Shear-wave Elastography of the UCL of the Elbow in Healthy Volunteers: A pilot study with implications for baseball

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Background: UCL Injuries

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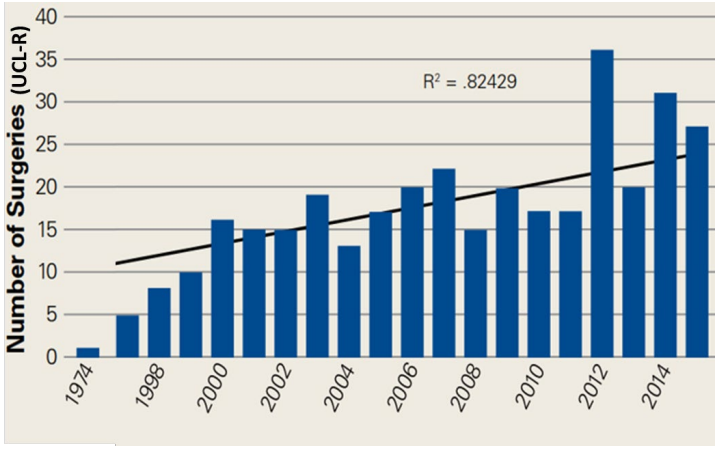
- The medial ulnar collateral ligament (UCL) of the elbow is the primary stabilizer against valgus stress in overhand throwing athletes
- Top injuries: shoulder (20.6%), elbow (19.6%)
- UCL-Reconstructions: 56% increase from 2006-2015 *(Conte et al. AJO, 2016)*
- Elbow injuries are a major cause of disability in pitchers
- Injuries to the UCL may occur either acutely or due to repetitive stress



The Thrower's Elbow At-Risk

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- There is no clear way to determine which elbows are at-risk
- Often presents with rupture
- The chronic "smoldering elbow"
- MRI predictive value is controversial and generally not used to follow pitchers clinically
- MRI of a thrower's elbow upon amateur draft or free-agent signing is generally not "normal"
  - Adaptive vs. pathologic changes
  - Thickening, fluid signal, calcifications

Elbow Stress Ultrasound is Not New

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- Ultrasound (US) is a non-invasive, relatively inexpensive modality.
- Standard portable US machine
- Use it to measure the gapping
  - Premise: ulnohumeral joint laxity may indicate UCL structural damage indicative of injury
  - Studies: conflicting results:
    - No association between UCL injury and ulnohumeral laxity
    - Ulnohumeral laxity associated with UCL injury

Stress Sonography of the Ulnar Collateral Ligament of the Elbow in Professional Baseball Pitchers
A 10-Year Study

Michael G. Ciccotti,*† MD, Alfred Atanda Jr,‡§ MD, Levon N. Nazarian,‖ MD, Christopher C. Dodson,*† MD, Laurens Holmes,§ MD, DrPH, and Steven B. Cohen,*† MD
The American Journal of Sports Medicine, Vol. 42, No. 3
DOI: 10.1177/0363546513516592

Using Stress Ultrasonography to Understand the Risk of UCL Injury Among Professional Baseball Pitchers Based on Ligament Morphology and Dynamic Abnormalities

Ellen Shanley,*† PhD, PT, OCS, Matthew Smith,‡ MD, Braden K. Mayer,‡ MD, Lane Brooks Bailey,§ PhD, DPT, Charles A. Thigpen,† PT, PhD, ATC, John M. Tokish,‖ MD, Michael J. Kissenberth,¶ MD, and Thomas J. Noonan,‡# MD
The Orthopaedic Journal of Sports Medicine, 6(8), 2325967118788847
DOI: 10.1177/2325967118788847

Background: Elastography

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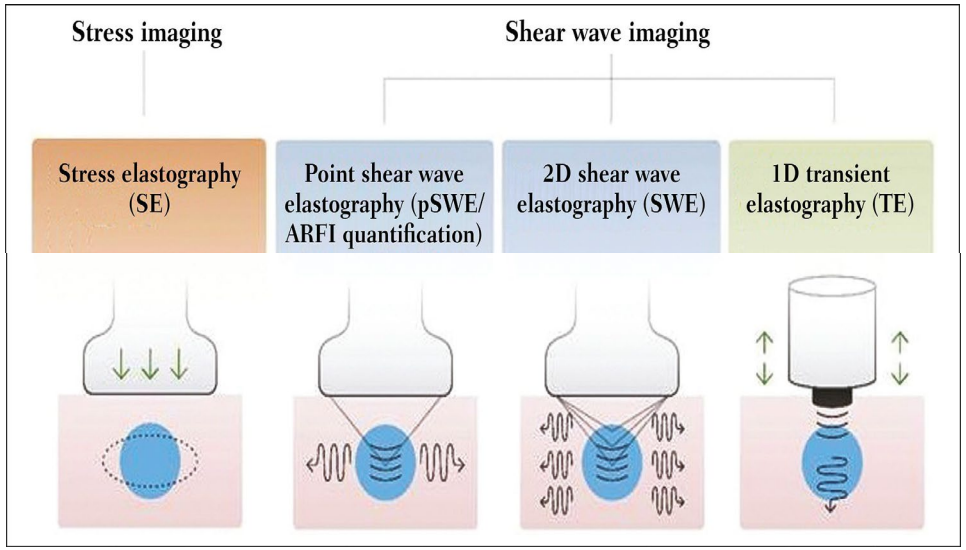
- Specialized US machines can perform “Elastography”
- Two Methods: Strain (static) and Shear-wave (dynamic)
- **Strain (SE)**
  - Repetitive compression cycles and software calculates strain from mechanical deformation
  - Highly operator-dependent
  - One study from Japan used this method to assess the UCL
    (Wada, K.W. et al. Ultrasound Elastographic Assessment of the Medial Collateral Ligament in Elbow Joints of Baseball Players. Showa University Journal of Medical Sciences, 2014.)
- **2D Shear-wave (SWE)**
  - Newer and felt to be more reproducible
  - The machine performs an acoustic stress
    - Acoustic Radiation Force Impulse (ARFI)
  - A method to measure tissue elasticity/stiffness
    - Structures which may be too deep to palpate
    - Objective/reproducible and less operator dependent
    - Quantifiable



Moraes, Pedro Henrique de Marqui, Sigrist, Rosa, Takahashi, Marcelo Straus, Schelini, Marcelo, & Chammas, Maria Cristina. (2019). Ultrasound elastography in the evaluation of thyroid nodules: evolution of a promising diagnostic tool for predicting the risk of malignancy. *Radiologia Brasileira*, *52*(4), 247-253. Epub August 08, 2019.https://dx.doi.org/10.1590/0100-3984.2018.0084

Shear-wave Elastography (SWE)

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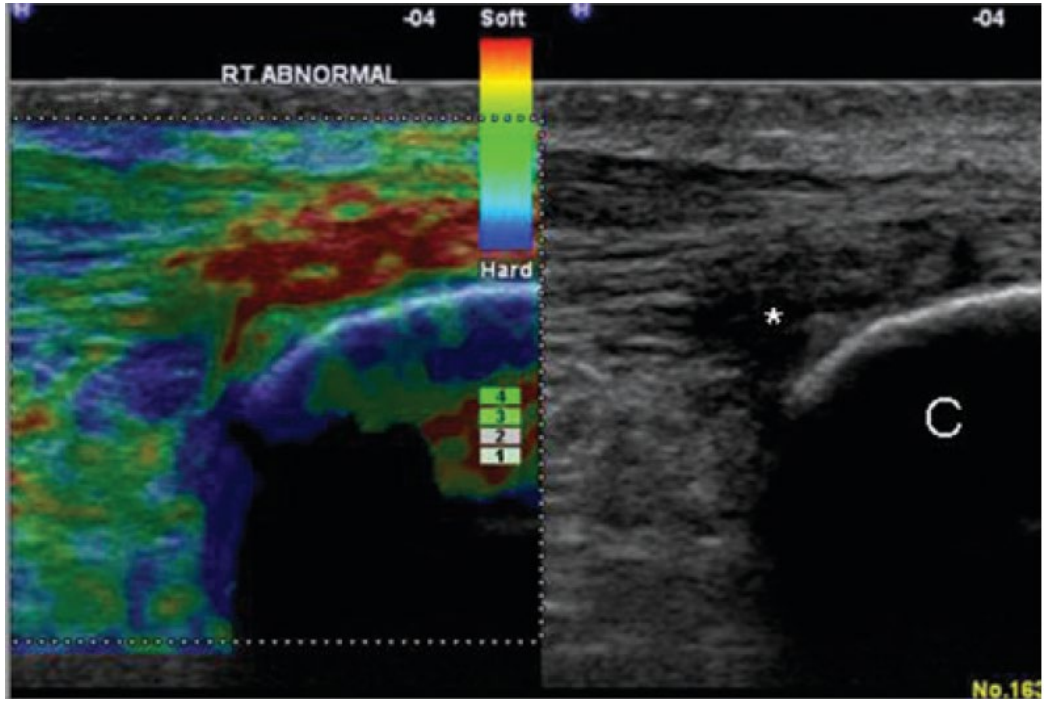
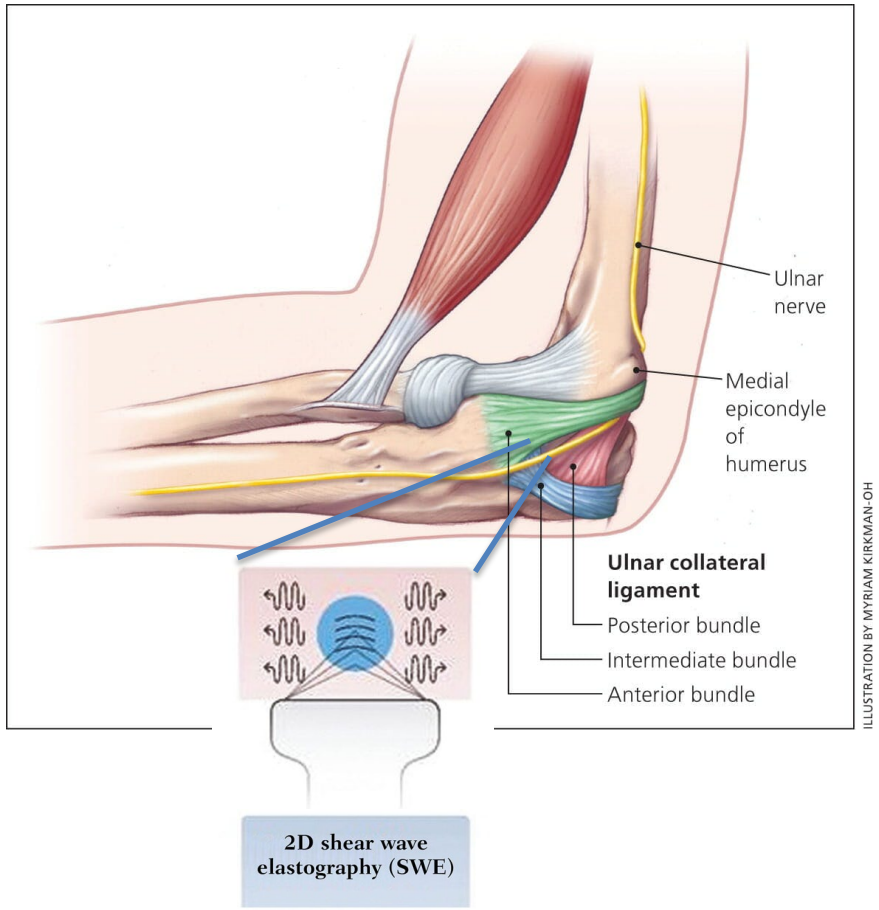
- Evolving musculoskeletal applications
- Has been shown to be useful for tendon problems (Achilles tendon, patellar tendon)
- Shear-wave Velocity (SWV)
  - High SWV = stiff tissue = “healthy”
  - Low SWV = soft tissue = “unhealthy”
- Can it be useful for measuring the properties of ligaments, and if so, what is normal?



Purposes



- To determine the feasibility and reliability of 2D-SWE in the measurement of UCL stiffness.
- To establish normative values of UCL stiffness in healthy volunteers.
- To determine side-to-side differences which correspond to hand dominance.

Methods

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- 20 Elbows in 10 healthy volunteers recruited
- 2D-SWE of UCL in dominant and non-dominant arms was performed
- Repeated over 3 different sessions within the same week.
- Standardized positioning
  - Elbow in approximately 15-30 degrees flexion
  - 5 daN valgus stress applied with a Telos stress device.

Results: SWE

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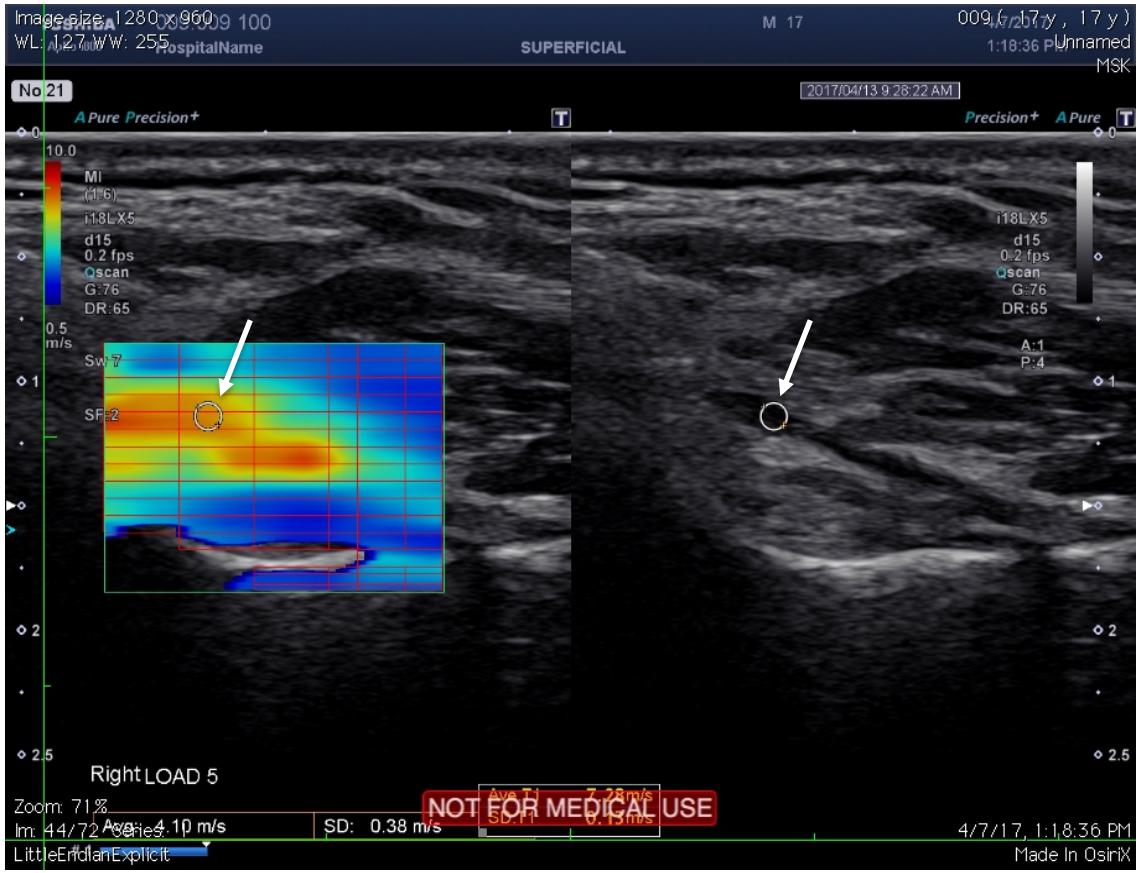
2D elastogram with circular region of interest (ROI) within UCL



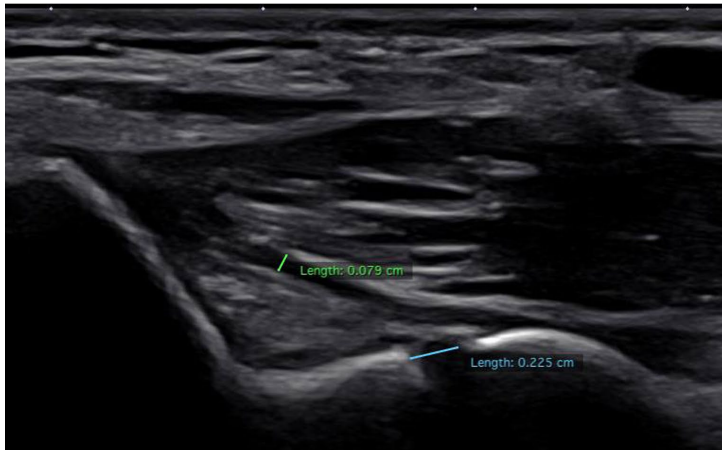
Shear wave velocity data aggregated across 3 scan sessions

	Dominant	Non-Dominant	Both
Mean (m/s)	5.14	5.24	5.19
Median (m/s)	5.21	5.40	5.23
SD (m/s)	0.53	0.39	0.46
Q1 (m/s)	4.68	4.70	4.67
Q3 (m/s)	5.43	5.75	5.65
IQR (m/s)	0.75	1.05	0.98
IQR/Median	0.14	0.19	0.19
Max (m/s)	6.90	6.83	6.90
Min (m/s)	3.62	3.71	3.62

SD standard deviation, *Q1* first quartile, *Q3* third quartile, *IQR* interquartile range

Results: SWE

- Sex, hand dominance, and overhead sports participation were not predictive of ulno-humeral distance.
- Average UCL thickness did not differ from dominant to non-dominant.
- Median SWV obtained from all 20 elbows pooled across all 3 sessions was 5.19 ± 0.76 m/s.
- Mean velocity in dominant arms was 5.14 m/s and 5.24 m/s in non-dominant ($p = 0.558$).
- Reliable results (IQR/Median < 0.3) were obtained in 88% of scan sessions.
- The ICC was 0.05 (95% CI; − 0.18–0.36; poor). Repeatability coefficient (95% limits of agreement) was 1.95 m/s (95% CI; 1.61–2.37 m/s).



Grayscale image along the length of the UCL
Green UCL mid-substance thickness
Blue Ulnohumeral distance

Conclusions

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- There was no significant difference in the UCL by SWE between dominant and non-dominant arms.
- This provides the normative mean and expected range SWV of the UCL in healthy elbows.
- While 2D-SWE may be a feasible method to evaluate UCL stiffness, further work is needed to improve reproducibility between scan sessions.
- Future studies should therefore evaluate diseased ligaments and develop techniques to improve elastogram quality.

(UNPUBLISHED DATA)

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Shear Wave Elastography of the Ulnar Collateral Ligament of Collegiate Pitchers Over One Season

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2) Department of Radiology, Houston Methodist Hospital, Houston, TX

Methods: Pitchers vs. Volunteers

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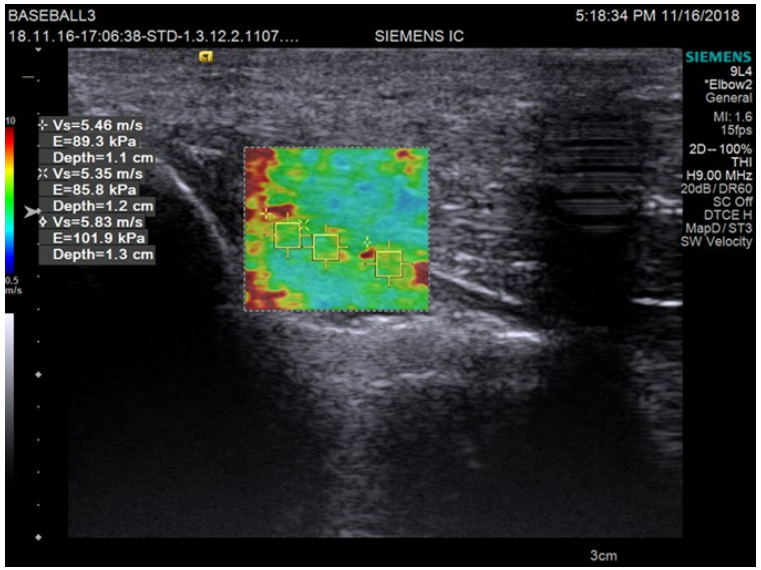
- Pitchers (College)
  - Time points: 2019 regular season, Early (January), Mid (March), Late (May)
  - SWV measured at 3 locations (3 times each location)
    - Proximal, midsubstance, distal

- Volunteers (New cohort)
  - Time points: October 2018, November 2018
  - SWV measured 10 times at midsubstance



Results: Pitchers vs Volunteers

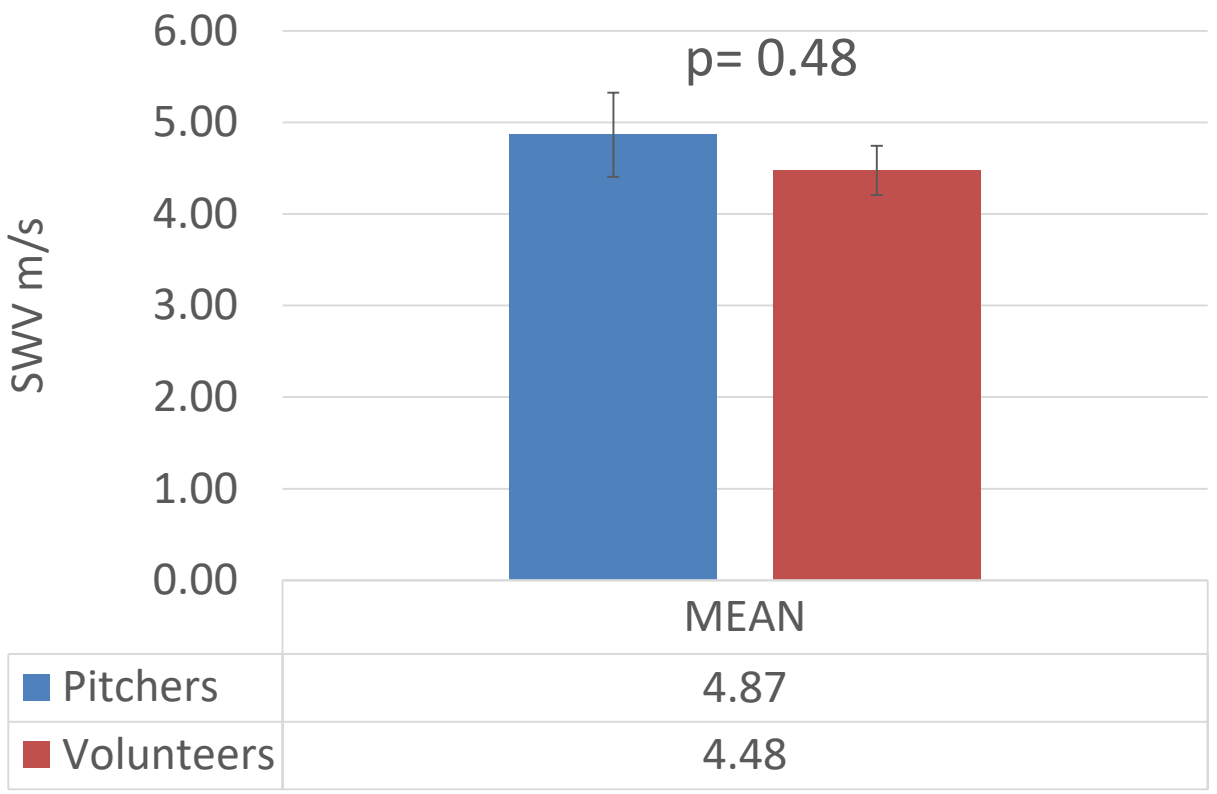


Figure 1. Mean ulnar collateral ligament (UCL) shear wave velocity (SWV) of collegiate baseball pitchers and healthy volunteers.

Results: SWE over the Season

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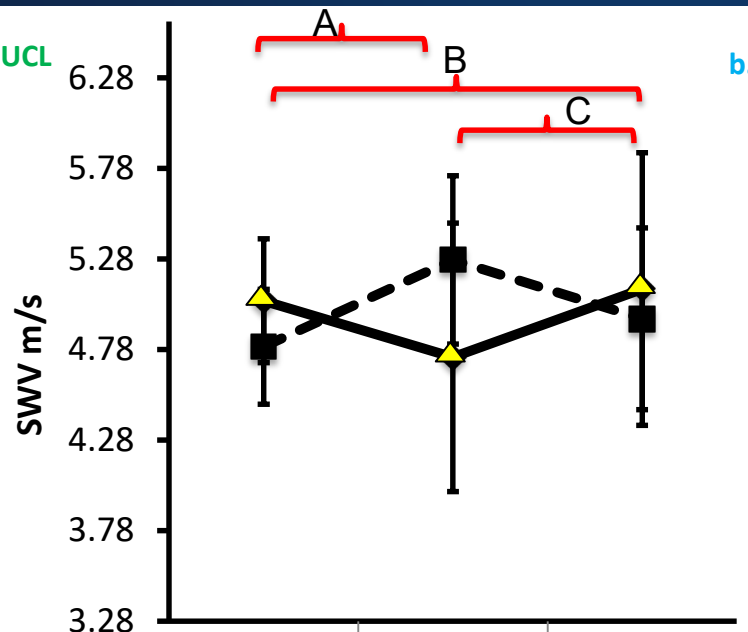
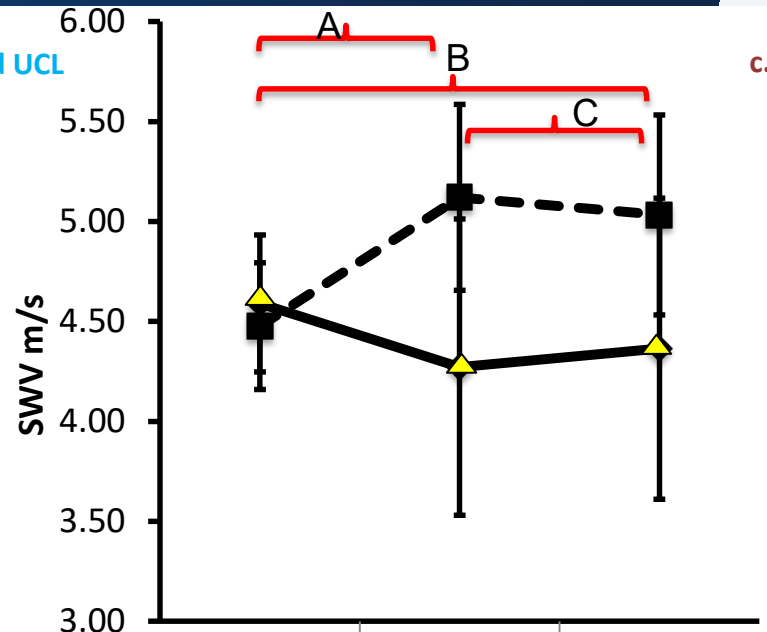
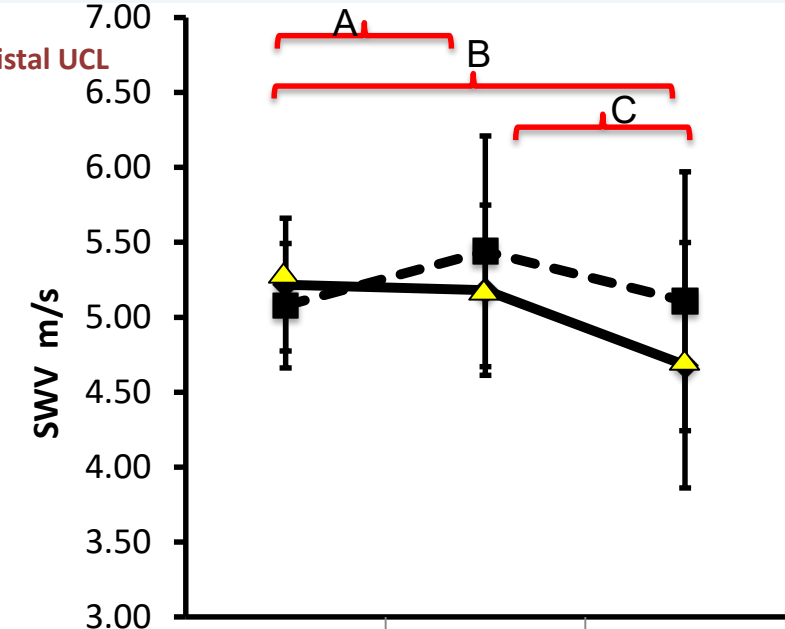
a. Proximal UCL



b. Mid UCL



c. Distal UCL



	Early	Mid	Late
Dominant	5.05	4.74	5.11
Nondominant	4.80	5.28	4.95

	Early	Mid	Late
Dominant	4.59	4.27	4.36
Nondominant	4.48	5.12	5.03

	Early	Mid	Late
Dominant	5.22	5.18	4.68
Nondominant	5.08	5.44	5.11

Within Group P-Values Across Time DOMINANT ARM			
	PROXMIAL	MID SUB	DISTAL
A. Early vs Mid	0.54	0.47	0.96
B. Early vs Late	0.93	0.77	0.49
C. Mid vs Late	0.74	0.92	0.60

Within Group P-Values Across Time NONDOMINANT ARM			
	PROXMIAL	MID SUB	DISTAL
A. Early vs Mid	0.44	0.41	0.62
B. Early vs Late	0.78	0.45	0.96
C. Mid vs Late	0.50	0.90	0.77

Summary for SWE of UCL in Pitchers

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- Mean SWV collegiate pitchers: 4.87 m/s
  - Not significantly different vs volunteers
- Mean SWV collegiate pitchers dominant vs nondominant
  - No significant differences between dominant and nondominant arms
- Mean SWV collegiate pitchers over course of 1 season
  - No significant change between any two time points

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