Challenges & Opportunities in Clinically Relevant Measurement of Shoulder Biomechanics

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Objectives

• Understand considerations in using the International Society of Biomechanics recommended standards for coordinate systems and rotation sequences
• Understand skin motion artifact considerations
• Recognize new measurement opportunities for understanding clinically relevant shoulder biomechanics
• Understand the latest biomechanical findings related to mechanical impingement and impingement tests
• Recognize new diagnostic considerations for shoulder disorders
Scapular Motions

B

Upward Rotation

C

Posterior Tilting
Scapular Internal Rotation (Winging)

Internal Rotation
International Shoulder Group

• First recommended 3 scapular landmarks of root of the scapular spine, inferior angle and posterior acromioclavicular joint
• Later changed acromioclavicular landmark to posterolateral acromion
• Results in different values for same movements
Comparison of scapular local coordinate systems

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Comparison to Glenoid Reference

<table>
<thead>
<tr>
<th>Initial</th>
<th>Scapular upward rotation</th>
<th>Scapular tilting</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.0° less</td>
<td>0.5° anterior</td>
<td></td>
</tr>
<tr>
<td>2.9° more</td>
<td>4.7° anterior</td>
<td></td>
</tr>
<tr>
<td>0.1° more</td>
<td>12.8° posterior</td>
<td></td>
</tr>
<tr>
<td>7.5° more</td>
<td>14.3° posterior</td>
<td></td>
</tr>
<tr>
<td>4.8° less</td>
<td>17.1° posterior</td>
<td></td>
</tr>
</tbody>
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Humeral Coordinate System Options

- Medial & lateral epicondylar axis
- Forearm based axis system
Rotation Sequence Effects

- Original proposal for humerothoracic and glenohumeral joints plane of elevation first, elevation second, axial rotation third
- Singularities/gimble lock elevation 0-20° and 16-180°
- Repeating sequence less clinically intuitive
Alternate Glenohumeral Sequence Recommendation

• Elevation 1\textsuperscript{st}, plane of elevation 2\textsuperscript{nd}, axial rotation 3\textsuperscript{rd}
• Singularities at 70-90° of plane of elevation
• Works for all but extremes of horizontal abduction and cross body adduction
• Removes repeating sequence
  – Phadke et al 2011; Senk & Cheze 2006
Skin Motion Artifacts

Karduna et al 2001
Skin Motion Artifacts

Fig. 3. Average errors (degrees) for each 3D rotation component during scapular plane abduction.
Fig. 4. Average errors (degrees) for each 3D rotation component during axial rotation with the elbow at the side.
Measurement of Translations

- Estimated center methods result in large rotations with skin based methods
- Helical axis methods result in plausible values even with skin sensors
- Imaging allows tracking of geometric center
Measurement of the Clavicle

• Can use sternoclavicular and acromioclavicular landmarks to track clavicle protraction/retraction and elevation/depression
• Surface marker reasonable for direct tracking of 3D motions to 90° with careful placement and monitoring
• Important to distinguishing sterno- and acromioclavicular joint motions
Clavicle Motion

• Group average values very similar to true 3D methods
• However, no axial rotation values
Shoulder Impingement

- Mechanical entrapment and abrasion of the rotator cuff tendons beneath the coracoacromial arch (superior/external/subacromial) or glenoid labral complex (internal); Classic descriptions 60-120° subacromial painful arc or abduction and external rotation
Linking Motion & Anatomical Data
Data Analysis

• Minimal distance values for tendon insertion to each potential impinging structure
• Color mapping of proximity between structures
30/60/90° Humerothoracic Elevation
Red = < 2.5mm
Orange = 2.5 – 5mm
Yellow = 5 – 7.5mm

Subacromial Risk 30-70°
Bey 2007
Giphart et al 2012
Internal Impingement

Classic description:
Abduction external rotation
Results – Rotator Cuff Insertion Proximity

• Supra and infraspinatus significantly closer to acromion at 60° versus 30° and 90° for abduction and scapular plane abduction

• Linear distance between the glenoid and supra and infraspinatus significantly less for the symptomatic group (~ 4-5 mm) at 90° and 120° of humerothoracic elevation
Shoulder Impingement

• Most common diagnostic label/disorder for the shoulder
• Large number of potential tissue pathologies
• Movement impairments variable between investigations of this condition
Rotator Cuff Disease
Mechanisms

Eccentric overload
Ischemia, degeneration: tendinopathy
Anatomic/acromial abnormalities

Motion abnormalities

Pain/Inflammation
Damage/Inhibition
Altered Kinematics
Rotator cuff disease/impingement/bursitis/long head biceps tendinopathy/partial thickness tears/isolated full thickness tears/labral tears

- Not well distinguished clinically and often occur in combination
- Some advocate for calling this anterior shoulder pain or anterior shoulder pain of unknown origin
  - “low back pain” label
Support for Mechanical Impingement

- Positional risk is present with arm elevation
- Evidence of abnormal movement patterns in symptomatic patients
- Cause vs. compensation?
- Epidemiologic evidence for positional risk (occupational risk of elevated arm positions)
- Mechanically reducing space interacts with eccentric overload to create disease
The Path Forward

Don’t subcategorize under Impingement, reconsider the condition, restart the conversation

Create a new diagnostic language

Use accurate terms

Mechanical impingement is a mechanism not the only mechanism, and not an ideal diagnostic label

Understand what many surgeons hear when you say “Impingement” and ensure that that is what you want them to hear.
RCT Summary Improvement

Looking closely at variety of shoulder pain RCTs including exercise and/or manual therapy
Using MCID as defining “improvement for an individual”

About 2/3 improve beyond chance improvement threshold
“Average” improvement is about 50%
How to Improve?

• There are clusters of patients with similar movement impairments who will likely benefit from similar treatments
  – Posterior shoulder tightness (Tyler et al 2010)
  – Microinstability

Need to target the right treatments to the right patients at the right dosages

Why not identify movement impairment related diagnostic categories?
So what should we be calling these problems?

- Currently diagnosis of exclusion
- Pain localization/history are important
- Need to identify clusters of movement impairments
- Pain provocation vs. pain relief tests
  - Scapular assistance test
- What is the appropriate level of specificity of a label?
Diagnosis Guides Intervention

Office Worker
- Dx: Scapular Dyskinesia/Rapid Downward Rotation
- Impairments/Tissue Status
- Impingement

Swimmer
- Dx: Scapular Dyskinesia/Glenohumeral Hypermobility
- Impairments/Tissue Status
- Impingement

Graduate Student
- Dx: Glenohumeral hypomobility associated with humeral retrotorsion
- Impairments/Tissue Status
- Impingement
Summary

• Use of Impingement diagnostic label evolved to be overly broad
• Practitioners and researchers miscommunicating about the condition
• Mechanistic condition does not behave as originally believed
• Classic impingement tests do not best identify mechanical impingement
• Need diagnostic labels that guide intervention with adequate specificity
• Clusters of movement impairments offer potentially useful diagnostic classification
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Thank You!

Questions

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