Investigation into the Mechanisms of Upper Extremity Labral Tears for the Optimization of Athletic Performance

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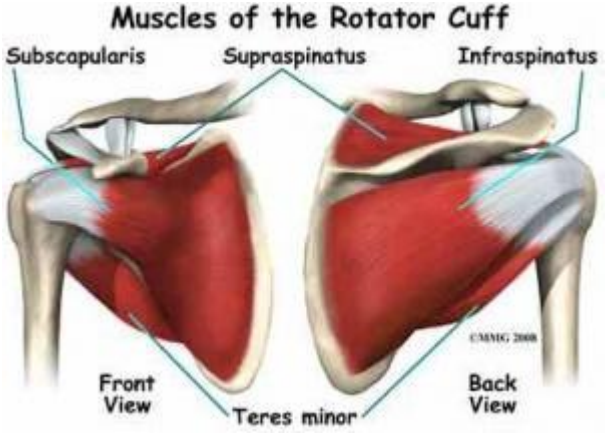
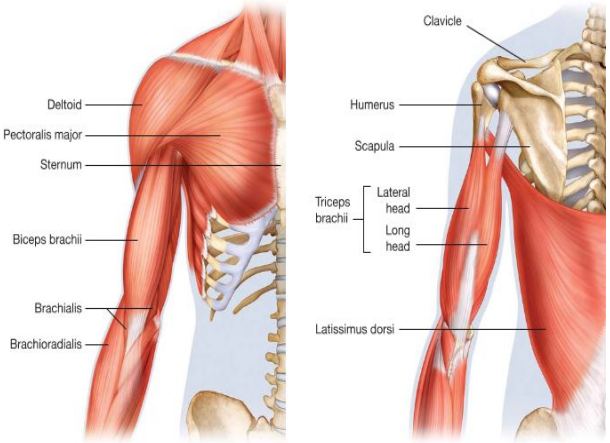
Anatomical Background

- Ball and socket joint ⟶ Range of Motion
- Nature of the shoulder labrum
  - Stiffness Gradient
  - “Cereal Bowl”
  - Common Tear Locations and Mechanisms of Tears
- The rotator cuff (infraspinatus, supraspinatus, teres minor, and subscapularis)
  - Injury Prevention and Shoulder Stabilization
  - Small Muscles and Low Force Generation
- Contribution to explosive and athletic movements
  - Significance of pectoralis, biceps, and deltoid



https://www.physio-pedia.com/Rotator_Cuff



https://muscularsystemdec2013.weebly.com/gross-anatomy-of-skeletal-muscles/muscles-of-the-upper-limb

Clinical Significance

https://www.onlinewebfonts.com/icon/140044

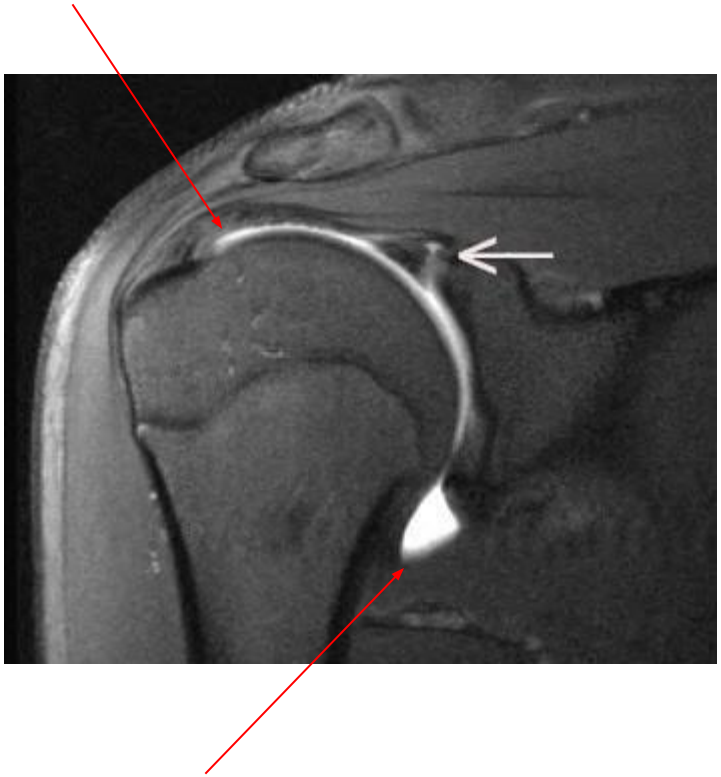
- Increased concerns regarding athlete health and safety
- Rate at which professional athletes are getting injured
  - Athletes getting paid on the scale of millions of dollars
  - 511 cited injuries in a 5-year span accounting for 20% of all injuries
  - Translation to injuries in youth athletes
- Repair requires surgery and/or physical therapy
  - Average of 6-8 weeks at $125 a session
- Inefficient repair methods and further limited mobility

Hypothesis

"Due to the structure and properties of the labrum, a "safety threshold" for active forces in upper extremity movements exists. If we are able to measure the moments enacted about the joint, using inverse kinematics, we can then determine these "thresholds" and alter movement mechanics to increase performance and decrease injuries."

*Mainly interested in the overhead throwing motion

*Red Arrows= "Thresholds"



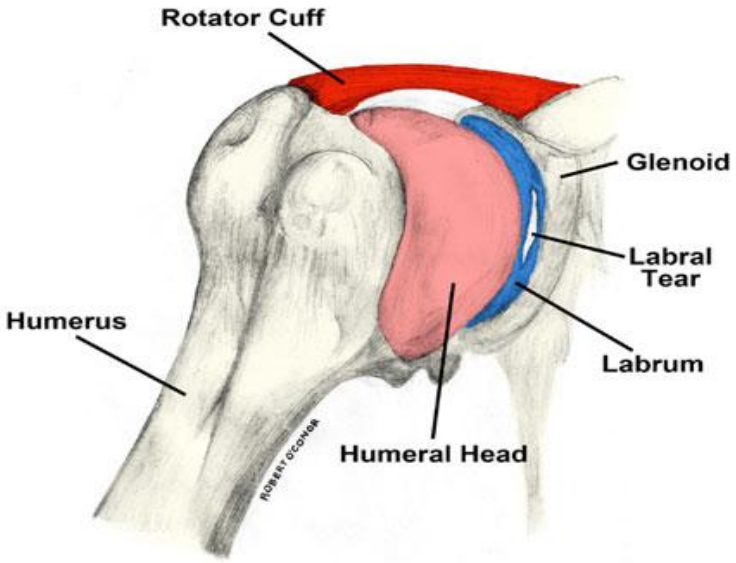
https://www.charterradiology.com/2017/05/28/extensive-shoulder-injury-sidelines-a-young-baseball-player-the-importance-of-mr-arthrogram-in-making-accurate-diagnosis/

Previous Biomechanical Studies and Relevant Research

- Shoulder Instability
  - Instability & Shoulder Dislocations: nonoperative treatment such as immobilization followed by physical therapy
  - After the first occurrence of dislodging your shoulder, the probability increases thus surgical repairs are advocated
  - The arthroscopic labral repair is successful but there are still patients that could potentially benefit from an anterior or posterior instability events.
- Labral Tears of the Shoulder
  - Difficult to repair superior labral anterior-posterior (SLAP) injuries
    - Failure of nonoperative treatments: history of trauma, positive compression-rotation tests and overhead arm usage in patients
  - Standardize the reported outcomes to help facilitate more robust comparison of treatment methods.

Previous Biomechanical Studies and Relevant Research

- Anatomical Variants in the Anterosuperior Aspect of the Glenoid Labrum: A Statistical Analysis of 73 Cases
  - Aim to characterize anterosuperior labral anatomical variations
  - Variations: anterosuperior portion of the labrum, sublabral foramen only, sublabral foramen (cord-like middle glenohumeral ligament) and the absence of labral tissue at anterior superior portion of the labrum
  - Anterosuperior labral variants may influence glenohumeral biomechanics & may predispose the shoulder to injuries



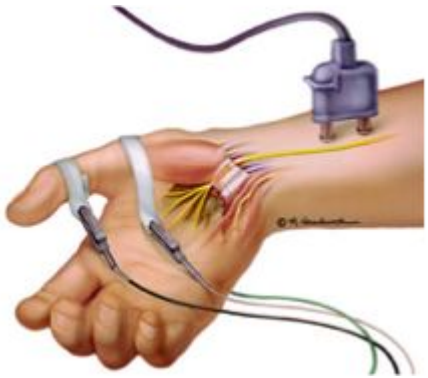
https://www.hss.edu/conditions_shoulder-labrum-tears-overview.asp

Previous Biomechanical Studies and Relevant Research

- Moment Generating Capacity of Upper Limb Muscles in Healthy Adults
  - Difference in max isometric joint moments in healthy subjects versus measured muscle volumes in cadaver
  - Assess the relative moment-generating capacity of muscles at the shoulder, elbow, and wrist along with evaluating the degree in which variation in moment-generating capacity can be explained via volume differences
  - Help improve parameter estimations for musculoskeletal modeling and creation of models for various sizes

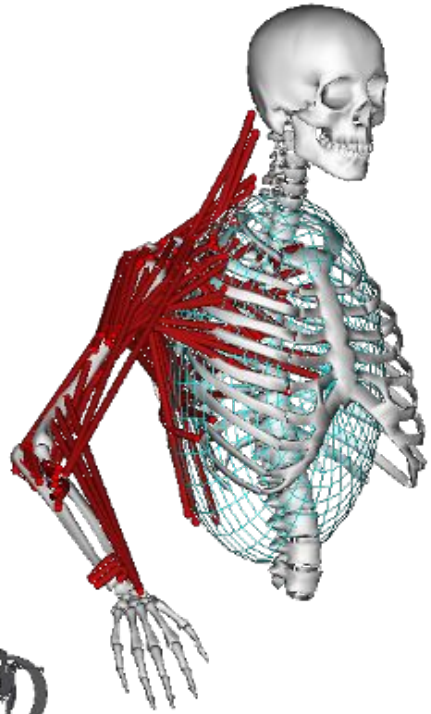
Previous Biomechanical Studies and Relevant Research

- The Effect of Movement Speed on Upper Limb Coupling Strength
  - Frequency of upper limb movements effects coupling and phase difference of associated movements
  - Revealed nature of the Central Nervous System (CNS)
  - Related to modeling of throwing motion
  - Potential injury prevention significance through energy exertion and muscle contraction analysis
- Relationship Between Limb Movement Speed and Associated Contraction of Trunk Muscles
  - Magnitude of upper limb reaction forces in relation to latency of trunk muscle contraction
  - Trunk contraction proceeded upper limb movement
  - Preparatory response to change in equilibrium



http://www.mayfieldclinic.com/pe-carpaltunnel.htm

Previous Musculoskeletal Modeling Studies and Relevant Research



https://simtk.org/

- OpenSim: A Musculoskeletal Modeling and Simulation Framework for in Silico Investigations and Exchange
  - Software libraries specialized for Musculoskeletal Modeling Elements (Biomechanical Joints, Muscle Actuators, etc)
  - Scaling to subject-specific data
  - Employment of Zajac and Hill Muscle Models
  - Determination of “Synthesis Simulation Results” through inverse kinematics
    i) Joint Reaction Forces and Induced Accelerations
- Three-Dimensional Representation of Complex Muscle Architecture and Geometries
  - Finite-Element Modeling based off of Magnetic Resonance (MR)
  - Changes in muscle surface geometry during rotation
  - Variation in muscle peak fiber moment arms within muscles

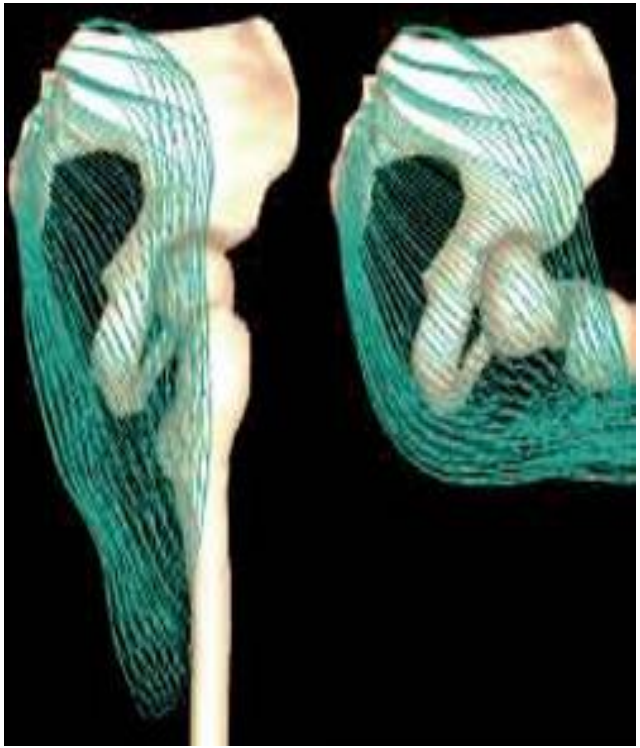
Previous Musculoskeletal Modeling Studies and Relevant Research

- Upper Extremity Kinematics during Functional Activities: Three Dimensional Studies in a Normal Pediatric Population
  - 8 Camera 3-D Motion Analysis System using a 10 Segment Biomechanical Model
  - Kinematic data recorded at a frequency of 60 Hz
  - Determination of Standardized Upper Limb Range of Motion
    - Flexion, Abduction, and External Rotation Motions
  - Measurements recorded in relation to trunk

https://www.optitrack.com/motion-capture-movement-sciences/

Proposed Study

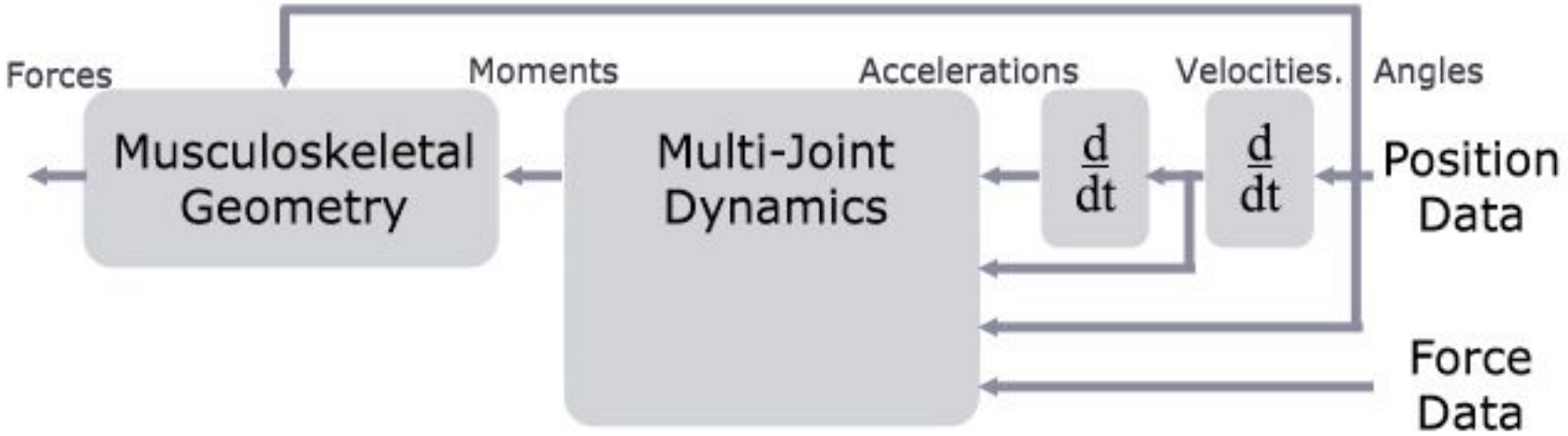
1) OpenSim Labral Modeling and Measurement
    a) Finite-Element Analysis to develop labral model from MRI
    b) Develop complex muscle architectures for all muscles about the shoulder joint
    c) Conduct Joint Moment Analysis at different throwing angles to determine peak moment arms within individual muscle fibers and muscle as a whole
        i) Throwing angle defined as trunk to upper arm
            (1) Arm at the side would be $\Theta=0$
    d) Kinematic Studies to determine Contact Forces about the Shoulder Joint and "Safe Force Thresholds"
        i) Inverse Dynamics
            (1) Moments to forces
    e) Relate to Hypothesis and Injury Mechanisms



https://www.researchgate.net/figure/Examples-of-fiber-geometries-mapped-to-the-psoas-A-gluteus-maximus-B-iliacus-C_fig5_7761742

Inverse Kinematics via OpenSim

- Measuring movement to gain an understanding of involved forces



http://rrg.utk.edu/resources/BME473/lectures.html

Proposed Study

https://imerit.net/computer-vision-revolutionizes-baseball-game-motion-capture-technology/

2) Motion Capture Verification
   a) Use determined “Safe Force Thresholds” to determine “Safe Throwing Angles”
   b) Gather a test population composed of both throwing athletes, non-throwing athletes, and non-athletes
      i) Asked to throw a variety of different objects (ie. baseball, softball, football, etc) at “Safe Throwing Angles”
   c) Use Motion Capture to verify achievement of these angles
   d) View results of throwing
      i) Comparison of performance before and after change in mechanics
      ii) Testing for accuracy and exit velocity from the hand

Future Directions

- Define relevant age range for preventative measures
- Post-surgical analysis of joint range of motion and physical performance
- Individual-specific OpenSim modeling for personalized mechanics analysis, treatment, and rehabilitation methods
- Possibility of “in-game” analysis
- Expansion into investigations of upper-leg movements
    - Hip Labrum versus Shoulder Labrum

Questions?

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