elevation.

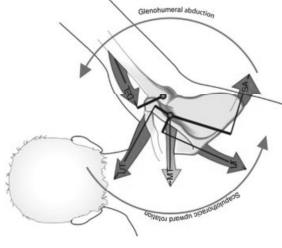


- The mean range of thoracic extension in end-range bilateral shoulder elevation was 12.8°.
 - Upper thoracic spine: $3.7 \pm 2.3^\circ$
 - Lower thoracic spine: $7.0 \pm 3.2^\circ$



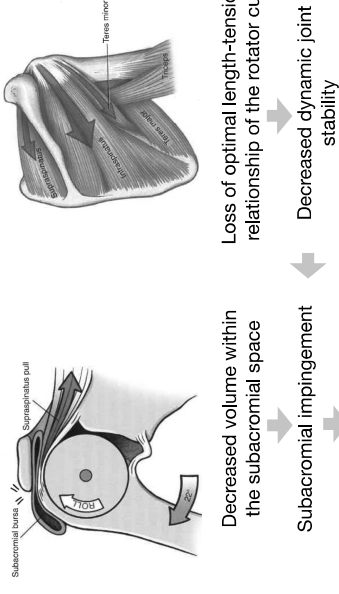
Biomechanics of arm elevation

- How many muscles attach to the scapula?
- Key muscles to upwardly rotate the scapula?



Biomechanics of arm elevation

- What if the scapula doesn't move enough during the arm motion?



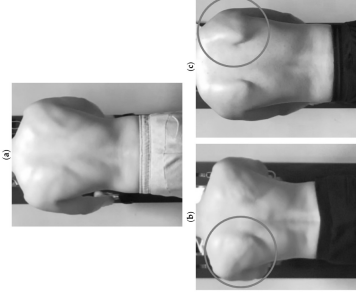
Decreased volume within the subacromial space
 → Subacromial impingement
 → Rotator cuff tear / biceps tendinopathy

Loss of optimal length-tension relationship of the rotator cuff
 → Decreased dynamic joint stability

Alteration in scapular kinematics in pathologic population

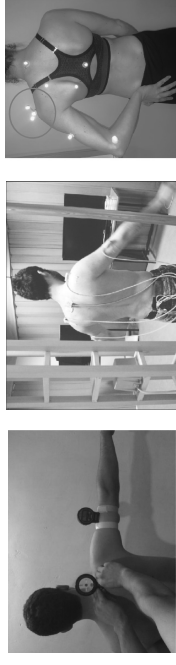
- Altered scapular kinematics and muscle activation pattern have been identified in patients with variety of shoulder pathologies.

- Multidirectional instability
- Subacromial impingement
- Posterior impingement
- Rotator cuff tears
- Neck pain



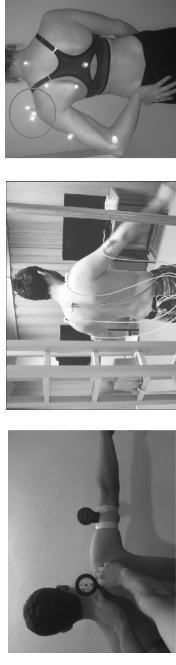
Kinematic analysis of scapular motion

- Goniometer / inclinometer
- X-ray
- MRI
- Electromagnetic tracking device
- Optical motion capture system



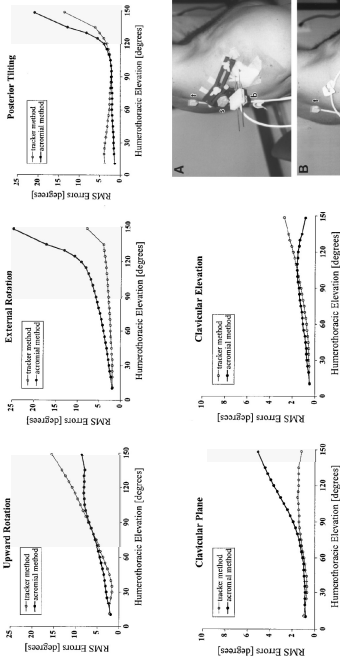
Kinematic analysis of scapular motion

- Goniometer / inclinometer
- X-ray
- MRI
- Electromagnetic tracking device
- Optical motion capture system

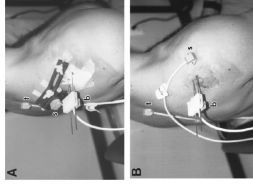


Kinematic analysis of scapular motion

Karduna (2001)



(A) Tracker method



- Assessment of scapular motion using video-based motion capture system.

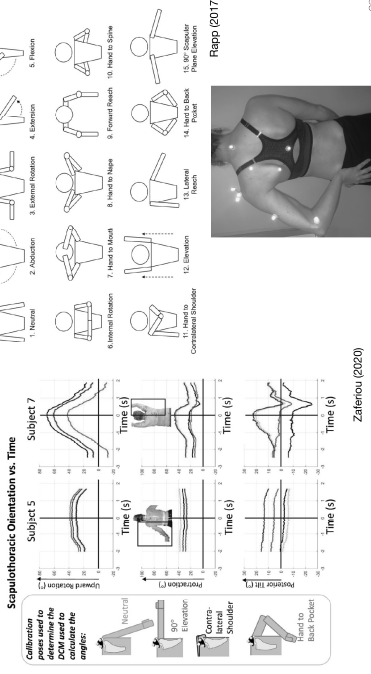
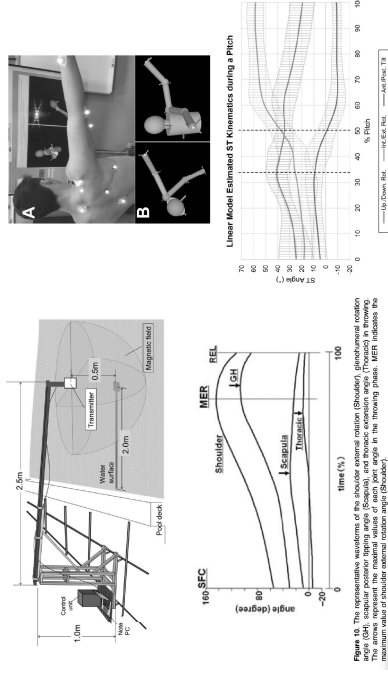


Figure 10. The representative waveforms of the shoulder external rotation (Shoulder), glenohumeral rotation angle (GH), scapular posterior tipping angle (Scapula), and thoracic extension angle (Thoracic) in throwing. The arrows represent the maximal values of each joint angle in the throwing phase. MER indicates the maximum value of shoulder external rotation angle (Shoulder).

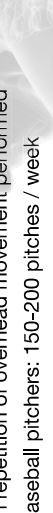


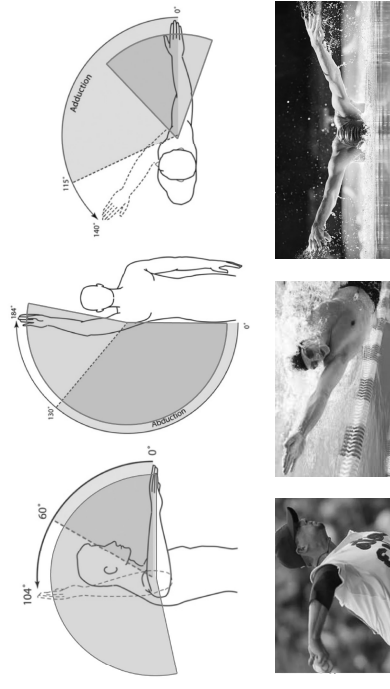
Shoulder biomechanics in overhead sports

- Swimming
- Softball windmill pitching
- Baseball pitching
- Javelin throw
- Cricket bowling etc.



“Threats” to glenohumeral (GH) joint in overhead sports

- 
1. High repetition of overhead movement performed
 - Baseball pitchers: 150-200 pitches / week
 - Swimming: 30,000 rotations/wk
 - Softball pitchers: 20 pitches x 7 innings x 5-7 games = 700-980 pitches over a 3 day weekend tournament
 2. Extreme range of motion.
 3. High external joint forces and moment.



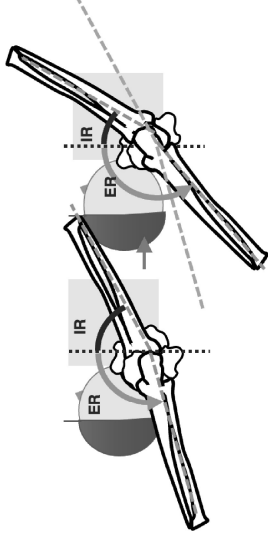
Shoulder biomechanics in overhead sports

- High magnitude of shoulder external rotation moment is produced during the arm-cocking motion.



Shoulder biomechanics in overhead sports

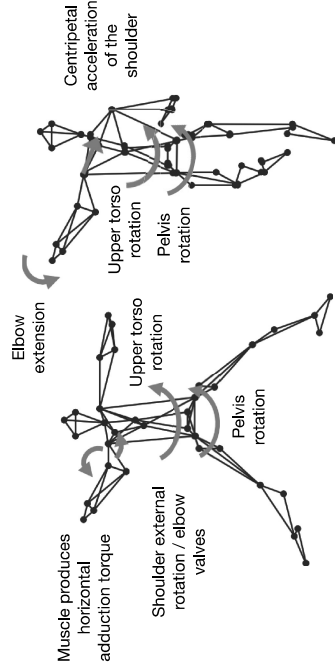
- ROM adaptation in overhead athletes' shoulder in response to the external rotation moment.



Humeral retrotorsion results in decreased IR ROM and increased ER ROM, but no change in total rotation ROM

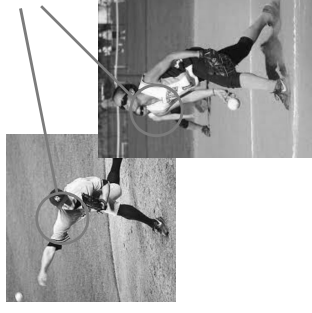
Shoulder biomechanics in overhead sports

- Shoulder joint forces and moments are influenced by the *proximal* segment kinematics.



Shoulder biomechanics in overhead sports

- High magnitude of shoulder distraction force results in tensile stress within the glenohumeral stabilizers near ball release.

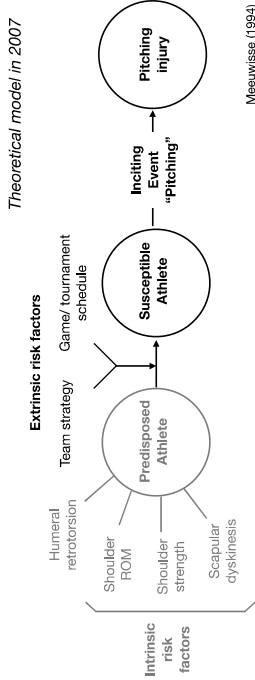


Sakiko Oyama, PhD, ATC

My research interests

- Prevention of upper extremity injuries in overhead athletes through:
 - Better understanding of *physical characteristics* that contribute to injury.
 - Better understanding the *baseball pitching kinematics* associated with increased joint loading.
- Modification of physical characteristics and kinematics associated with injuries.
- Improving evaluation of individuals with disability using motion analysis and wearable technology.

Pitching-related upper extremity injuries



34

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Asymmetry in scapular posture in overhead athletes

Journal of Athletic Training
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original research

Asymmetric Resting Scapular Posture in Healthy Overhead Athletes

Sakiko Oyama, MS, ATC^{1,2,3,*}; Joseph B. Myers, PhD, ATC^{1,2}; Craig A. Wassinger, PhD, PT¹; R. Daniel Ricci, MS, ATC²; Scott M. Lephart, PhD, ATC²

¹University of Pittsburgh, Pittsburgh, PA; ²The University of North Carolina at Chapel Hill, Chapel Hill, NC; ³Marshall University, Huntington, WV



Table. Scapular Resting Position and Orientation (Between-Limits Main Effect)

Position and Orientation	Mean ± SD	P Value
Scapular upward-downward rotation, °	3.45 ± 6.17	
Dominant	2.00 ± 7.42	
Nondominant	1.45 ± 6.05	
Bilateral difference		.279
Scapular internal-external rotation, °		
Dominant	29.34 ± 7.57	
Nondominant	26.47 ± 7.35	
Bilateral difference	3.86 ± 7.52	.001 ^a
Scapular anterior-posterior tilt, °		
Dominant	15.09 ± 6.82	
Nondominant	14.02 ± 5.30	
Bilateral difference	1.08 ± 3.57	.001 ^a
Scapular protraction-retraction, °		
Dominant	-16.28 ± 5.59	
Nondominant	-15.45 ± 5.33	
Bilateral difference	2.50 ± 6.03	.003 ^a
Scapular elevation-depression, °		
Dominant	6.80 ± 5.03	
Nondominant	6.55 ± 5.05	
Bilateral difference	0.38 ± 5.40	.455

The dominant-side scapula of the overhead athletes was more internally rotated and anteriorly tilted than the non-dominant-side scapula.

* Significant difference at a level of .05.

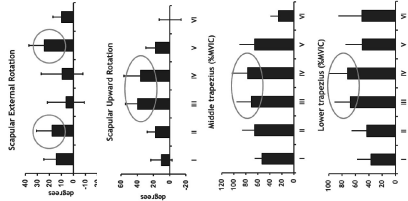
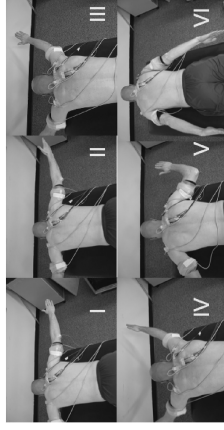
35

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Physical characteristics of the shoulder

- Investigation of scapular kinematics and muscle activation level during scapular retraction exercises.

Scapular retraction exercises



37

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Physical characteristics of the shoulder

Effects of Non-Assisted Posterior Shoulder Stretches on Shoulder Range of Motion Among Collegiate Baseball Pitchers

Sakiko Oyama, MS, ATC, Candice P. Goeger, MS, ATC, Benjamin M. George, MS, ATC, Scott M. Lephart, PhD, ATC, and Joseph B. Myers, PhD, ATC



38

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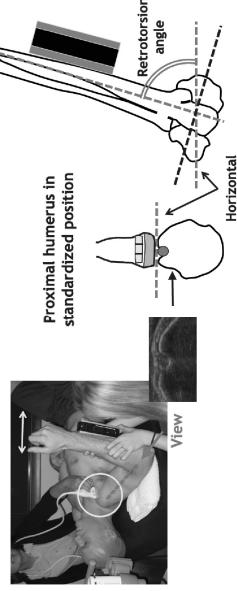
Physical characteristics of the shoulder

SAGE
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The American Journal of Sports Medicine
Volume 40, Issue 5, May 2012, Pages 1155-1160
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Ultrasonographic Assessment of Humeral Retrotorsion in Baseball Players: A Validation Study

Joseph B. Myers, PhD, ATC^{1,2,3,*}, Sakiko Oyama, MS, ATC^{1,2}, and John P. Clarke, MD¹



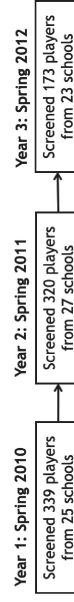
39

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Physical characteristics of the shoulder

Physical contributors to throwing injuries: A prospective NIAMS study

- Prospective cohort design.
- Screen high school baseball players during preseason.
- Track participation and incidence of throwing-related upper extremity injury during season through weekly online survey.

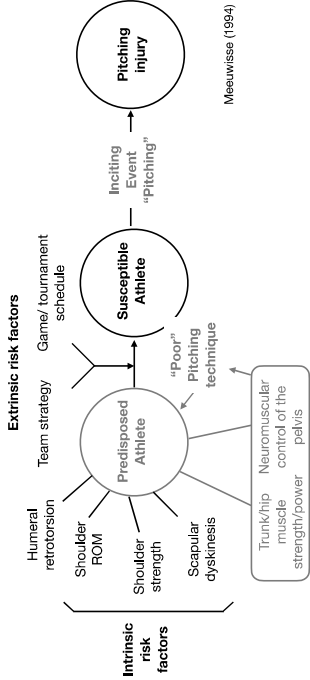


40

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Pitching-related upper extremity injuries

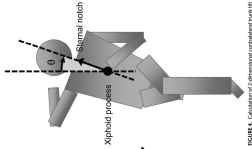
Theoretical model in 2014



Physical characteristics of the trunk

Trunk Muscle Function Deficit in Youth Baseball Pitchers With Excessive Contralateral Trunk Tilt During Pitching

Sakiko Oyama, PhD, ATC,* Andrew G. Wadtham, PT, PhD, LAT, CSCS,§ Araceli R. Souza, BS,* Ravina R. Patel, BS,* and Derrick L. Kohnowski, BS,*



The pitchers with high (>30°) CLT angle demonstrated weaker trunk rotation strength towards the pitching-arm side compared to pitchers with low (<15°) CLT angle (p=.015)

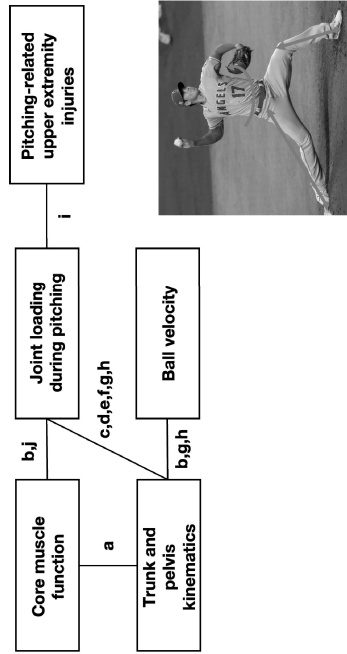
Intervention to improve pitching biomechanics

GRANT INFORMATION SUMMARY

Investigation of lumbo-pelvic-hip muscle function, trunk/pelvis kinematics and joint loading in baseball pitching

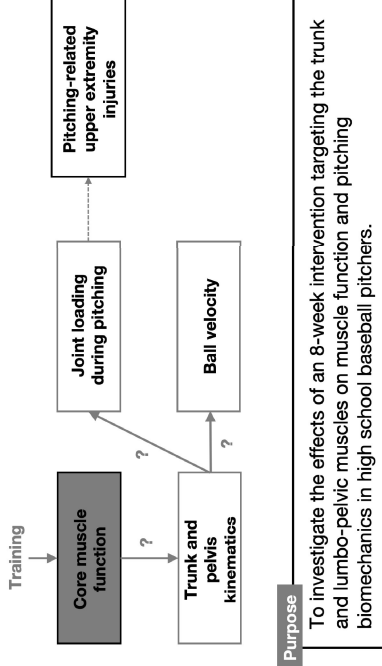


Trunk/pelvis kinematics and core muscle



a. Oyama (2017), b. DeZee (2024), c. Aguinado (2009), d. Oyama (2013), e. Solomito (2014), f. Escamilla (2022), g. Tanaka (2022), h. Lin (2022), i. Anz (2010), j. Laudner (2019)

Trunk/pelvis kinematics and core muscle



Purpose

To investigate the effects of an 8-week intervention targeting the trunk and lumbo-pelvic muscles on muscle function and pitching biomechanics in high school baseball pitchers.

Participants

- Inclusion criteria:
 - Age between 14 and 18
 - Have at least 1 year of baseball pitching experience.
 - Actively pitches on a baseball team.
 - No injury/pain at the time of baseline test.

Intervention group (INT)

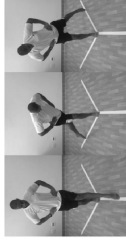
- Completed the training program.
- Recruited: 27
- Dropped out: 4
- Included: 23

Control group (CON)

- No intervention
- Age-matched to INT pitchers.
 - Recruited: 27
 - Dropped out: 2
 - Data issue: 1
 - Included: 24

Assessment of core muscle function

- Assessments used:
 - Y-balance test
 - Inline lunge toss
 - Isometric trunk flexion strength
 - Isometric trunk extension strength
 - Isometric trunk rotation strength
 - Isometric hip abduction strength
- High intrasession reliability has been established for all measures
- $ICC_{2,k} = .837 - .985$



64

Assessment of baseball pitching mechanics

- Kinematic data were captured in the lab using Vicon 8-camera motion capture system (600Hz)
- Outcome variables:
 - Peak ball velocity (m/s)
 - Mean ball velocity (m/s)
 - Max separation (°)
 - Peak pelvis rotation velocity (°/s, % Pitch)
 - Peak upper torso rotation velocity relative to pelvis (°/s, % Pitch)
 - Normalized peak elbow varus moment (Nm/ht/BW)
 - Normalized peak shoulder internal rotation moment (Nm/ht/BW)



Intervention program

- Training (60min) occurred twice a week over 8 weeks at the high school or at the training facility.

Training focus	Stability & muscular endurance (Weeks 1&2)	Basic Strength (Weeks 3&4)	Strength/Power (Weeks 5&6)	Power (Weeks 7&8)
Endurance / stability exercises (ex. planks, Russian twists etc.)				
Resistance exercises (ex. Exercises using weights/medicine balls)				
Perturbation exercises (Exercises using Bosu /physio-balls)				
Plyometric exercises (ex. medicine ball tosses)				

65

Data analysis

- Independent t-test was used to compare the changes in each outcome variables between INT and CON groups.
- Pearson correlation coefficient was used to examine the relationship between improvements in core muscle function and pitching biomechanics variables in INT group pitchers.
- A prior $\alpha = 0.05$.



Intervention effects on core muscle function

Variables	Intervention group (n=23)	Control group (n=25)	p-value
Δ Y-balance composite score (Stance leg) (% leg length)	12.2 $\pm$ 19.5	1.11 $\pm$ 23.7	.085
Δ Y-balance composite score (Lead leg) (% leg length)	9.41 $\pm$ 19.8	1.68 $\pm$ 20.1	.186
Δ Inline-lunge toss (throwing arm side) (m)	1.25 $\pm$ 0.89	0.56 $\pm$ 0.89	.011
Δ Inline-lunge toss (non-throwing arm side) (m)	1.33 $\pm$ 0.80	.55 $\pm$ 0.83	.002
Δ Trunk flexion strength (%BW)	14.0 $\pm$ 12.6	5.81 $\pm$ 13.7	.036
Δ Trunk extension strength (%BW)	10.2 $\pm$ 13.0	3.84 $\pm$ 12.1	.085
Δ Trunk rotation strength (throwing arm side) (N/BW)	12.2 $\pm$ 7.62	3.54 $\pm$ 9.64	.001
Δ Trunk rotation strength (non-throwing arm side) (%BW)	12.6 $\pm$ 7.96	0.86 $\pm$ 9.80	<.001
Δ Hip abduction strength (throwing arm side) (%BW)	3.24 $\pm$ 4.49	0.64 $\pm$ 3.10	.023
Δ Hip abduction strength (non-throwing arm side) (%BW)	3.03 $\pm$ 3.92	-0.17 $\pm$ 2.61	.002

67

Intervention effects on pitching biomechanics

Variables	Intervention group (n=23)	Control group (n=25)	p-value
Δ Peak ball velocity (m/s)	0.86 $\pm$ 0.88	0.16 $\pm$ 0.89	.010
Δ Mean ball velocity (m/s)	0.75 $\pm$ 1.07	-.020 $\pm$ 1.02	.014
Δ Max separation (°)	0.03 $\pm$ 8.20	0.55 $\pm$ 11.0	.231
Δ Peak pelvis rotation velocity (°/s)	-32.3 $\pm$ 162.0	-39.5 $\pm$ 123.5	.225
Timing of peak pelvis rotation velocity (% Pitch)	-2.91 $\pm$ 18.1	3.50 $\pm$ 17.7	.863
Δ Peak upper torso rotation velocity (°/s)	-30.5 $\pm$ 182.4	8.73 $\pm$ 115.0	.380
Timing of peak torso rotation velocity (% Pitch)	-1.83 $\pm$ 16.0	0.27 $\pm$ 17.7	.672
Δ Peak elbow varus moment (Nm/height/body weight)	0.28 $\pm$ 0.36	-0.12 $\pm$ 0.87	.046
Δ Peak shoulder internal rotation moment (Nm/height/body weight)	0.27 $\pm$ 0.38	-0.74 $\pm$ 0.83	.077

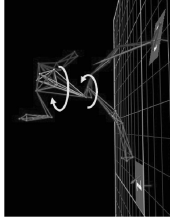
68

69



Relationship between changes in function and biomechanics

- Within the INT group ($n=23$)
 - Greater improvement in isometric trunk rotation strength to the dominant arm side was correlated with a greater increase in max separation ($r=.467$).
 - Greater improvement in trunk rotational power was correlated with:
 - Greater increase in max separation angle ($r=.425-.548$).
 - Later initiation of trunk rotation ($r=.436-.562$).
 - Later occurrence of peak upper torso rotation velocity ($r=.456-.526$).



60



Relationship between changes in function and biomechanics

- Within the INT group ($n=23$)
 - Greater improvement in trunk rotational power to the dominant side ($r=.424$) and trunk extension strength ($r=.468$) was correlated with greater increase in peak shoulder internal rotation moment.

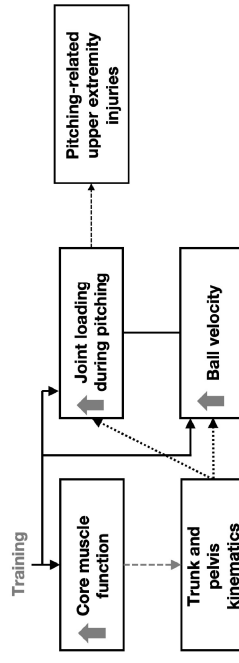


61



Summary of the study

- The intervention significantly improved core muscle function and ball velocity, but also increased elbow varus moment.
- Improved core muscle function was correlated with changes in pelvis/upper torso kinematics.
- Need to protect the joint from increased loading associated with increased ball velocity.



62