Scapular Kinematics: So how is the scapula supposed to move?

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Methods of measurement of scapular kinematics
1. Two – dimensional: Radiographs, goniometers, video
2. Three – dimensional: Radiographs, digitizers, magnetic tracking device

Scapular Kinematics

- Normal motion
  - 3 Rotations:
    - Upward Rotation (UR) / Downward rotation (DR)
    - Internal rotation (IR) / External rotation (ER)
    - Anterior tilt (AT) / Posterior tilt (PT)
  - 2 Positions / Translations:
    - Superior / Inferior
    - Anterior / Posterior
- Translations defined by clavicular motion because the scapula is constrained at AC jt

- With GH elevation, via direct bone pins the scapula: (McClure et al, JSES, 2001):
  - Rotations:
    - UR (Mean = 50°)
    - ER (Mean = 24°)
    - PT (Mean = 30°)
  - Positions / Translations:
    - Clavicular elevate (Mean = 10°)
    - Clavicular retraction (Mean = 21°)
Scapulohumeral Rhythm
- 2:1 is standard
- 5:4 (Poppen & Walker, JBJS, 1976); 1.7:1 (McClure et al., JSES, 2001); 1.5 – 2.4:1 (Graichen et al., Clin Ortho, 2000); 2.15:1, 0-30: 4.23 : 1 (> H), 91-120: 1.65:1 (Padua D et al., MSSE, 2003)

Scapular Kinematic Control and Limitations by:
- Scapular muscles, RC muscles, Spine (thoracic and cervical), pathology of the shoulder joint, ligaments, GH joint capsule, clavicle (via AC joint)

Scapular muscle fatigue and weakness:
- ↓ed UR w/ upper trap & serratus anterior fatigue (McQuade et al., JOSPT, 1998)
- ↓ed UR and PT w/ upper & lower trap fatigue (McQuade et al., Clin Biomech, 1995)
- ↓ed PT, ER, UR w/ ↓ed serratus & ↑ed lower trap activity (SAIS) (Ludewig & Cook, Phys Ther, 2000)
- External load alters kinematics; fatigue?? (Pascoal et al., Clin Biomech, 2000; McQuade, 1995)

Rotator cuff muscle fatigue and weakness:
- ↓ed PT with infraspinatus & teres minor fatigue (Tsai et al., Arch Phys Med Rehab, 2003)
- Same effect with RC tendonitis?

Muscle fatigue and weakness: scapular or rotator cuff muscles
- Alters scapular kinematics
- Less scapular stability?
- Is it a motor control issue, rather than strength?
- Altered GH kinematics?...evidence for this later
- Implication: overhead athletes / workers?

Spinal posture
- ↑ed cervical flexion
  - ↓ed UR & PT (Ludewig & Cook, J Occ Rehab, 1996)
  - ↑ed thoracic flex (change of 12 degrees from upright):
    - ↑ed (sup) position, & ↓ed posterior tilt
- Slouched posture vs. upright:

Others
- Ligaments, Clavicle : No evidence
- Capsule: posterior
  - Simulated tightness and clinical exam:
  - ↓ed GH IR, limited cross-body adduction at 90 deg (PSTT), ↑ed superior translation of HH (Tyler, et al., AJSM, 2000; Harryman et al; JBJS, 1990; Branch et al; AJSM, 1995)
- Pathology
  - SAIS, RCT, instability, AC jt arthritis, Humeral head position
Impingement Syndrome and scapular kinematics

- Kinematics (during glenohumeral elevation):
- Position:
  - ↑ed winging (AT & IR) (Warner JJ et al, 1992)
  - ↑ed Sup & Med trans (Lukasiewicz et al, JOSPT, 1999)
- Adequate scapular motion required for “maintenance” of adequate SA space
- Pattern of decreased UR, ER, and PT has been demonstrated to decrease the area of the SA space (Solem-Bertolf, Clin Ortho, 1993)

Rotator Cuff Full-thickness tears and scapular kinematics

- ↑ed humeral head superior translation during simulated or active GH elevation; in patients or cadavers with FT RCT (Thompson, AJSM, 1996; Poppen & Walker, 1976; Deutsch, 1996; Paletta, 1997; Yamaguchi, 2000)
- No evidence of altered scapular kinematics
- This may cause altered scapular position or kinematics with RC weakness

Glenohumeral instability and scapular kinematics

- Abnormal scapular DR disrupts the “shelf mechanism” of the inferior glenoid fossa support of the humeral head…resulting in inferior instability (Itoi et al; JSES; 1992)

Adhesive capsulitis and scapular kinematics

- Patients with shoulder adhesive capsulitis (n=10)
- Altered SHR, increased contribution of scapular upward rotation
- Altered in elevation in scaption, flexion, and abd (Vermeulen HM et al, Ann Rheum Dis, 2002)
- With a stiff GH joint, the ST articulation appears to be able to compensate to allow for total shoulder ROM

Altered scapular kinematics

- Can we capture differences?
  - With treatment or comparison to healthy?
- Consider the “robustness” of the neuromuscular system
- Is the “best” measure to examine kinematics with a combination of all 3 rotations or 3 rotations and 2 positions
- Is a larger insult needed to see “obvious” measurable differences?
Scapular Dyskinesis: Examination and Intervention in Patients with Upper Quarter Dysfunctions

Clinical Evaluation of the Scapula: Phil McClure PhD, PT  Arcadia University

Existing Literature
Kibler  Am J Sp Med 98
Sobush et al JOSPT 96 (Lennie Test)
Odom  et al Phys Ther 2001
Johnson et al JOSPT 2001

Basic Problem: Attempts to capture a 3-dimensional, dynamic phenomenon with static, 2-dimensional measurements are likely to fail

Judgements Based on Visual Observation
Kibler et al. JSES 2002
Type 1 (Inf angle prominence)
TypeII (medial border prominence)
Type III (early scap elevation)
  Intertester K=(0.31-0.42)
  Intratester Κ=(0.40-0.59)

McClure et al JOSPT 2003 (abstract)
  7 prescribed tasks
  Winging (medial or inf angle) OR Dysrhythmia (abnormal upward rot or elevation)
  Intertester Kappa=0.6, 72% agreement

Tate et al  JOSPT 2004 (abstract)
  -validation of visual judgements using 3D motion analysis
  -Dyskinesia group showed ant tilt, internal rotation, protraction

Our Current Approach
Scapular Dyskinesia Test
  - 5 test movement (flexion, abduction with and without weight, flip test)
  - Winging OR Dysrhythmia
  - posterior and superior view

Scapular Reposition Test
  - alteration of symptoms during provocative tests by repositioning scapula
  - move scapula toward posterior tilt and external rotation by grasping shoulder girdle from
    behind and bringing forearm obliquely across medial border
  - look for decreased pain or increased strength for + test

Other Important Considerations
  Specific muscle testing
  - Trapezius
  - Serratus Anterior
  - Distinguishing between true weakness (palsy) vs motor control deficit
  Key Areas of Hypomobility
  - upper thoracic extension
  - pec minor
  - posterior capsule
References


SCAPULAR DYSKINESIS: EXAMINATION AND INTERVENTION IN PATIENTS WITH UPPER EXTREMITY DYSFUNCTION
REHABILITATION CONSIDERATIONS

Tim L. Uhl PT, PhD, ATC Division of Athletic Training, Department of Rehabilitation Science, University of Kentucky, Lexington, KY 40536, tluhl2@uky.edu

Description:
Rehabilitation goals following shoulder injury is to implement a continuum of exercises that restores optimal function while protecting the anatomic integrity of the injured or repaired tissues. The exercises should allow a progression of intensity and load that is within the healing tissue’s capabilities. A key element in rehabilitation is the successful transition in the flow of exercises from the protected exercises of the acute phase to the functional phase. Emphasis of this presentation will be on the component of scapular muscle exercises. The scapular muscles are not exercised in isolation of the other shoulder musculatures but need to work synergistically with the other shoulder girdle musculature for upper extremity function. Exercise selection for scapular musculature strengthening exercises based on EMG research is readily available. This presentation attempts to organize the previous available information along with new information obtained by the presenter into logical progression from low to high demand exercises in order to better rehabilitate your patients.

Objectives:
To describe treatment interventions to facilitate mobility, strength and neuromuscular control of the shoulder.
To provide evidence and or scientific rationale that is available to support these interventions.

Key Points:

• Therapeutic Exercises are beneficial in rehabilitation of patients with
  • Shoulder instability\(^{11}\)
  • Rotator cuff pathology\(^{12,25}\)
  • Appear to be helpful in recover of associated scapular dysfunctions long thoracic neuropathy and snapping scapula\(^{35}\)

• Proximal Stability
  • Without proximal control distal structures are moving on poor foundation
  • Motion and force applied by distal upper extremity initiates proximally\(^ {17,37}\)
  • Strength and endurance of upper extremity is dependent on trunk\(^ {16}\)

• Posture of spine effects scapular position, motion, and shoulder strength\(^ {14}\)

• Position and motion of the scapula effects glenohumeral joint function and subacromial space
  • Impingement patients have decreased scapular mobility\(^ {19,21}\)
  • Tight pectoralis major decreases scapular motion\(^ {4}\)

• Neuromuscular Control of scapular musculature is diminished in the presence of pathology\(^ {19,29,30}\)
  • Diminished force production of scapular musculature\(^ {6}\)
  • Scapular muscular activation diminished due to imbalance and pain\(^ {27,29,30}\)
Exercises that facilitate posterior tilting and external rotation (retraction) of scapula are critical for overhead function. Exercise that facilitate lateral translation and internal rotation (protraction) of scapula are critical for accelerating sport implements and absorbing energy.

Therapeutic Interventions need to address:
- Proximal stability and posture
  - Flexibility to reverse anterior tilt and internal rotation posture
  - Shoulder mobility associated with improved function
  - Rehabilitation programs may positively effect posture and scapular position
  - Integrate the kinetic chain to facilitate activation of trunk
  - Transmission of force along kinetic chain typically incorporates rotation (Serape muscles)
  - Rehabilitation of the shoulder should incorporate exercises to promote erect trunk posture and stable scapular position.

- Strengthening exercises should progress from low to high demand
  - Progressive resistive exercises can increase shoulder strength and improve patient function
  - Avoiding inflaming healing tissues
    - Pain inhibits muscle activation at a central level
    - Altering central motor drive may effect muscle activation patterns for movement
  - Arm supported activities diminishes muscular demand
  - Progression of muscular demand can be monitored by load placed through arm

- Re-establish neuromuscular control of shoulder musculature
  - Closed kinetic chain exercises promote joint compression and activation of proximal musculature to provide stabilization
  - Scapular re-education can be accomplished through several tasks
  - Consider upper trapezius/serratus anterior EMG ratio during exercise selection to minimize superior scapular translation (shrug) and facilitate medial scapular border control

Clinical Application
Incorporation of rehabilitation techniques that address trunk, scapular, and humeral mobility and control appear to effectively address impairment of diminished strength, motion, and pain commonly seen in patients with musculoskeletal disorders. Gradual introduction of therapeutic exercises while minimizing inflammation of healing tissue and restoring neuromuscular control is the ultimate goal of re-establishing function.
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<tr>
<td>Supine PROM¹⁵</td>
<td>3 ± 1</td>
<td>1 ± 6</td>
<td>1 ± 2</td>
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<tr>
<td>Forward Bow¹⁵</td>
<td>2 ± 1</td>
<td>5 ± 6</td>
<td>2 ± 3</td>
<td>5 ± 4</td>
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<td>Sidelying Elevation¹⁰</td>
<td>10 ± 6</td>
<td>2 ± 6</td>
<td>2 ± 3</td>
<td>11 ± 7</td>
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<td>Towel Slides¹⁰</td>
<td>12 ± 7</td>
<td>7 ± 7</td>
<td>4 ± 3</td>
<td>7 ± 4</td>
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<td>Supine Press-up 1#¹⁵</td>
<td>11 ± 4</td>
<td>3 ± 7</td>
<td>1 ± 3</td>
<td>16 ± 8</td>
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<td>T-Bar¹⁰</td>
<td>24 ± 9</td>
<td>9 ± 9</td>
<td>9 ± 8</td>
<td>17 ± 6</td>
<td>10 ± 10</td>
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N.A. = Not available
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<td><strong>Wedge Press-up</strong>&lt;sup&gt;15&lt;/sup&gt;</td>
<td>20 ± 9</td>
<td>8 ± 11</td>
<td>11 ± 11</td>
<td>17 ± 8</td>
<td>2 ± 1</td>
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<td><strong>Ball Rolls</strong>&lt;sup&gt;10&lt;/sup&gt;</td>
<td>25 ± 8</td>
<td>11 ± 10</td>
<td>9 ± 3</td>
<td>21 ± 7</td>
<td>5 ± 4</td>
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<td><strong>Ipsilateral Step- up</strong>&lt;sup&gt;15&lt;/sup&gt;</td>
<td>21 ± 7</td>
<td>22 ± 20</td>
<td>21 ± 8</td>
<td>15 ± 5</td>
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<td><strong>Active Elevation</strong>&lt;sup&gt;10&lt;/sup&gt;</td>
<td>32 ± 8</td>
<td>19 ± 12</td>
<td>19 ± 9</td>
<td>23 ± 7</td>
<td>19 ± 8</td>
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<td><strong>Standing Press-up</strong>&lt;sup&gt;15&lt;/sup&gt;</td>
<td>30 ± 11</td>
<td>30 ± 17</td>
<td>24 ± 8</td>
<td>29 ± 13</td>
<td>9 ± 5</td>
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<tr>
<td><strong>Rows with elastic tubing</strong>&lt;sup&gt;7,13&lt;/sup&gt;</td>
<td>N.A</td>
<td>PK 39 ± 16</td>
<td>PK 34 ± 23</td>
<td>PK 10 ± 6</td>
<td>N.A.</td>
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<tr>
<td>Scaption $&gt; 120^\circ$</td>
<td>72 ± 13</td>
<td>64 ± 28</td>
<td>79 ± 19</td>
<td>96 ± 24</td>
<td>61 ± 19</td>
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<tr>
<td>Scaption $&lt; 80^\circ$</td>
<td>91 ± 26</td>
<td>82 ± 27</td>
<td>72 ± 19</td>
<td>62 ± 18</td>
<td>50 ± 21</td>
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<td>Unilateral Rows $^9,32$</td>
<td>72 ± 20</td>
<td>N.A.</td>
<td>63 ± 17</td>
<td>14 ± 6</td>
<td>45 ± 17</td>
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<td>Prone Flexion @ $135^\circ$ ABD $^9$</td>
<td>N.A.</td>
<td>N.A.</td>
<td>79 ± 18</td>
<td>43 ± 17</td>
<td>97 ± 16</td>
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N.A. = Not available
PK = peak amplitude during phase
AVG = average amplitude during phase

**Functional Phase Exercises graded by (%MVIC ± S.D.)**

1. **Forward Punch** $^{13}$
   - PK: 39 ± 23
   - AVG: 9 ± 4

2. **Shrugs with elastic tubing** $^{13}$
   - PK: 44 ± 25
   - AVG: 10 ± 6

3. **Scaption**
   - Scaption $> 120^\circ$
     - PK: 72 ± 13
     - AVG: 64 ± 28
   - Scaption $< 80^\circ$
     - PK: 91 ± 26
     - AVG: 82 ± 27

4. **Unilateral Rows** $^{9,32}$
   - PK: 72 ± 20
   - AVG: 63 ± 17

5. **Prone Flexion @ 135° ABD** $^{9}$
   - PK: 79 ± 18
   - AVG: 43 ± 17
<table>
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<th>Exercise Description</th>
<th>Value 1</th>
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<th>Value 3</th>
<th>Value 4</th>
<th>Value 5</th>
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<td>Diag Flex/ Horiz Add/ Ext. Rot.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>66 ± 10</td>
<td>100 ± 24</td>
<td>39 ± 15</td>
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<tr>
<td>Military Press</td>
<td>72 ± 24</td>
<td>56 ± 48</td>
<td>64 ± 26</td>
<td>82 ± 36</td>
<td>N.A.</td>
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<tr>
<td>Unilateral shoulder press supine w/plus</td>
<td>N.A.</td>
<td>N.A.</td>
<td>7 ± 3</td>
<td>62 ± 19</td>
<td>11 ± 5</td>
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<tr>
<td>Push up w/plus</td>
<td>N.A.</td>
<td>N.A.</td>
<td>50</td>
<td>140</td>
<td>30</td>
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<tr>
<td>Prone Horizontal ABD</td>
<td>79 ± 20</td>
<td>78 ± N.A.</td>
<td>66 ± 18</td>
<td>9 ± 3</td>
<td>74 ± 21</td>
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<td>Prone ER @ 90°</td>
<td>N.A.</td>
<td>50 ± N.A.</td>
<td>20 ± 18</td>
<td>57 ± 22</td>
<td>79 ± 21</td>
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N.A. = Not available

References


