The Role of Pain and Fatigue on Muscle Function

Stages of Rotator Cuff Tendinopathy

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Stages of Rotator Cuff Tendinopathy

Edema & Hemorrhage
Tendinitis & Fibrosis
Cuff tear & Bony changes

Extrinsic (Impingement) and Intrinsic Mechanisms

Weakness? Why?

Cuff Tears
Muscle Atrophy
Fatty Infiltrate

Shoulder Pain and Weakness: Background

• Causes of reduced force capacity
  – Loss of mechanical integrity (tears) (Gerber 2007)
  – Atrophy from disuse (Gladstone 2007)
  – Fatty Infiltrate into Muscle (Goutallier 1999)
  – Failure of voluntary activation (VA) ??
    • Decreased central drive (decreased ability for the nervous system to recruit and activate the muscle)
      – Learned non-use and pain? (Gladstone 2007)
      – Fatigue?
    • Musculoskeletal pain theorized to impede central (cortical and/or spinal) activation (Johansson 1999)

Voluntary Activation (VA) of Muscle

• Cortical & subcortical pathways to activate the alpha motor neuron pool.
• Force generation is driven by motor unit recruitment and rate coding.
• Decreased force generation ("weakness") may be due to:
  – central mechanisms (poor VA)
  – peripheral mechanisms (poor muscle/tendon)

Pain and Muscle Function Evidence from Other Regions

• Neck Pain
  – (Elliot et al, 2006, 2011, many others)
• Low Back Pain
  – (Hodges et al ’96, ’97; Hides ’96, many others)
• Knee Pain
  – ACL, AKP, TKA
  – Hart et al, 2010; Mizner 2005
• Ankle Fx
  – Stevens et al 2006
Motor Control and LBP
Hodges & Richardson, 1996 Spine and Phys Ther 1997

- Used fine wire electrodes in abdominals and multifidus during self-initiated leg and arm movements
- Healthy subjects contracted abdominals prior to extremity movements, especially transverse abdominis
- Subjects with LBP failed to properly activate abdominals prior to limb prime mover
- Concluded LBP subjects had motor control deficit, esp in transverse abdominis

Multifidus Atrophy
Hides et al, Spine 1996

- 1st episode of LBP, randomized to
  - Medical rx (n=20, meds and < 2 day bedrest) or
  - Medical + Ex’s (n=21, emphasize multif+deep abdominals)
- Multiple outcome measures plus US of multifidus to get cross section
- At 4 weeks:
  - all pts had sig multifidus atrophy usually at only L5 (decrease 24% vs unaffected side)
  - both groups functionally better at 4 wks
    - re: pain, motion, SLR and RM disability
- At 10 wks med group still had significant multifidus atrophy

Long-Term Effects of Specific Stabilizing Exercises for First-Episode Low Back Pain
Hides et al, Spine 2001

- Long-term follow-up (1 & 3 years)
  - Telephone questionnaire: recurrence rate

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2-3</th>
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<tbody>
<tr>
<td>Control</td>
<td>16/19</td>
<td>12/16</td>
</tr>
<tr>
<td></td>
<td>(84%)</td>
<td>(75%)</td>
</tr>
<tr>
<td>Specific Exercise</td>
<td>6/20</td>
<td>7/20</td>
</tr>
<tr>
<td></td>
<td>(30%)</td>
<td>(35%)</td>
</tr>
</tbody>
</table>

Quadriceps Activation Following Knee Injuries: A Systematic Review
Hart et al, 2010 J Ath Tr

“Arthrogenic muscle inhibition is an ongoing, reflex response after joint injury. The term describes the inability to completely contract a muscle despite no structural damage to the muscle or innervating nerve. It is considered a reflex response to joint injury because it is beyond conscious, voluntary control.”

Pain and Muscle Dysfunction

- Multiple regions, most work done in lower extremity or spine
- Happens EARLY (likely < 4 wks)
- Not always associated with symptomatic or functional loss
- May be related to worse long term outcome
- Shoulder ???
McClure: Shoulder Pain and Muscle Activation

**Background**

*Which Muscle?*

**Infraspinatus** - key external rotator
- Stabilizes the humeral head
- Weakness leads to increased superior translation
  - Associated with impingement (Chen 99, Teyhan 08, Scoleri 08)
- Impingement likely involved in rot cuff degeneration (Globisky 02, Scoleri 08)
- ER Force Associated with Outcomes
  - Conservative Management of Tendinopathy (McClure 2006)
    - \( r = 0.39 \) (change in ext rotation force and change in outcome)
  - Rotator cuff repair (Edwards et al., 2007)
  - Shoulder arthroplasty (Edwards et al., 2002)

**Materials and Methods**

**Basic Technique for Assessing “Voluntary Activation”**

Max Effort (MVIC)

Add Strong E-stim: Additional Force Output?

- Yes
- No

Less than full voluntary activation

Full voluntary activation

**Development of Technique for Shoulder (Rotator Cuff)**

Voluntary activation of the infraspinatus muscle in nonfatigued and fatigued states

Scott A. McClure, PhD, Matthew A. Dobson, BPT, Dwayne A. Wagner, BPT, Philip A. McClure, PhD

**Purpose:**
- To develop a test of voluntary activation (VA) in a key rotator cuff muscle (n=20)
- Validate by two methods:
  - Test different levels of voluntary effort (n=20)
    - (25%, 50%, 75%, 100% MVIC)
  - Compare normal to fatigued states (n=8)

**Experimental Setup**

Isometric External Rotation Force
-30 deg abduction
-neutral rotation

**Results: VA vs. % MVIC force**

Technique showed a strong (non-linear) relationship between Force and VA

\[ y = -0.00006x^2 + 0.01573x \]

\[ R^2 = 0.92; F=559.82; P<0.001 \]
McClure: Shoulder Pain and Muscle Activation

Fatigue Test: force data

Change in VMA

Voluntary activation deficits of the infraspinatus present as a consequence of pitching-induced fatigue

St Clair Gibson, 2004
Br J Sp Med

Voluntary activation deficits of the infraspinatus present as a consequence of pitching-induced fatigue

JSES 2011

Fatigue: 6/10 post game

Velocity: mean 65 pre to mean 63 post (p=0.01)

ER torque: Decreased 27.3 to 25.6 (p=0.06)

ER Vol Activation: Decreased 96 to 89 (p<0.01)

Bottom line: Game fatigue and functional performance loss associated with decreased neural drive

Experimental pain inhibits infraspinatus activation during isometric external rotation

Scott R. Stockhausen, PT, PhD1,2,3, Anthony Eichorst, DPT1,2,3, Jonathan Bremel, DPT1,2,3, Michelle Lemon, DPT1,2,3, Brett A. Swanson, PhD1,2,3, Philip W. McClure, PT, PhD

J Shoulder Elbow Surg 2012
Materials and Methods

- 17 healthy adults
  - 11 females, 6 males
  - Mean age: 27.3 (22-49)
  - All subjects’ dominant arms used
    - 16 R arm dominant
    - 1 L arm dominant
- Secured to dynamometer

Materials and Methods

- Hypertonic Saline Injection
  - 5 minute intervals
  - 1.5cc of Hypertonic Saline (5%)

Results: Force, VA and Pain

- Mean initial pain 6.6/10
- Resulted in 32.8% decline in force
- 22.7% decline in VA

Results: VA and Force

- Change between baseline and peak pain
  - $y = 0.7782x - 0.0277$
  - $R^2 = 0.78$ ($p<0.05$)
- Strong relationship between change in VA and force

Conclusion

- Experimental subacromial pain causes substantial decline in infraspinatus voluntary activation and force with resolution linked to pain relief
- Further studies needed to probe effect of chronic pain on voluntary motor recruitment in patients
Is this response segmental (local) or supraspinal (global)?

Next Question

Subjects

- Demographics
  - 19 adult subjects
    - Average age: 26.4 (sd 5.5)
    - 8 males, 11 females
  - 20 subjects for infraspinatus testing
    - Contralateral to painful injection
  - 5 subjects for quadriceps testing
    - Ipsilateral to painful injection

Results

- Pain
  - Shoulder Subjects
    - Mean initial pain post-injection: 6.4/10± 0.97
    - Mean pain 10 min post-injection <1/10
  - Quadriceps Subjects
    - Mean initial pain post-injection: 6.2/10± 0.4
    - Mean pain 10 min post-injection <1/10

Pain Distribution

Subacromial Pain: Infraspinatus Activation & Force

7.6% ↓ in force  3.3% ↓ in VA

Subacromial Pain: Quadriceps Activation & Force (no effect)

<1% ↓ in force  2.4% ↓ in VA
Force & Activation Changes

<table>
<thead>
<tr>
<th></th>
<th>Ipsilateral Infraspinatus</th>
<th>Contralateral Infraspinatus</th>
<th>Ipsilateral Quadriceps</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Force</strong></td>
<td>-31.9%</td>
<td>-7.6%</td>
<td>&lt;-1%</td>
</tr>
<tr>
<td></td>
<td>CI -22 to -46%</td>
<td>CI -4 to -14%</td>
<td>CI 3 to -4%</td>
</tr>
<tr>
<td></td>
<td>p = 0.001</td>
<td>p = 0.01</td>
<td>p = 0.368</td>
</tr>
<tr>
<td><strong>VA</strong></td>
<td>-23%</td>
<td>-3.3%</td>
<td>-2.4%</td>
</tr>
<tr>
<td></td>
<td>CI -12 to -34%</td>
<td>CI 5 to -14%</td>
<td>CI 9 to -19%</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.001</td>
<td>p = 0.48</td>
<td>p = 0.830</td>
</tr>
</tbody>
</table>

Subgroups?

- 8/20 subjects showed > 10% decrease in force following injection
  - Force was decreased 15.6% (6.1)
  - VA was decreased 9.8% (15.2)
- Possible subgroup susceptible to contralateral pain (effect washed out in group)

Clinical Relevance:

- Pain \(\rightarrow\) Decreased VA and force
- So what ?????
- Index to "Uninvolved " Side
- Training and Exercise

Manual Therapy for Shoulder Pain

- Best evidence for *spinal* manual therapy
  - Mintken et al Phys Ther 2010
  - Boyles et al Man Ther 2009
  - Bergman et al Ann Int Med 2004
  - Bang JOSPT 2000
- Cervicothoracic junction
- Thoracic Spine
- High Velocity Low Amplitude thrust
- Low Velocity mobilization
**Purpose**

1. Determine if thoracic spine manipulation immediately reduces pain and impairment in subjects with signs of shoulder impingement
   - a) Pain (provocative maneuvers and ROM)
   - b) Force (shoulder elevation)
   - c) ROM (shoulder, cervical, thoracic)

2. Determine if thoracic spine manipulation improves shoulder function and pain 7-10 days (versus initial)
   - a) Penn Shoulder Score (PSS)
   - b) DASH

3. Assess changes scapular kinematics and shoulder muscle electromyographic activity following thoracic spine manipulation
   - a) 3D electromagnetic tracking
   - b) Surface EMG (IS, SA, UT, LT)

**Subjects**

- 30 subjects with signs of impingement
- Mean Age = 30.64 ± 7.92
- 16 male, 14 female
- Athletes: Recruited from Temple, LaSalie and Arcadia Universities, Penn Athletic Club, Vesper Boat Club, and Bachelors Barge Club as well as Master's swim clubs in the Philadelphia region and personal contacts
- Most participants in this study were not seeking medical attention for their shoulder pain

**Mid Thoracic spine manipulation**

**Cervicothoracic junction manipulation**

**Effect of Manipulation : shoulder pain**

<table>
<thead>
<tr>
<th>Change in Pain w/Provocative test</th>
<th>2 procedures, up to 2 reps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neers</td>
<td>Decrease 2.6 pts (0-10)</td>
</tr>
<tr>
<td>Hawkins</td>
<td>Decrease 2.6 pts (0-10)</td>
</tr>
<tr>
<td>Jobe's (empty can)</td>
<td>Decrease 2.8 pts (0-10)</td>
</tr>
</tbody>
</table>

Kinematic Changes: NO
EMG Changes: NO
- minor (8%) increase Mid Trap

Muth et al Dissertation data
Subacromial Pain and Rotator Cuff Fatigue: Bottom lines

- **Acute Pain** leads to cuff weakness and neural inhibition
- **Fatigue** is associated with decreased neural drive (voluntary activation)
- Cuff fatigue assoc with unwanted **superior GH translation**
- Pain related muscle dysfunction may lead to long term changes?

**THEREFORE:**
- Manage pain before overload exercise
  - injections, manip, other
- Use rehab strategies to enhance neural drive
  - NMES, biofeedback
- Respect fatigued status rather than pushing through

Work in Progress

- **Rotator Cuff Tendinopathy**
  - vs Matched controls (Harrington)
  - Before / after pain relief with subacromial anaesthetic injection
  - Before and after Thoracic Manip and Sham Manip (Muth)

- **Rotator Cuff Tendinopathy**
  - vs Matched controls
  - Before / after pain relief with subacromial anaesthetic injection
  - Before after 6 wk exercise

**Thank You**

**Collaborators**
- Scott Stackhouse
- Brett Sweitzer
- Ann Harrington
- Stephanie Muth

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