Shoulder Rehabilitation: Applying EMG Studies to Your Practice
Session 102
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Background
• Rehabilitation exercises are often based on EMG findings
• Understanding how theses studies are performed is often unclear
• As a young clinician selecting proper exercise progression seems to be a lot of art
• Our profession is asking clinicians to provide scientific evidence on which they base their exercise selection decisions

Objectives
• Describe capabilities and limitation of EMG data
• Review physiology of healing as it applies to prescribing therapeutic exercises
• Describe rehabilitation exercise progression based on EMG activity

Electromyography
• The recording and analysis of myoelectrical signals derived from motor unit activity
• Motor Unit
  – Nerve cell body in the spinal cord
  – The motor nerve (axillary)
  – The muscle fibers that the nerve innervates

When a Muscle Contracts
• Action potential travels down motor unit to end plate near the fibers
• ACh causes breakdown of membrane to produce motor action potential
• Potential created across sarcolemma

What does EMG measure?
Action Potential Propagation
• The recording electrodes detect the relative voltage difference between the two electrodes as the action potential propagates along the muscle fibers

This is EMG
• Electrical activity of Upper and Lower Trapezius during arm elevation
• Electrodes detect the electrical signal from muscular contraction produced by the nerve innervating tissue
• Computer stores the data

EMG is a Sinusoidal Wave
Considerations for Collecting and Using EMG data
• Electrode
Type
Size
Placement

• Skin preparation to diminish impedance
• Electrode location
• Data analysis parameters (processing)
• Kinematic data collected simultaneous with EMG

Types of Electrodes
• Indwelling Electrode
  – Fine wire
  • Commonly nickel-chromium with nylon or Teflon coating (50μ)
  • 25-27 gauge needle
  • Bend ends to prevent backing out
  • Indwelling EMG electrodes measure energy from a few motor units (millivolts or microvolts)

Surface Electrodes
• Electrode made of Ag/AgCL
  – conductive medium
• Electrode geometry
  – disc, bar, rectangular
  – Size ~10mm
• Inter-electrode distance
  – 10-40mm most common 20mm
  – Too far apart pick up other muscle activity
• Surface EMG records energy from multiple motor units (microvolt)

Volume Conduction
• Motor units closes to electrodes have most effect on electrical recording
• Skin, fat, fascia act as low pass filter

Skin preparation
• Impedance = Opposition to the flow of electrons or current flow in alternating currents
• To diminish impedance: Remove hair, skin, oils
• Procedure
  – Shave hair
  – Debride dead skin with sand paper
  – Clean with alcohol

Electrode Placement
• Orientation of electrodes and location on muscle effects signal response
• Ideal location between mid portion and musculotendinous junction

Electrode Placement
• Consistent position enhances reliability
Use of bony landmarks and percentage of distance from landmarks

Bipolar Electrode Configuration Critical
Differential amplification
• Records relative voltage difference between the electrodes as the AP changes underneath the surface electrodes
• Voltage that is common to each electrode is eliminated (ground electrode)
• Orient electrodes parallel to muscle
• Works because electrical signal reaches electrodes at two different times

Application Recommendations
• Bipolar surface electrodes with detection surface of 1.0cm, spaced 1-2cm apart.
• Placed between motor end plate and tendon oriented parallel to muscle fibers
• Parallel to muscle orientation
• Minimize input impedance with clean skin

Gain
• Multiplier to amplify the signal
• 2000 often used for surface electrodes
• Example
  • the original signal is .000063V or 63microV
  • If gain at 2000
  • 2000 x .000063v =.126V or 126millivolts

EMG Signal Processing
• Various procedures used depending on the question
• To determine onset
• Rectify signal
• Smoothing
  – Low pass filters (allow frequencies under set frequency pass)
  – High pass filters
  – Band pass filters (allow frequencies between boundaries pass)
• Most of the signal for Surface EMG is in 5-500Hz
• Indwelling ranges 10 - 1500Hz

EMG Signal Processing
• To determine onset a criteria has to be set to determine when muscle is on or off
• 3 standard deviations above resting amplitude
• Muscular activity remains above that level for 25-50msecs

Onset of Muscular Activity
• Upper Trapezius on 225ms prior to arm elevation
• Lower Trapezius turns on 343ms after arm elevation
Utilization of EMG in Rehabilitation and Research

- Initiation of muscle activation (Onset)
- Duration of muscle activation
- Reflex latencies – time it takes muscle to respond to a disturbance
- Amount of muscle activation (Amplitude)
- Measure of fatigue occurring in a muscle

Do Athletes have Quicker Reaction Times than Non-Athletes?

- Reflex latency and onset
- (Muscle latency) from pushing the arm into internal rotation
- We measured how quickly does the supraspinatus, infraspinatus, and posterior deltoid turn on

Measure of EMG Amplitude

- To determine how much muscular activity for a particular exercise
- EMG activity is translated from Volts to percentage of muscle activity.\textsuperscript{43}
  - MVC – maximal voluntary contraction
  - RVC – reference voluntary contraction

Relative Amount of Muscular Activity

- Normalization of EMG signal to an event or to a specific task
- Allow for comparison across individuals for the same activity

Normalization allows for Comparison

- Assist in comparison of EMG signals
  - Across muscle
  - Between subjects
  - Between exercises

- 100% isometric contraction (MVIC)
  - Most commonly used
  - Need to perform for 3-5 sec duration
  - Multiple repetitions with at least 30-90 sec rest

- The highest time interval (one second) of EMG signal is considered 100% MVIC
- EMG data is expressed as a % MVIC

Normalization

- Often manual muscle test positions are used\textsuperscript{24}
- Specific positions identified for rotator cuff musculature\textsuperscript{22}

EMG Amplitude during Elevation

- Divide activity of event by MVIC to get percentage
- Using RMS amplitude
- Upper Trapezius = 39%
- Lower Trapezius = 23%
EMG Amplitude during Elevation
• Divide activity of event by MVIC to get percentage at different arcs of motion
• Using Linear Envelop (IEMG)
• Upper Trapezius =
  – 0-20 = 40%
  – 20-40 = 36%
• Lower Trapezius =
  – 0-20 = 18%
  – 20-40 = 13%

Muscle Performance Question
• Research questions related to EMG amplitude allows us to identify what exercise activates particular
  muscles to a greater extent relative to the other
  — Does OPEN or CLOSED chain exercises activate the supraspinatus more?
• To answer this question need to evaluate relative muscle activity

Exercise Protocol
• Open vs Closed Chain
  — Vertical position
  — Diagonal position (45°)
  — Horizontal position
• Sphygmomanometer: Used to monitor load

Open vs Closed
All 3 Positions Combined
EMG Amplitude Categorization
• 0 – 20% Low activity
  — 0 – 5% Minimal EMG activity (background noise)\textsuperscript{35}
• 21 – 40% Moderate activity
• 41 – 60% High activity
• 61% + Very High activity\textsuperscript{12}

Limitations of EMG
• Possibility of “cross-talk”
  — Surface EMG activity is not always pure
  — Use small electrodes and small interelectrode distance
• Not a measure of force or strength
  — Moderate correlation in an isometric conditions\textsuperscript{20}

• During dynamic activities muscles move under skin motor units
• Limited number of muscles to test
Limitations of EMG
• Noise or Artifact
• Moving / loose electrodes
• Cable connections
• Electrocardiogram (heart beat signal)
• Electrical fields

Objective 2
• Review physiology of healing as it applies to prescribing therapeutic exercises

Tendon Anatomy
• Interposed between bone and muscle to transmit and absorb force
• Specialize insertions
• Viscoelastic structure that responds to load and rate of loading

Tendon Properties
• Tolerates tremendous tensile stresses due to collagen construct
  – 50-100 N/mm²
  – 1cm² can support ~500kg
• Has good flexibility due to elastic fibers
  – Ruptures at ~8% elongation
• Does not tolerate compression and shear forces as well

Tendon Attachment
• Myotendinous junction
  – Muscle force is transmitted to tendon
  – Finger like processes to increase contact area thereby reducing force per area
• Osteotendinous junction
  – Transitioning through fibrocartilage provides a buffer for the tensile loads and the various load orientations

Tendon Attachment
• Direct
  – Bone
  – Mineralized fibrocartilage
  – Unmineralized fibrocartilage
  – Tendon
• Indirect
  – Collagen fibers blend with periosteum and is anchored to bone via Sharpey’s fibers

Rotator Cuff Tendon Rupture
• Not typically traumatic
• Degenerative overuse mechanism most common
• Combination of compression and eccentric overload
Tendon Healing

Extrinsic

- Peritendinous structures infiltrate injured tendon provide blood supply and form granulation tissue
- Reliant on adhesions to heal
- Immobilization facilitates this type of healing

Intrinsic

- Repair of tendon derives from the epitendon and endotendon of the injured tendon
- Dependent on preservation of microcirculation & sheath, good suturing, intermittent motion

Time Frame for Tendon Healing

- Inflammatory phase 0-3 days
- Proliferative phase initiates in 1st week with fibroblasts increasing over the next 4 wks
- Collagen maturing over several months
- 4 - 6 months see maturation of repair

Inflammatory Stage

- Platelets start clot formation with fibrin & fibronectin
- Chemical mediators attract WBC
- Histamine, Bradykinin increases vascular permeability
  - Fxn: to stop bleeding and debride area

Supraspinatus Tendon

- Normal

Proliferative Phase

- 4 weeks into healing see new bone forming decreased ECM and vascularity and sporadic connections to bone
- 8 weeks post surgery see cellular proliferation

Remodeling Phase

- Reduction in cellular activity
- Synthesis of type I collagen
- ECM less watery
- Collagen fibers align along tensile forces
- Fibroblasts revert less active fibrocytes (tenocytes)
  - Fxn: Organization of final structure

Biomechanical Properties of Rotator Cuff Tendon

- Maximal active force generated across supraspinatus has been estimated to be 302N = 68lbs

Maximal Load to Failure of Repaired Rotator Cuff

- Comparison of simple vs. mattress suture repair directly to bone
  - Simple 190 N
  - Mattress 136N
- ~ 50% of normal strength

Cyclic Loading

- Methodology that replicates physiological loading of a rotator cuff tendon
- Intact human cadaver loaded with 180N at 33mm/s tolerates 3500 cycles no failure
- Transossseous fixation failed at 188 (5%) cycles
• Suture anchor fixation failed at 285 (8%) cycles
  – < 45yo failed at 478 cycles
  – > 45yo failed at 91 cycles
• Implication: More repetitions is not necessarily better

Biomechanical Properties of Healing Tendon\textsuperscript{15}
• Tendon maximal strength ranges from 50 – 150MPa
• Rat maximal tensile load =25 \pm 9 \text{ MPa}\textsuperscript{5}
  – 6wks = 8%
  – 12 wks = 12%
  – repaired supraspinatus post-op does not approach intact values

Biomechanical Properties of Healing Tendon\textsuperscript{28}
• Sheep model: At 26 weeks of healing revealed return to maximal loads to failure equal to control limb
  – Control 2500 \pm 101N
  – Immobilized for 6 weeks 2954 \pm 242N
  – No immobilized 2572 \pm 168N

Rehabilitation Implications\textsuperscript{15}
• Tendon Response to Remobilization
• Gradual return of biochemical and biomechanical properties
• Early controlled motion prevents adhesion and facilitates healing

Tendon Response to Inactivity
• Immobilization reduces contact area between muscle and tendon
• Reduces sulfate glycosaminglycan “glue” of the myotendinous junction

Immobilization Positioning
• Hypovasularity of supraspinatus with arm at side\textsuperscript{36}
• Adduction increases stress to the rotator cuff below 30°\textsuperscript{16}
• EMG activity present in immobilizer\textsuperscript{39}
• Caution for certain activities to protect of rotator cuff
  – Bimanual tasks (biceps)
  – Pulling open door (Infraspinatus)
  – Fast forward reaching (deltoid)

Immobilization Effect on Healing\textsuperscript{40}
• 65 rats repaired supraspinatus
  – 25 immobilized in cast
  – 20 cage activity
  – 20 exercise – 1 wk post op- treadmill exercise (1 hr/day 5 x wk)
  – 11 control (no surgery)
• Results
  – Histological
  – Organizational: IM> CA & EX groups
— Biomechanical: (load to failure) all groups equal less than control
— Viscoelastic properties: IM> CA & EX groups

Rehabilitation Implications
• First 3-6 wks loads across the tendon have to be minimal
• Gradual introduction of stresses during the maturation process
• Pain may not be a guide due to new arthroscopic techniques

EMG Application to Rehabilitation
• Objective 3: Describe rehabilitation exercise progression based on EMG activity

• EMG is often used to determine which muscle is activated and to what degree (amplitude) during an exercise

Exercise Continuum
Acute Phase Rehabilitation
• Initiate ROM within pain tolerance and physiological healing restraints — prevent substitution patterns

• What exercises meet these goals?
Muscle of Interest
• Supraspinatus
• Infraspinatus
• Subscapularis
• Serratus Anterior
• Upper Trapezius
• Lower Trapezius

EMG Categorization
• 0 – 20% Low activity
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PROM Exercises
• Performed by another
• Performed by patient
• Using stable surface
PROM = Low Demand (>10%)
AAROM Exercises
- Critical period to avoid abnormal movement patterns or substitution patterns
- Various assistive devices (Pulley, Stick, Wall) to minimize loads on healing tissue
- Facilitates muscle activation and dynamic muscular control of the joint
- Caution using long lever arms may be too much demand for recovering tissues

Gravity Minimized AAROM Exercises
- Use of water provides buoyancy decreases load on musculature
  - Slow motion low demand on muscles <10%
  - Fast motion moderate demand 20 – 40%
- Facilitates proximal trunk control
- Wound considerations

Movable Boundary No Load
- Exercises that allow hand to move with support but minimally load arm
- Unloading the weight of arm

Sidelying Elevation AAROM
- Unloading through a greater range of motion
  - Arm supported
  - Horizontal plane
- Are all AAROM exercises basically the same?

AAROM Exercises (Rotator Cuff)
AAROM Exercises (Scapular Muscles)

- Upper Trapezius
- Lower Trapezius
- Serratus Anterior

EMG Activity (% MVIC)

AAROM = Arm Supported (~10%)

1. Gravity Minimized
2. Assisted Elevation
3. Unassisted Elevation

Sub-acute Phase Goals (6-12 wks)
- Intermediary exercises
- Re-establish coordinated UE movement
- Enhance strength
- Loads on muscle critical
  - Resistance
  - Speed
  - Lever arm
- Increase Endurance
RROM Varies According to Load (20 - 50%)

Scapular Stabilization Exercises in Sling

- EMG activity for subscapularis was moderate to high (30 – 70% MVC)
- All other cuff and deltoid musculature low <20% MVC
- Addition of step with exercise slightly increased EMG activity <10%
- Lawnmower exercise keeping elbow low activated Serratus Anterior to very high levels > 80% while other muscles remain <20%
- Lawnmower exercises are safe in early phases of shoulder rehab except for subscapularis repairs

Incorporating Scapular Stabilization Exercises without Sling

- Low Row and Inferior Glide
  - 20+20% for LT and SA
  - UT <10%
- Lawnmower & Robbery
  - 20-40% for all scapular musculature
- These exercises are appropriate for intermediate phase scapular strengthening

What about Closed Chain?

- Fixed Boundary Axial Load
- Greater joint congruency thereby decreasing shear forces
- Facilitates motor control
- EMG activity correlated to load R² = .95

Muscular Demands with Common CKC Exercises

- Prayer
- Quadriped
- Tripod
- Pointer
- Push up
- Push up elevated
- One hand push up

Closed Chain Exercises

- Limited research in this area
- One arm position biases the infraspinatus & posterior deltoid
- Low load activities (<20% BW) facilitate co-activation

Elastic Resistance Exercises

- Rubber tubing for shoulder exercises
- Developed for throwing athletes (on-field)
- Identified 7 exercises that moderately activated primary muscle involved in throwing
**Elastic Resistance Exercises**

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<td>38 27</td>
<td>24 20</td>
<td>81 65</td>
<td>40 26</td>
<td>27 16</td>
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**Emphasize Shoulder Endurance**
- Shoulder fatigue increase total translation of humerus 2.5mm
- Emphasize high reps, good technique not heavy weights

**Endurance Considerations**
- Deltoid muscle fatigues at a faster rate than scapular muscle during prolonged elevation activities
  - Upper Trap
  - Serratus Anterior
  - Lower Trap
- Median power spectral analysis

**Strengthening Progressions**
- Progressions are muscular specific
  - Scapular Musculature
  - Rotator cuff
Serratus Anterior Exercises (%MVIC)

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Mosely '92</th>
<th>Ekstrom '03</th>
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<tr>
<td>Flexion</td>
<td>96 ± 45</td>
<td>NT</td>
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<tr>
<td>Abduction</td>
<td>96 ± 53</td>
<td>NT</td>
</tr>
<tr>
<td>Surrection &gt; 120°</td>
<td>91 ± 52</td>
<td>96 ± 24</td>
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<tr>
<td>Diag Flex/ Horiz Add/ Ext. Rot.</td>
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<td>100 ± 24</td>
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<tr>
<td>Military Press</td>
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<td>NT</td>
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<tr>
<td>Unilateral shoulder press supine w/plus</td>
<td>NT</td>
<td>62 ± 19</td>
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<tr>
<td>Push up w/plus</td>
<td>80 ± 38</td>
<td>NT</td>
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<tr>
<td>Push up w/ hands wide</td>
<td>57 ± 36</td>
<td>NT</td>
</tr>
<tr>
<td>Bilateral scapular protract.</td>
<td>NT</td>
<td>57 ± 22</td>
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Lower Fibers of Serratus Anterior

- Protraction focuses on upper fibers
- Elevation above 120 deg is needed to address lower fibers of Serratus Ant.
- Diagonal Flexion / Adduction / Ext. Rot.
### Upper Trapezius Exercises (%MVIC)

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<th>Exercise</th>
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<tbody>
<tr>
<td>Rowing</td>
<td>112 ± 89</td>
<td>63 ± 17</td>
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<tr>
<td>Shrug</td>
<td>NR</td>
<td>119 ± 23</td>
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<tr>
<td>Shrug NR</td>
<td>54 ± 16</td>
<td>79 ± 19</td>
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<tr>
<td>Prone Horiz. Abd w/ER</td>
<td>75 ± 27</td>
<td>66 ± 18</td>
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<tr>
<td>Prone Flex at 135°</td>
<td>NT</td>
<td>79 ± 18</td>
</tr>
<tr>
<td>Prone Horiz. Abd (neutral)</td>
<td>62 ± 53</td>
<td>NT</td>
</tr>
<tr>
<td>Diag Flex/ Horiz Add/ Ext. Rot.</td>
<td>NT</td>
<td>66 ± 10</td>
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### Middle Trapezius Exercises (%MVIC)

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<tbody>
<tr>
<td>Prone Horiz. Abd (neutral)</td>
<td>108 ± 63</td>
<td>NT</td>
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<tr>
<td>Prone Flex at 135°</td>
<td>NT</td>
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<tr>
<td>Prone Horiz. Abd w/ER</td>
<td>96 ± 73</td>
<td>87 ± 20</td>
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<td>Rowing</td>
<td>59 ± 51</td>
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<td>Shrug</td>
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<td>Scaption &gt; 120°</td>
<td>62 ± 53</td>
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<td>Prone Extension</td>
<td>77 ± 49</td>
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<td>Prone Ext. Rot @ 90°</td>
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<td>45 ± 36</td>
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Lower Trapezius Exercises (%MVIC)

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<tr>
<td>Prone Flex at 135°</td>
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<td>Abduction</td>
<td>68 ± 53</td>
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<td>Prone Horiz. Abd w/ER</td>
<td>63 ± 41</td>
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<tr>
<td>Rowing</td>
<td>67 ± 50</td>
<td>45 ± 17</td>
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<tr>
<td>Scaption &gt; 120°</td>
<td>60 ± 22</td>
<td>61 ± 19</td>
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<td>56 ± 24</td>
<td>NT</td>
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Rotator Cuff Core Exercises

Advanced Phase
Goals
• Progress to dynamic ballistic activities
• Return to work/sport specific tasks
• Normalize neuromuscular control

Plyometrics
• Overhead plyometric simulate and prepare body to return throwing activities

Baseball Throwing

Football Throwing

Conclusion
• EMG studies can help you select appropriate exercise for your patient
• There are often multiple variations to activate the muscle
  — Think along a continuum of exercises
• Using small steps of progression can keep your patient motivated
• Design your program based on tissue physiology, available evidence, and your clinical judgement

“The whole of science is nothing more than a refinement of everyday thinking.”
— Albert Einstein (1879 - 1955), Physics and Reality 1936

References


## Appendix of exercises and EMG data

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<td>Forward Bow</td>
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<td>2 ± 3</td>
<td>5 ± 4</td>
<td>2 ± 2</td>
</tr>
<tr>
<td>Sidelying Elevation</td>
<td>10 ± 6</td>
<td>2 ± 6</td>
<td>2 ± 3</td>
<td>11 ± 7</td>
<td>8 ± 5</td>
</tr>
<tr>
<td>Towel Slides</td>
<td>12 ± 7</td>
<td>7 ± 7</td>
<td>4 ± 3</td>
<td>7 ± 4</td>
<td>1 ± 1</td>
</tr>
<tr>
<td>Supine Press-up 1#</td>
<td>11 ± 4</td>
<td>3 ± 7</td>
<td>1 ± 3</td>
<td>16 ± 8</td>
<td>1 ± 1</td>
</tr>
<tr>
<td>T-Bar</td>
<td>24 ± 9</td>
<td>9 ± 9</td>
<td>9 ± 8</td>
<td>17 ± 6</td>
<td>10 ± 10</td>
</tr>
</tbody>
</table>

N.A. = Not available
<table>
<thead>
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<tbody>
<tr>
<td>Low Row(^{25})</td>
<td>42 + 23</td>
<td>N. A.</td>
<td>10 ± 8</td>
<td>28 ± 21</td>
<td>15 + 12</td>
</tr>
<tr>
<td>Inferior(^{25}) Glide</td>
<td>9 ± 6</td>
<td>N. A.</td>
<td>8 ± 6</td>
<td>23 ± 19</td>
<td>19 ± 26</td>
</tr>
<tr>
<td>Shrugs with elastic tubing(^{18})</td>
<td>N.A.</td>
<td>PK 44 ± 25 AVG 10 ± 6</td>
<td>PK 53 ± 29 AVG 13 ± 8</td>
<td>PK 31 ± 24 AVG 5 ± 4</td>
<td>N.A.</td>
</tr>
<tr>
<td>Lawnmower(^{25})</td>
<td>16 ± 10</td>
<td>N.A.</td>
<td>22 ± 16</td>
<td>26 ± 21</td>
<td>27 ± 21</td>
</tr>
<tr>
<td>Robbery(^{25})</td>
<td>14 ± 9</td>
<td>N.A.</td>
<td>32 ± 17</td>
<td>21 ± 17</td>
<td>27 ± 21</td>
</tr>
<tr>
<td>Rows with elastic tubing(^{9, 18})</td>
<td>N.A.</td>
<td>PK 39 ± 16 AVG 9 ± 2</td>
<td>PK 34 ± 23 AVG 9 ± 6</td>
<td>PK 10 ± 6 AVG 5 ± 4</td>
<td>N.A.</td>
</tr>
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</tr>
<tr>
<td>Wedge Press-up</td>
<td>20 ± 9</td>
<td>8 ± 11</td>
<td>11 ± 11</td>
<td>17 ± 8</td>
<td>2 ± 1</td>
</tr>
<tr>
<td>Ball Rolls</td>
<td>25 ± 8</td>
<td>11 ± 10</td>
<td>9 ± 3</td>
<td>21 ± 7</td>
<td>5 ± 4</td>
</tr>
<tr>
<td>Ipsilateral Step-up</td>
<td>21 ± 7</td>
<td>22 ± 20</td>
<td>21 ± 8</td>
<td>15 ± 5</td>
<td>13 ± 6</td>
</tr>
<tr>
<td>Active Elevation</td>
<td>32 ± 8</td>
<td>19 ± 12</td>
<td>19 ± 9</td>
<td>23 ± 7</td>
<td>19 ± 8</td>
</tr>
<tr>
<td>Standing Press-up</td>
<td>30 ± 11</td>
<td>30 ± 17</td>
<td>24 ± 8</td>
<td>29 ± 13</td>
<td>9 ± 5</td>
</tr>
<tr>
<td>Forward Punch&lt;sup&gt;18&lt;/sup&gt;</td>
<td>PK 39 ± 23 AVG 9 ± 4</td>
<td>PK 48 ± 83 AVG 8 ± 3</td>
<td>N.A.</td>
<td>PK 49 ± 14 AVG 10 ± 3</td>
<td>N.A.</td>
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</tbody>
</table>

N.A. = Not available  
PK = peak amplitude during phase  
AVG = average amplitude during phase
<table>
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<tbody>
<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>
</tr>
<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>
</tr>
<tr>
<td>Unilateral Rows</td>
<td>72 ± 20</td>
<td>N.A.</td>
<td>63 ± 17</td>
<td>14 ± 6</td>
<td>45 ± 17</td>
</tr>
<tr>
<td>Prone Flexion @ 135° ABD</td>
<td>N.A.</td>
<td>N.A.</td>
<td>79 ± 18</td>
<td>43 ± 17</td>
<td>97 ± 16</td>
</tr>
<tr>
<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>
</tr>
<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>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>---------</td>
<td>---------------</td>
<td>-----------</td>
<td>-----------</td>
<td>------------</td>
</tr>
<tr>
<td>Unilateral shoulder press supine w/plus¹⁴</td>
<td>N.A</td>
<td>N.A</td>
<td>7± 3</td>
<td>62 ± 19</td>
<td>11 ± 5</td>
</tr>
<tr>
<td>Push up w/plus²⁶</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 ABD³, ¹⁴</td>
<td>79 ± 20</td>
<td>78 ± N.A.</td>
<td>66± 18</td>
<td>9 ± 3</td>
<td>74 ± 21</td>
</tr>
<tr>
<td>Prone ER @ 90°³, ¹⁴</td>
<td>N.A.</td>
<td>50 ± N.A.</td>
<td>20± 18</td>
<td>57 ± 22</td>
<td>79 ± 21</td>
</tr>
</tbody>
</table>

N.A. = Not available