Getting the Most Bang for your Exercise Buck:

Which Exercises Best Activate the Scapular and Rotator Cuff Muscles

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- Thanks to GLATA for allowing us to exchange information!

- Speakers have no conflicts of interest
  - We do discuss the use of Theraband; however, neither speaker has direct involvement with Hygenic Corporation

Objectives

- Explain the role of the scapular upward rotators and the rotator cuff in proper shoulder mechanics.
- Identify which exercises demonstrate a higher percent maximal voluntary isometric contraction (%MVIC) of the serratus anterior and lower trapezius while concurrently demonstrating a lower %MVIC of the upper trapezius.
- Compare various rotator cuff exercises, and, based upon electromyographical (EMG) findings, identify which exercises preferentially activate the supraspinatus, infraspinatus, teres minor and subscapularis.
- After observation, demonstrate appropriate performance of exercises for the scapular upward rotators and the rotator cuff.

Before we talk scapula……

- We need to talk thoracic spine!

- Thoracic spine mobility is important and critical for mobility of the UQ
  - “thread the needle”
  - Mobilization
  - Foam rolling

No change
Kardouni, Man Ther, 2015
Rosa, J Manipulative Physiol Ther, 2013

Improvement
Go, J Phys Ther Sci, 2016
Haider, J Pak Med Assoc, 2018
Wassinger, Man Ther, 2016

Let’s Start with the Foundation: Scapular Mechanics

- During overhead movement, the rotator cuff and the periscapular musculature must work together to stabilize the glenohumeral joint and scapulothoracic articulation for pain-free movements (especially overhead)

The rotator cuff musculature provides dynamic compression to seat the humerus vs. the glenoid.

If not, superior migration will cause subacromial pain

The scapula muscles must upwardly rotate the scapula (3D) in order to create space and an optimal position to “seat” the humeral head in the first place

Scapular Movement

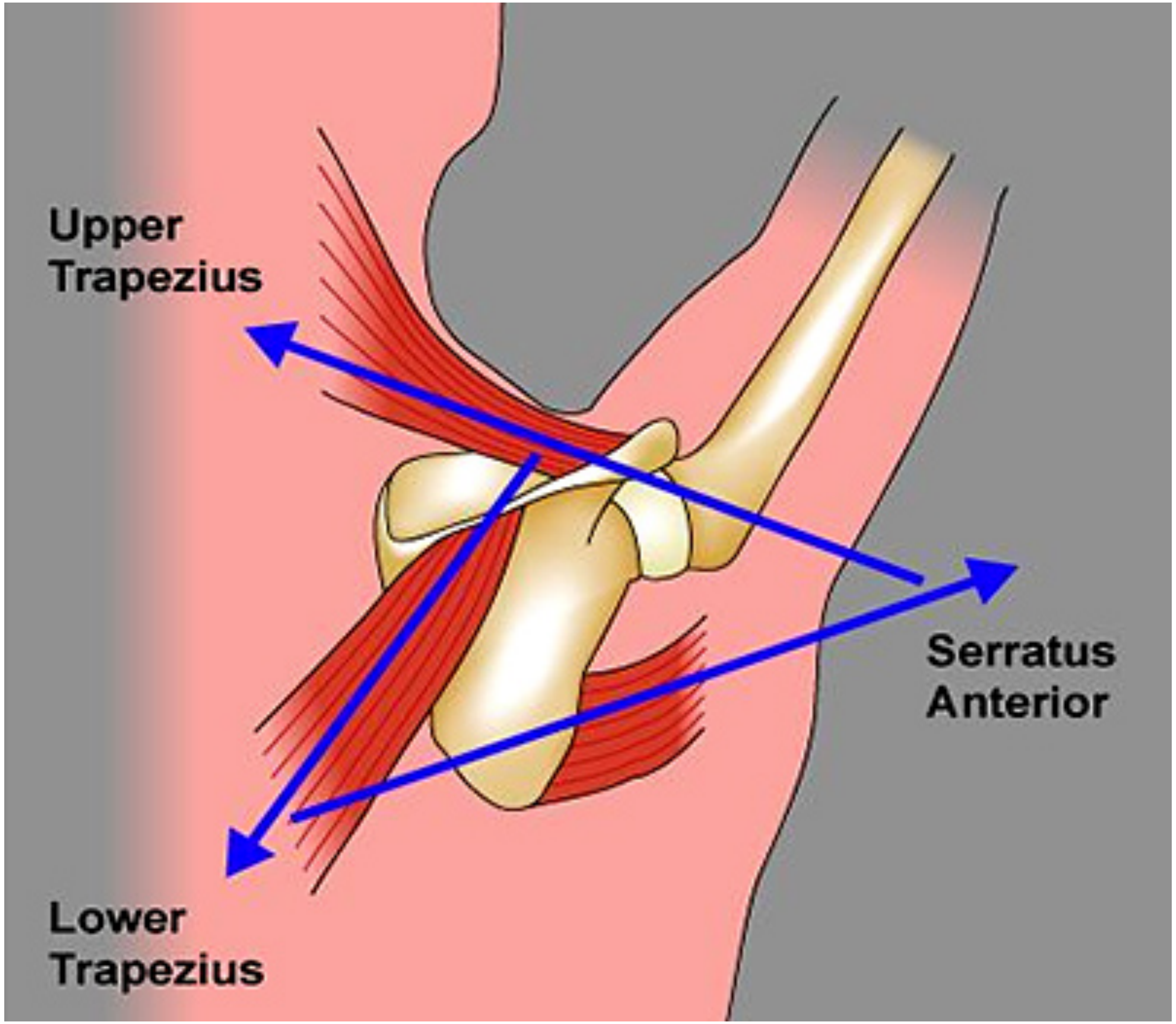
- Upward rotators: Trapezius (UT, MT, LT), serratus anterior (SA)
- An optimal interaction (timing and activity) is needed so that efficient glenohumeral movement can occur
- "Force couple"

Castelein, J Hand Ther, 2017

Force Couple for Upward Rotation

- UT: scapular upward rotation and elevation
- MT: retracts and externally rotates the scapula
- LT: upward rotation and depression of the scapula; inferomedial-directed fibers may contribute to posterior tilt and external rotation of the scapula
- SA: upward rotation and protraction; also posteriorly tilts and externally rotates the scapula during elevation; stabilizes the medial border of the scapula against the thorax

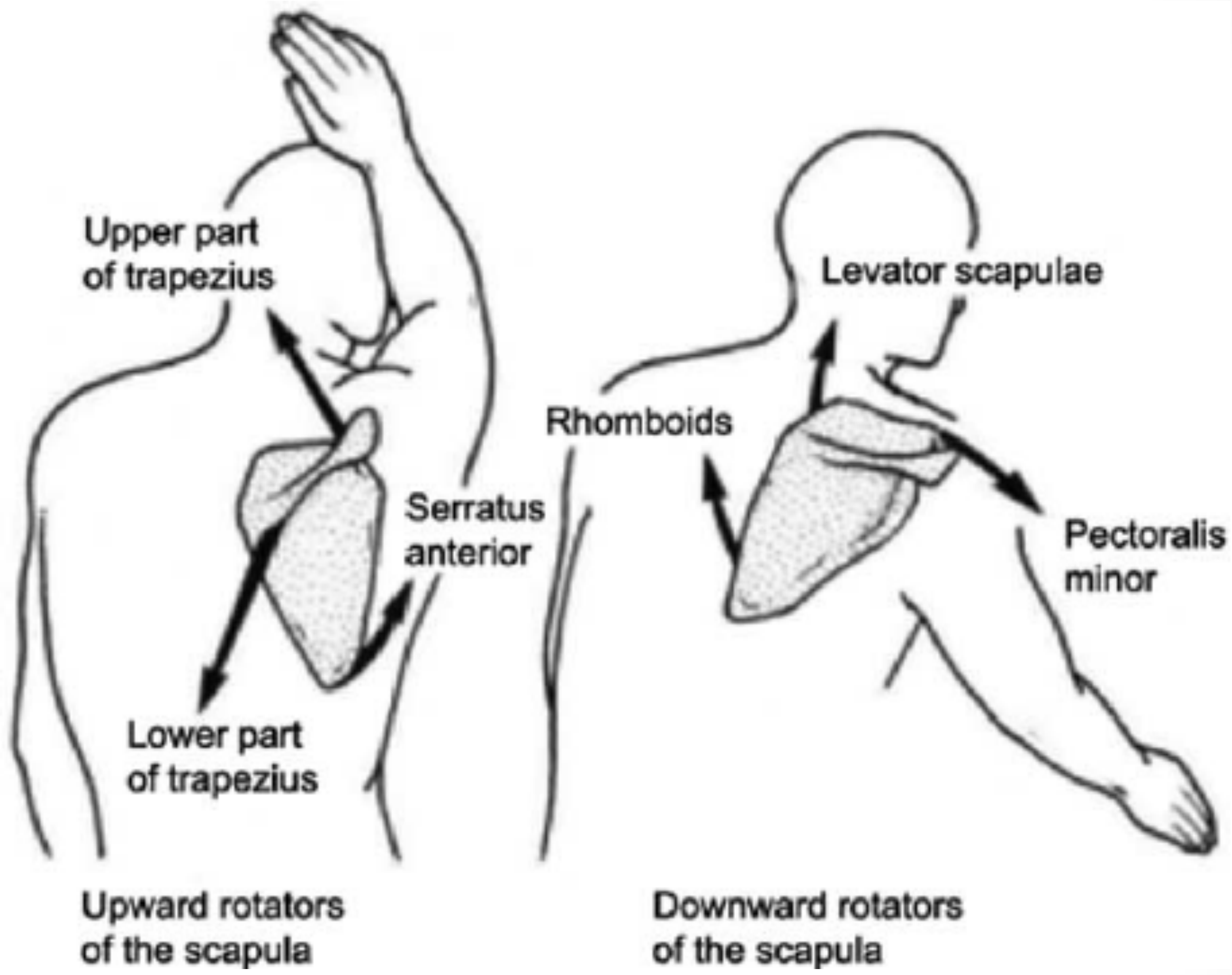
Castelein, J Hand Ther, 2017

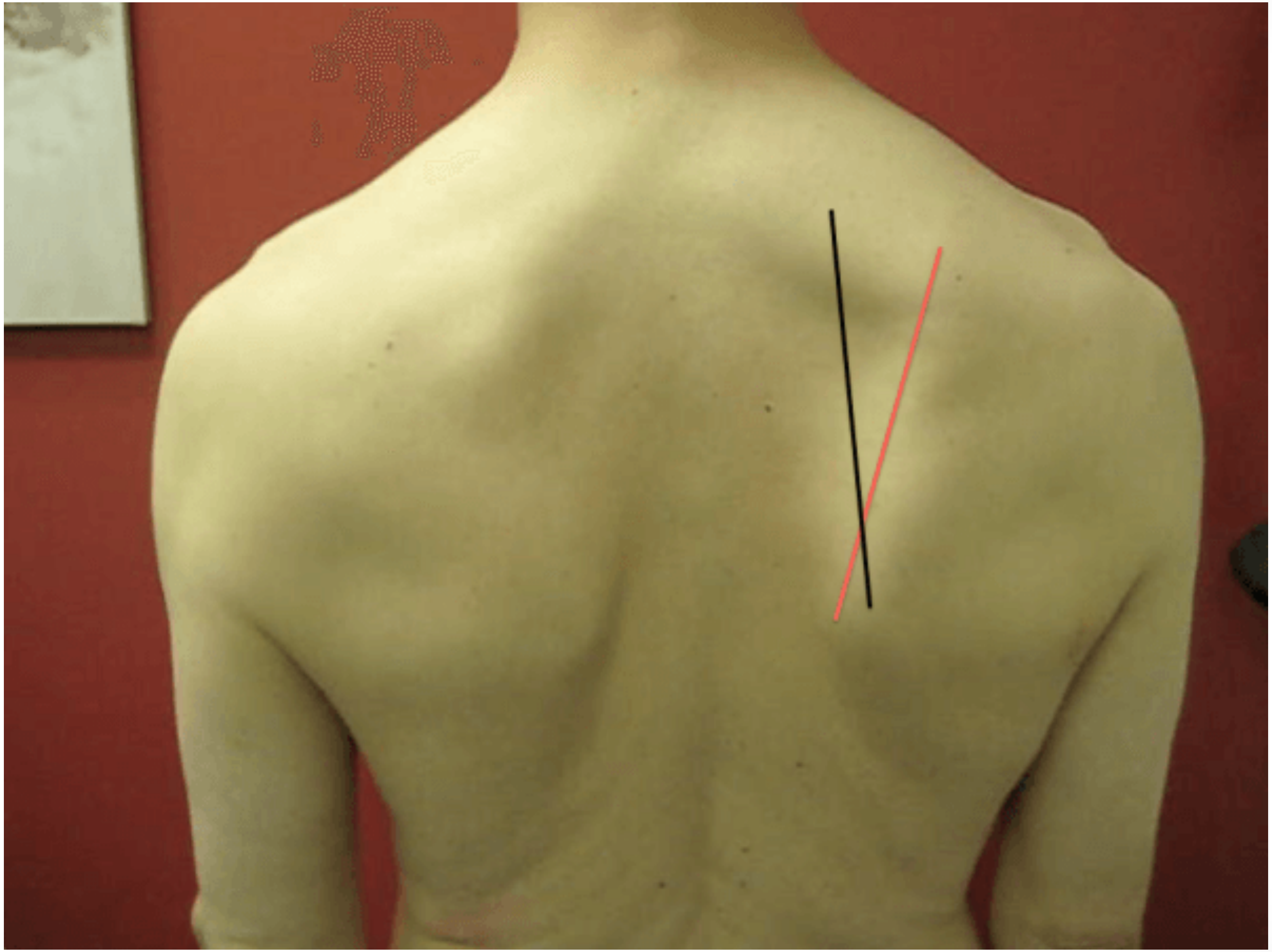

Upper Trapezius
Serratus Anterior
Lower Trapezius

Downward Rotators

- Pectoralis minor (Pm): protraction, anterior tilt, depression, and downward rotation
- Levator scapulae (LS): elevate the scapula and to rotate the scapula downward
- Rhomboid major (Rm): stabilize the medial border of the scapula, retracts the scapula, and works together with the LS to rotate the scapula downward

Castelein, J Hand Ther, 2017


Upper part
of trapezius
Serratus
anterior
Lower part
of trapezius
Levator scapulae
Rhomboids
Pectoralis
minor
Upward rotators
of the scapula
Downward rotators
of the scapula



Downward Rotators

- Typically not the issue, the issue is LACK of eccentric control of the upward rotators as the arm is lowered.

Scapular Dyskinesis

Abnormality in scapular motion or resting position of the scapula

↓

Subacromial Pain

Subacromial Pain

- Subacromial pain syndrome: “dynamic” vs. “static” anatomical phenomenon
  - Typically no pain at rest, pain with elevation/overhead movements
- Group of symptoms; has been considered to be an umbrella of various shoulder conditions
- Many diagnoses may be associated with subacromial pain
  - Rotator cuff pathology, shoulder instability, scapular dysfunction, biceps pathology, SLAP lesions

Castelein, J Hand Ther, 2017

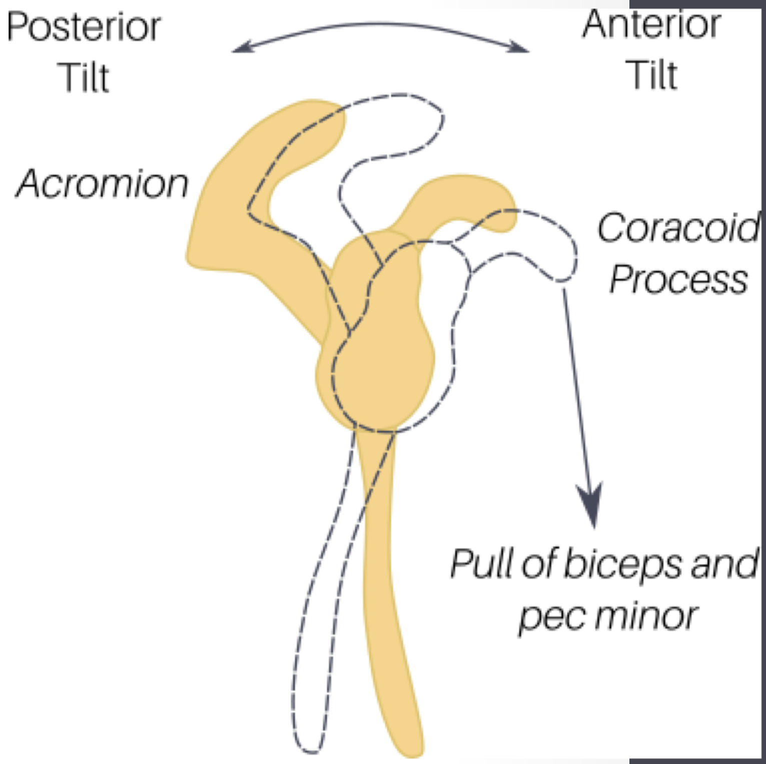
However……

- A Systematic Review of 22 papers
- Determine whether evidence exists of differences in EMG characteristics between subjects with and without subacromial pain
- For the majority of muscles, regardless of task, load or arm position, significant differences were not demonstrated between the 2 groups

Kinsella, Shoulder & Elbow, 2017

We want minimal activation of the downward rotators

- Excessive activation of the pec minor may impede normal posterior tipping (ie-keep the scapular anteriorly tipped) that is necessary during humeral elevation
- Upward rotation may be inhibited by excessive activation in the levator scapulae and/or rhomboid major

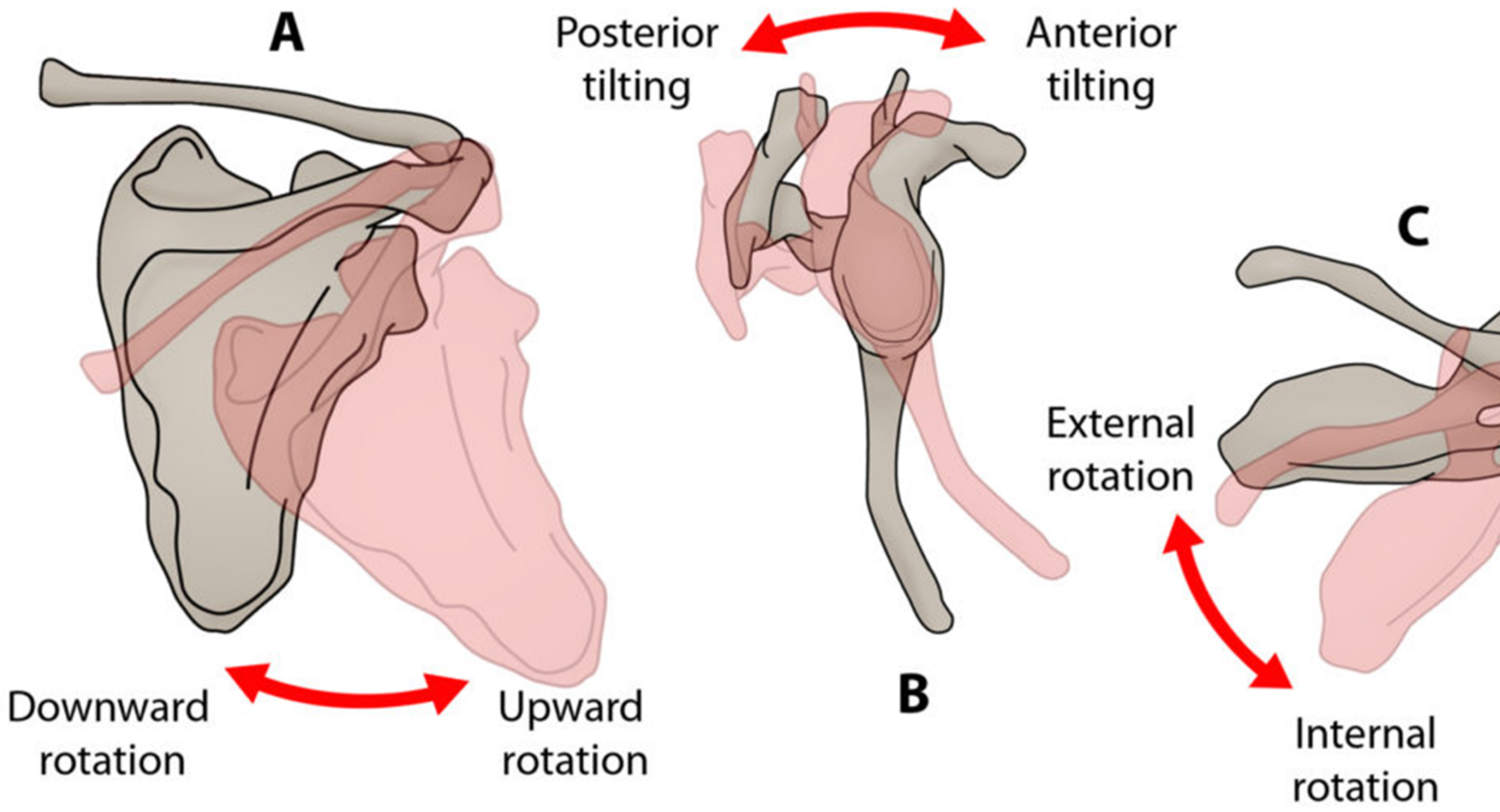


Cricchio, J Hand Ther, 2011

Patients with subacromial pain have….

- Reduced upward rotation, reduced posterior tilting, and increased internal rotation
- Increased EMG of the UT and decreased activity of the LT and SA

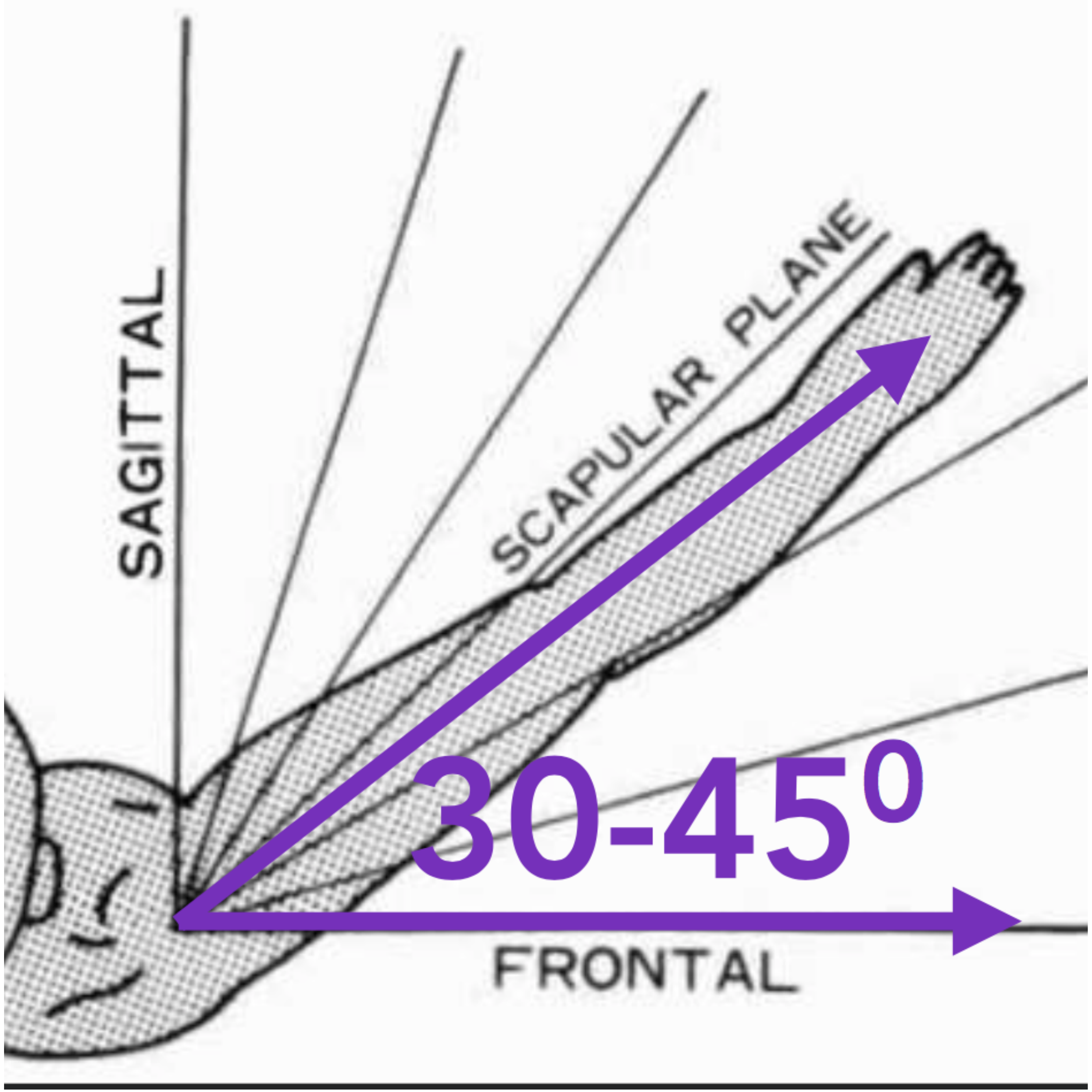
Castelein, J Hand Ther, 2017
Cricchio, J Hand Ther, 2011


A
Posterior tilting
Anterior tilting
C
External rotation
Downward rotation
Upward rotation
B
Internal rotation

Scaption

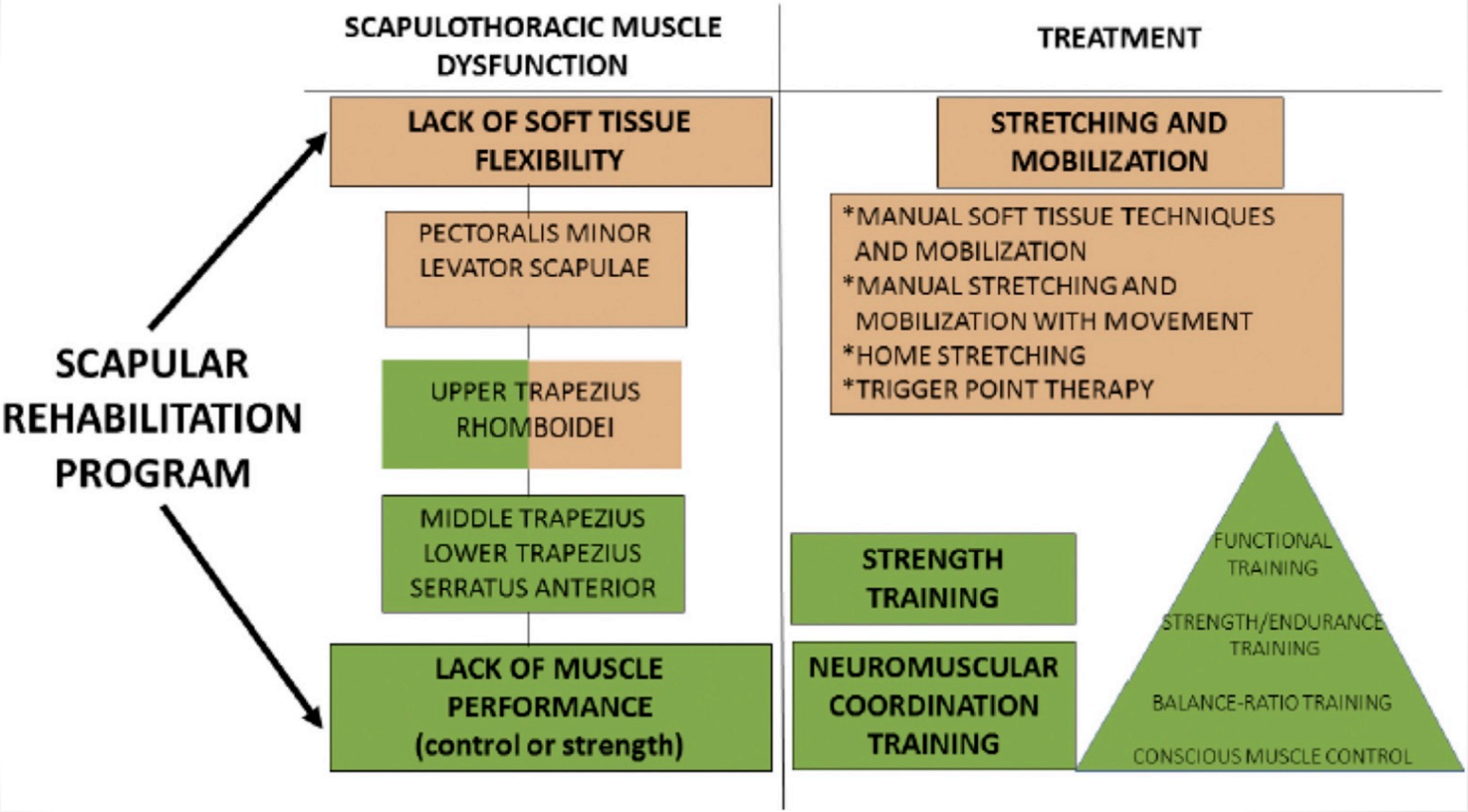
- The most efficient plane for movement
- Stabilizes the humeral head in the glenoid
- Patients with scapular dysfunction show lower MT, LT and SA EMG activity, even in scaption, vs. healthy subjects

Ludewig, Phys Ther, 2000


SAGITTAL
SCAPULAR PLANE
30-45⁰
FRONTAL

Based on all of this, what we know:

- Need LT, SA (and UT) to fire in synchrony
- A tight pec minor causes the scapula to be tilted (tipped) anteriorly, and that is bad
- We need minimal (to no) activation of the pec minor, levator scapula or rhomboids to get the scapula upwardly rotated
- Which exercises are best?



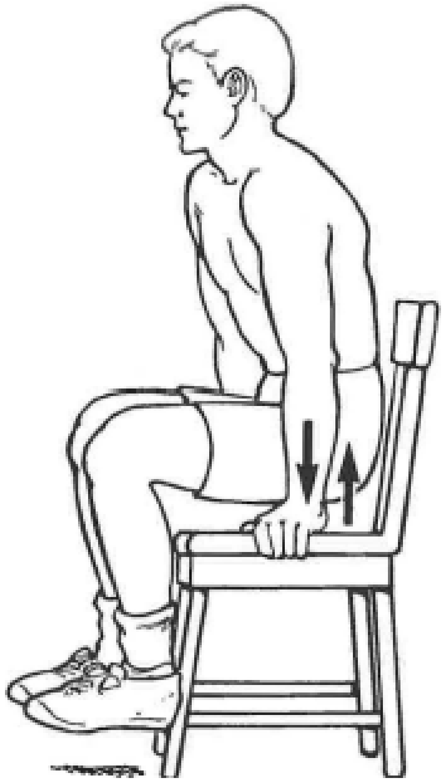
Castelein, J Hand Ther, 2017

The Landmark Study

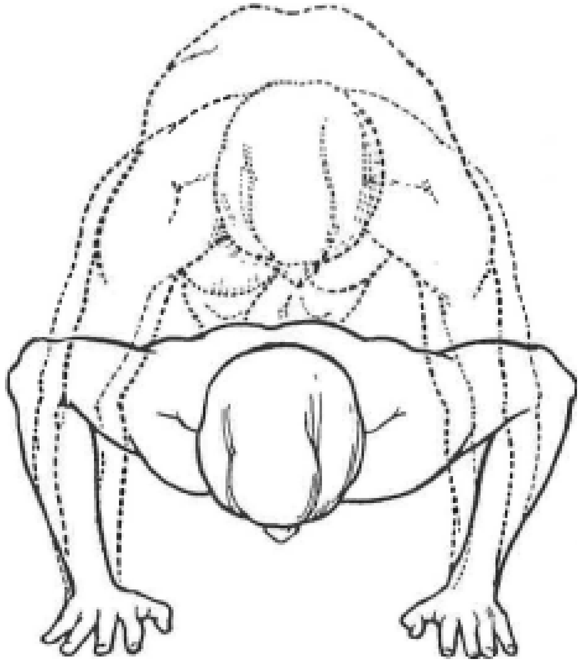
- 4 exercises was shown to make up the core of a scapular muscle strengthening program.
  - press-up
  - push-up with a plus
  - scapular plane elevation
  - rowing

- N=9 healthy young subjects, but fine wire EMG

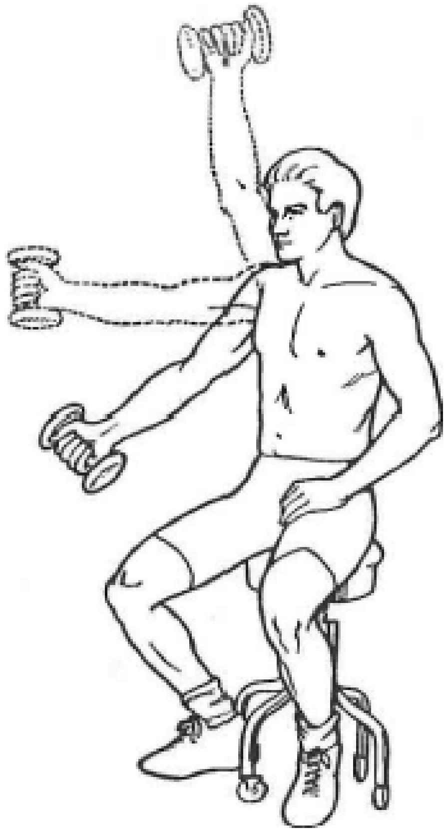
Moseley, Am J Sports Med, 1992



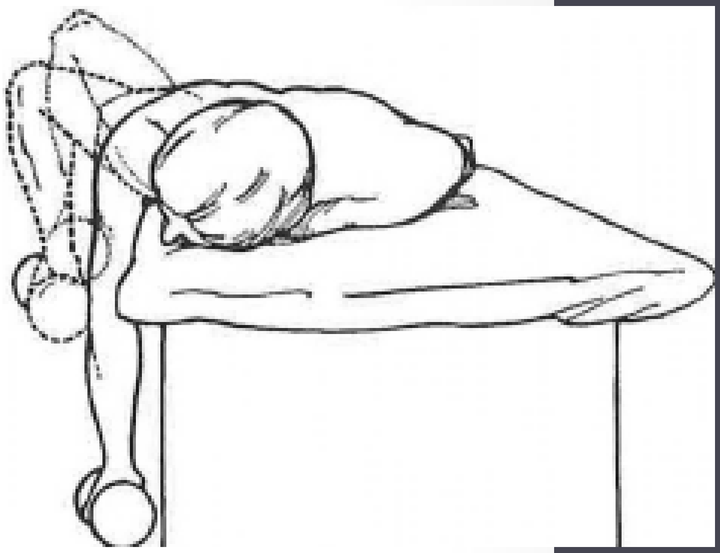
Press up



Push up with a plus



Elevation in scaption



Rowing

Moseley, Am J Sports Med, 1992

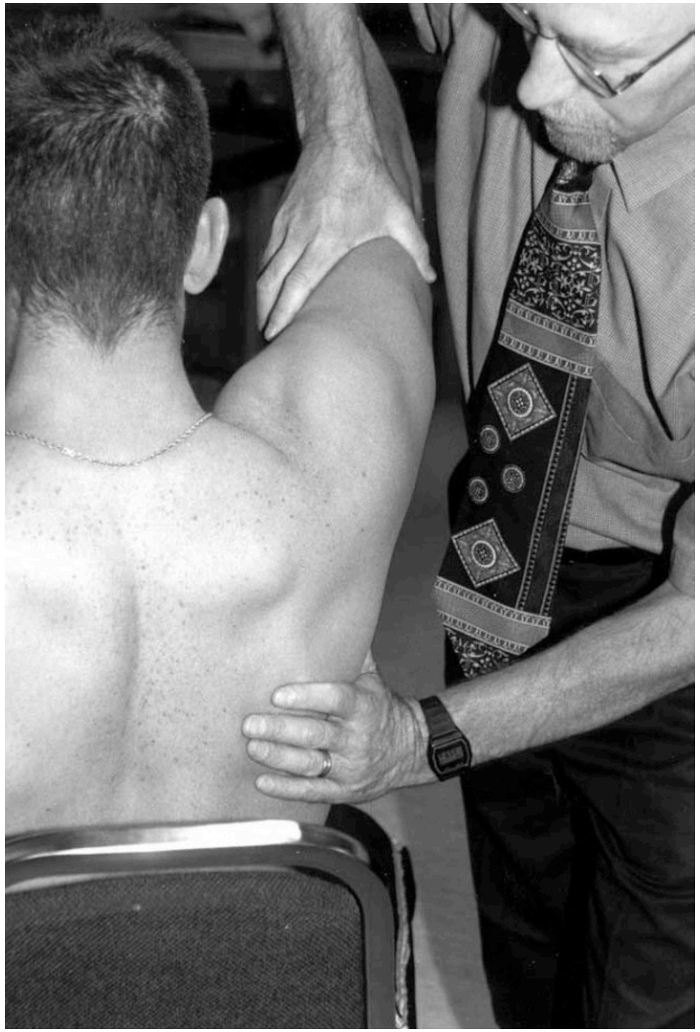
Then along came Ekstrom, Soderberg and Donatelli…

- We are comparing all these exercises to MVIC (g
- Is the position we are testing in REALLY ition?
- Went back to various MMT p e which REALLY produced high levels of EMG of the SA, UT, MT and LT
- sEMG in n = 30

One size does NOT fit all!!!!

Ekstrom, Journal Electromyo Kines, 2005

Serratus Anterior MMT

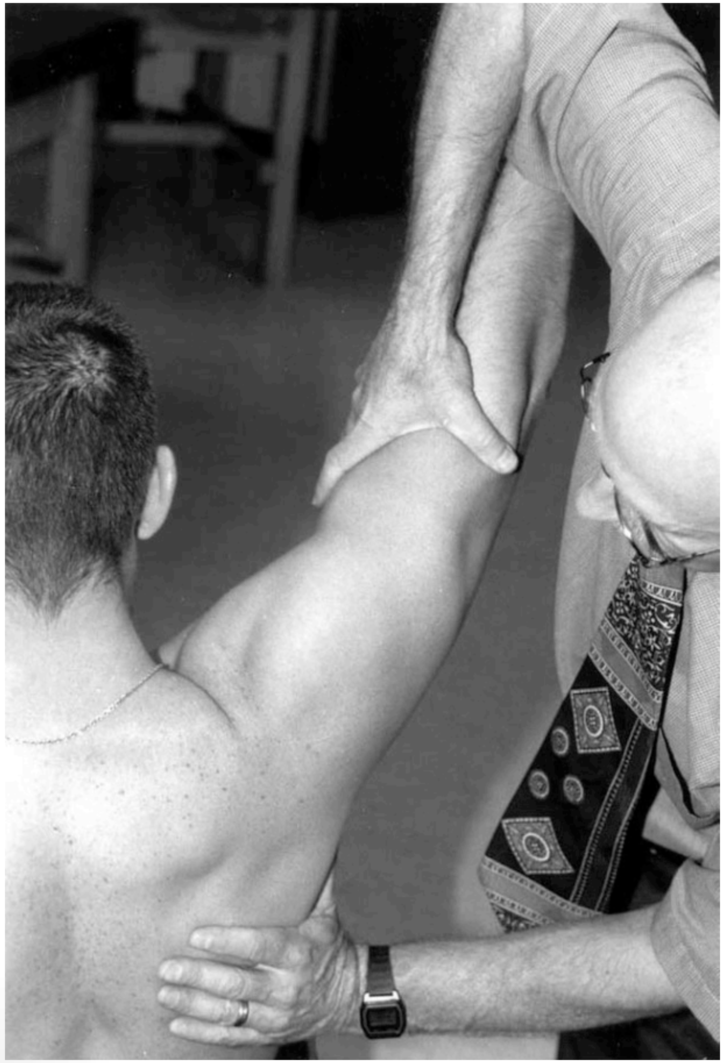


Shoulder **flexed** to 125° as resistance is applied above the elbow **and at the inferior angle of the scapula attempting to de-rotate the scapula** with the subject sitting in an erect posture with no back support.

%MVIC: 91 ± 13

Ekstrom, Journal Electromyo Kines, 2005

Serratus Anterior MMT



Shoulder **abducted** to 125° in the plane of the scapula as resistance is applied above the elbow **and at the inferior angle of the scapula attempting to de-rotate the scapula** with the subject sitting in an erect posture with no back support.

%MVIC: 89 ± 11

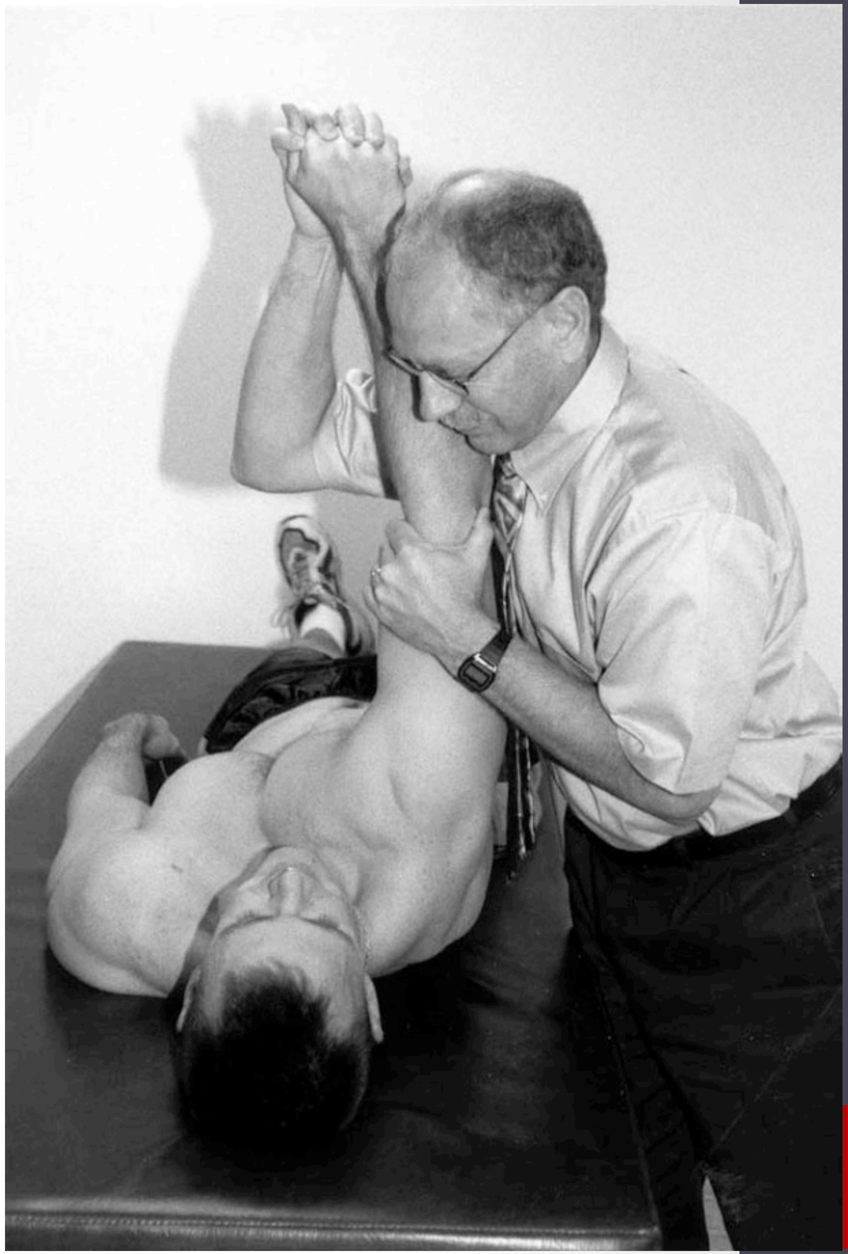
*THM: MVIC is almost identical as flexion; if patient has impingement, abduct the GH a bit!

Ekstrom, Journal Electromyo Kines, 2005

Serratus Anterior MMT

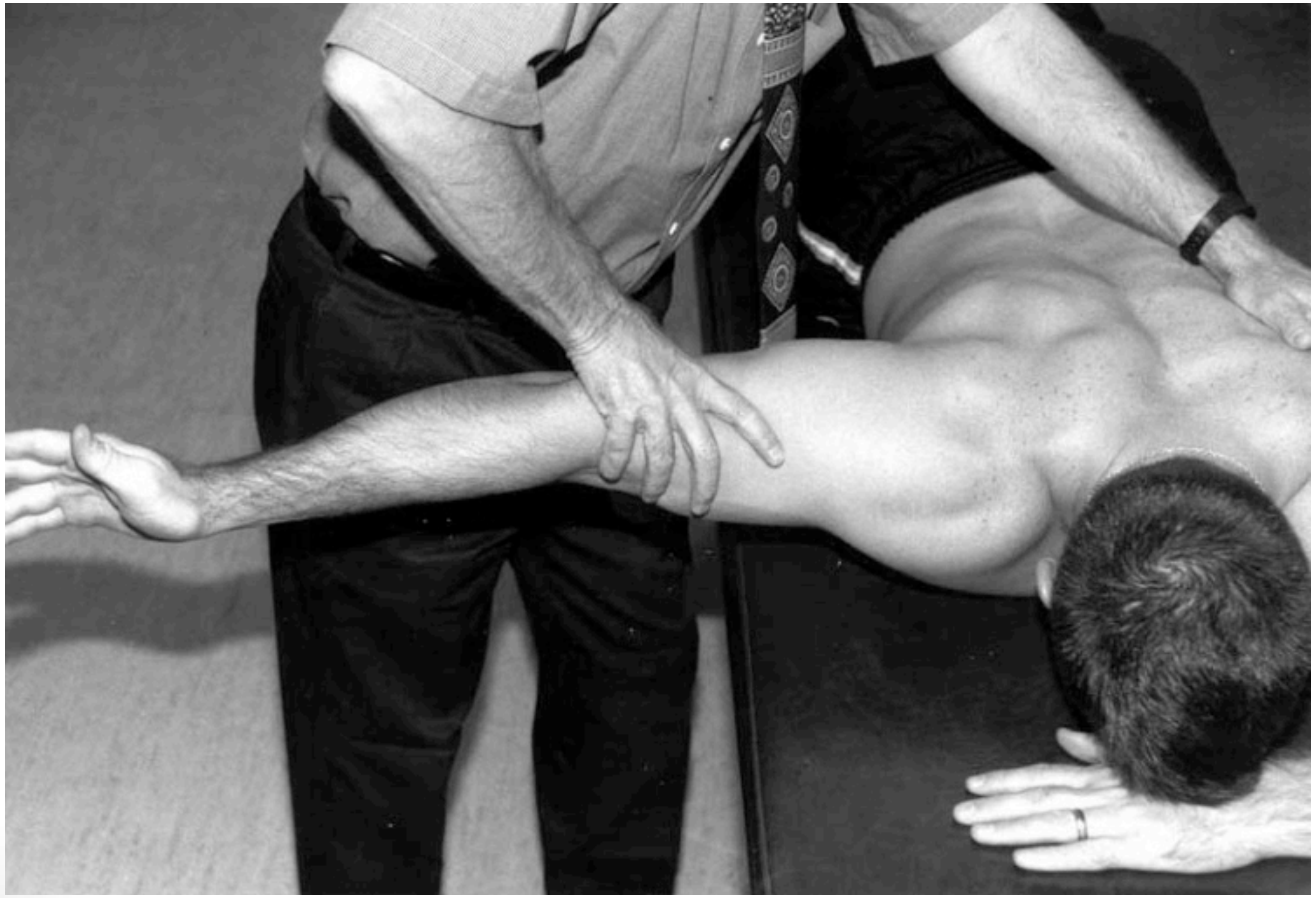
Scapula protracted at 90° of shoulder flexion as resistance is applied over the hand and at the elbow with the subject in the supine position.

%MVIC: 57 ± 20



Ekstrom, Journal Electromyo Kines, 2005

Middle Trap MMT



Shoulder horizontally abducted and externally rotated as resistance is applied above the elbow with the subject in the prone position.

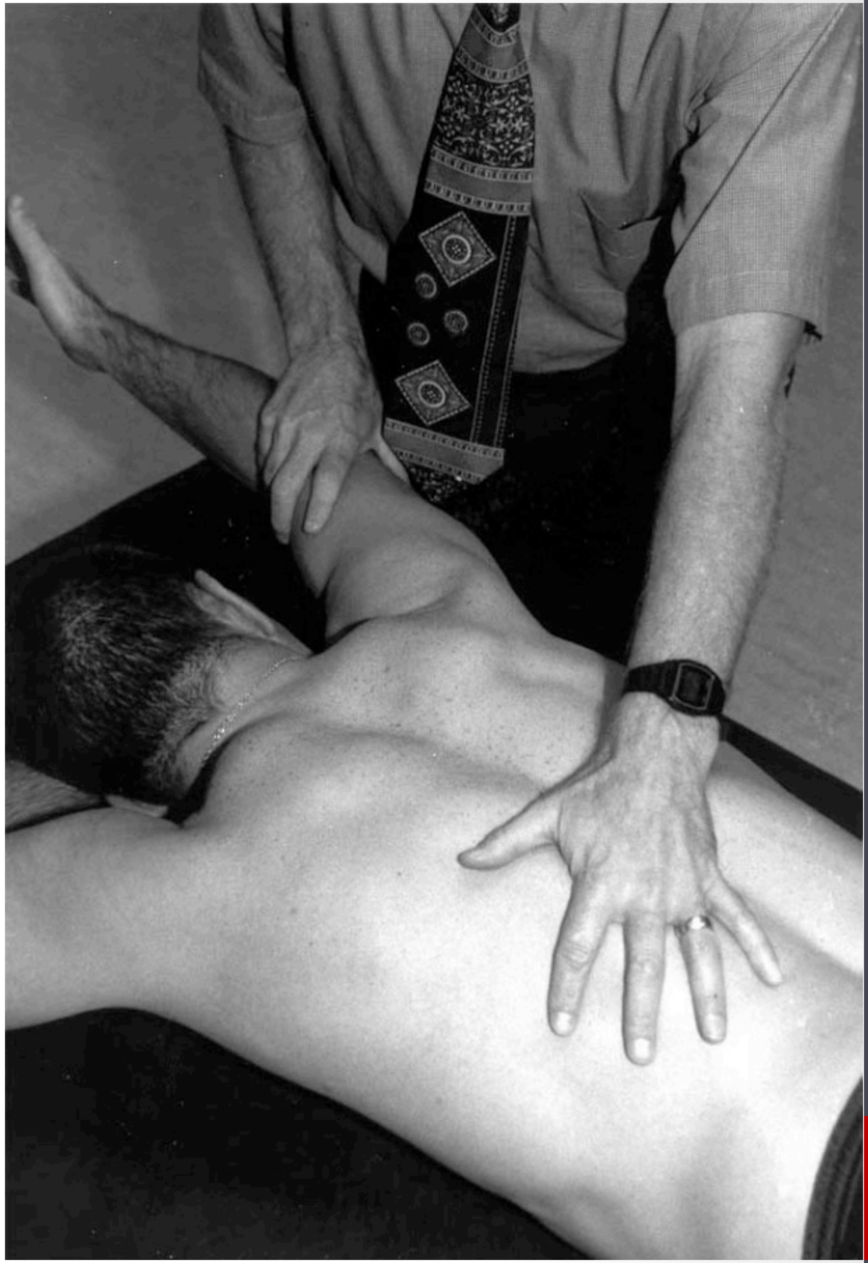
%MVIC: 94 ± 12

Ekstrom, Journal Electromyo Kines, 2005

Middle Trap MMT

Arm raised above the head in line with the lower trapezius muscle fibers as resistance is applied above the elbow with the subject in the prone position.

%MVIC: 87 ± 13

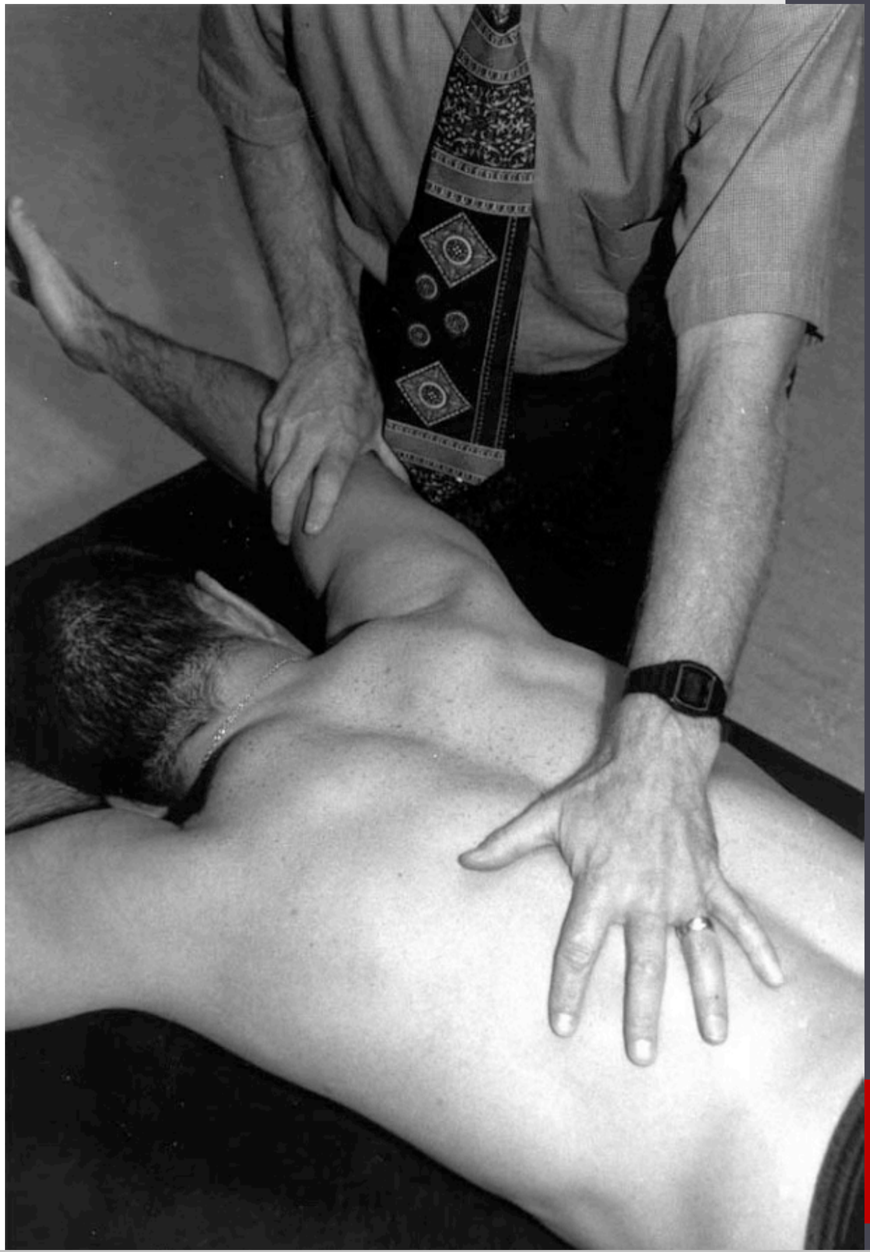


Ekstrom, Journal Electromyo Kines, 2005

Lower Trap MMT

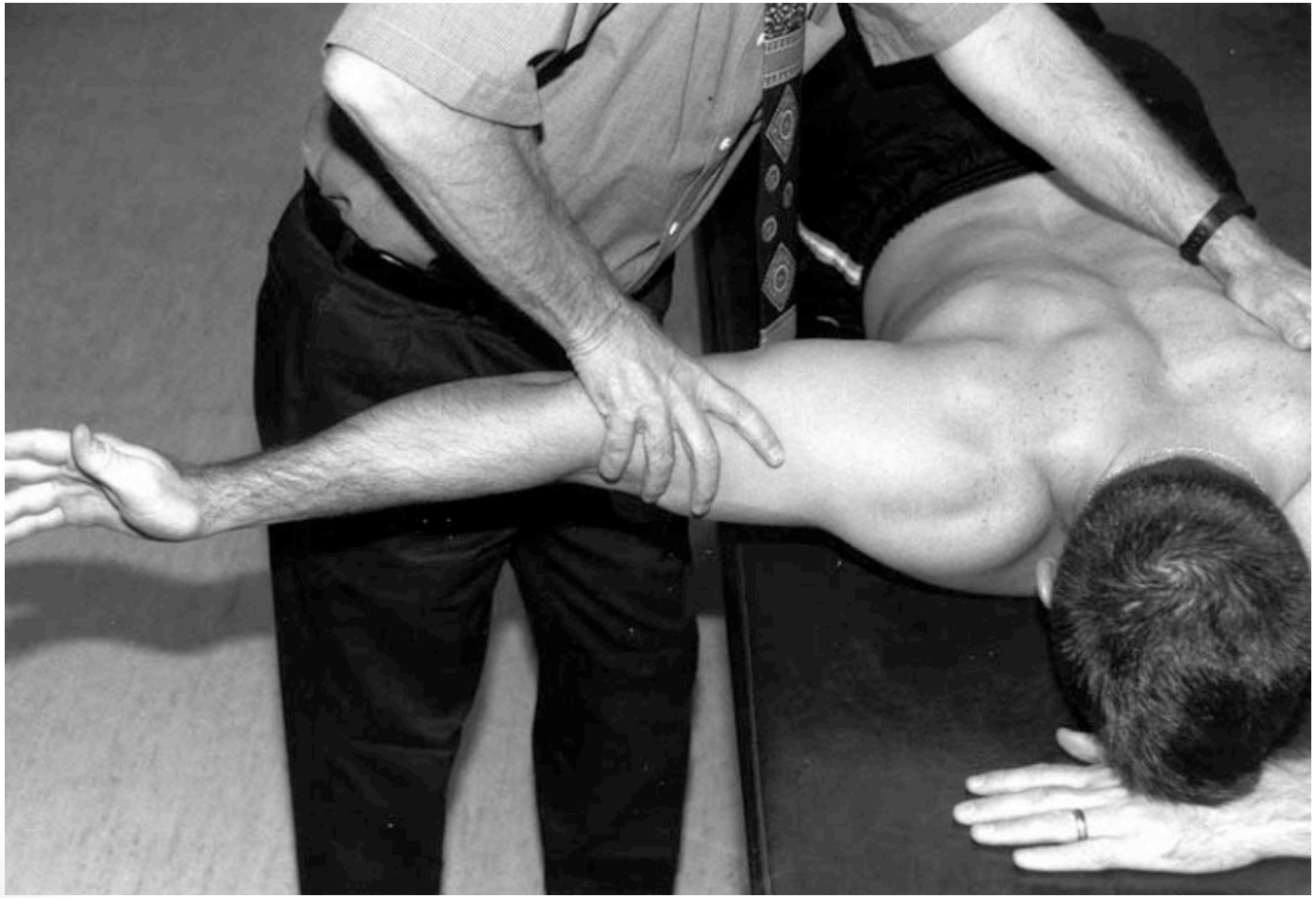
Arm raised above the head in line with the lower trapezius muscle fibers as resistance is applied above the elbow with the subject in the prone position.

%MVIC: 95 ± 11



Ekstrom, Journal Electromyo Kines, 2005

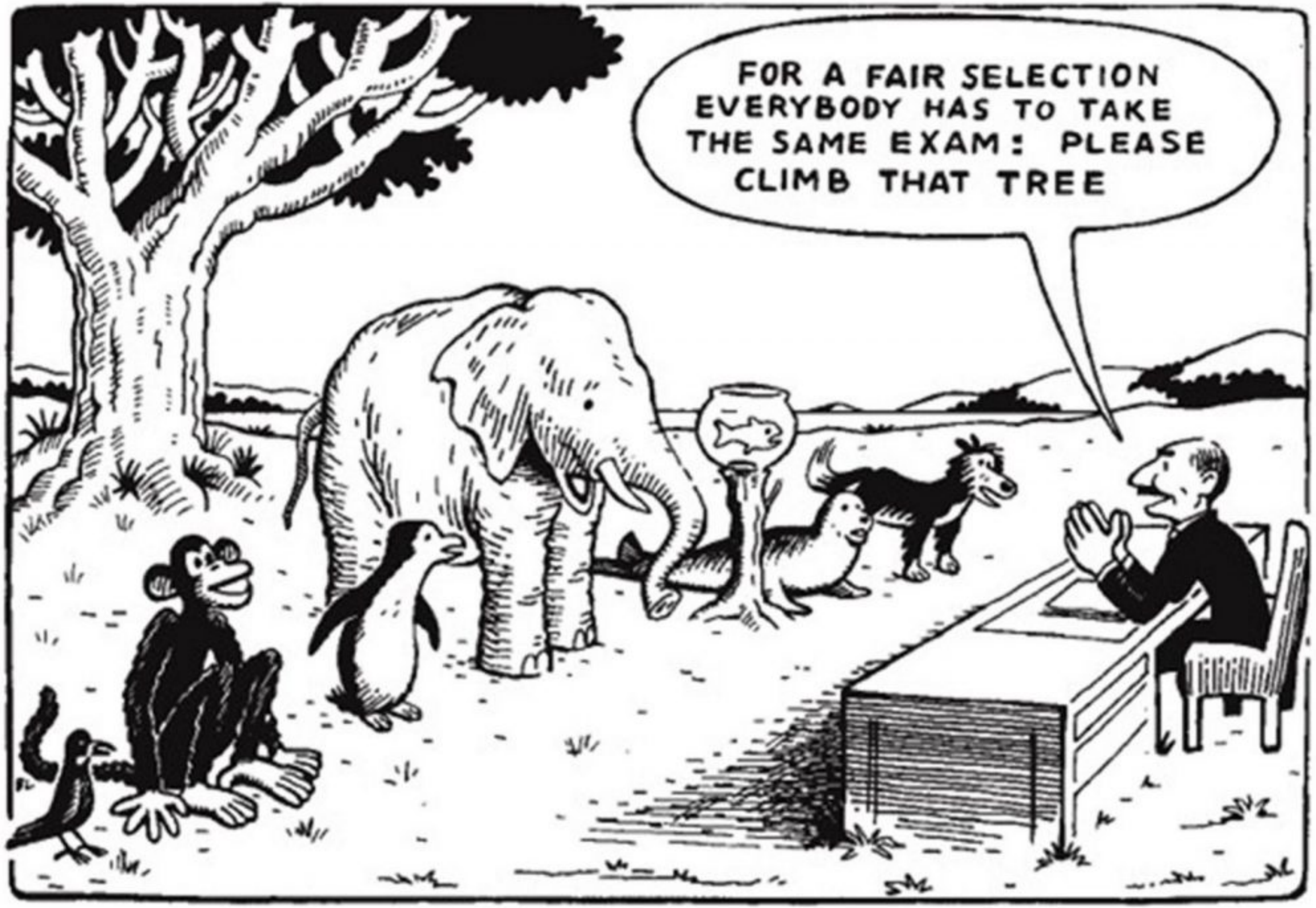
Lower Trap MMT



Shoulder horizontally abducted and externally rotated as resistance is applied above the elbow with the subject in the prone position.

%MVIC: 80 ± 16

Ekstrom, Journal Electromyo Kines, 2005

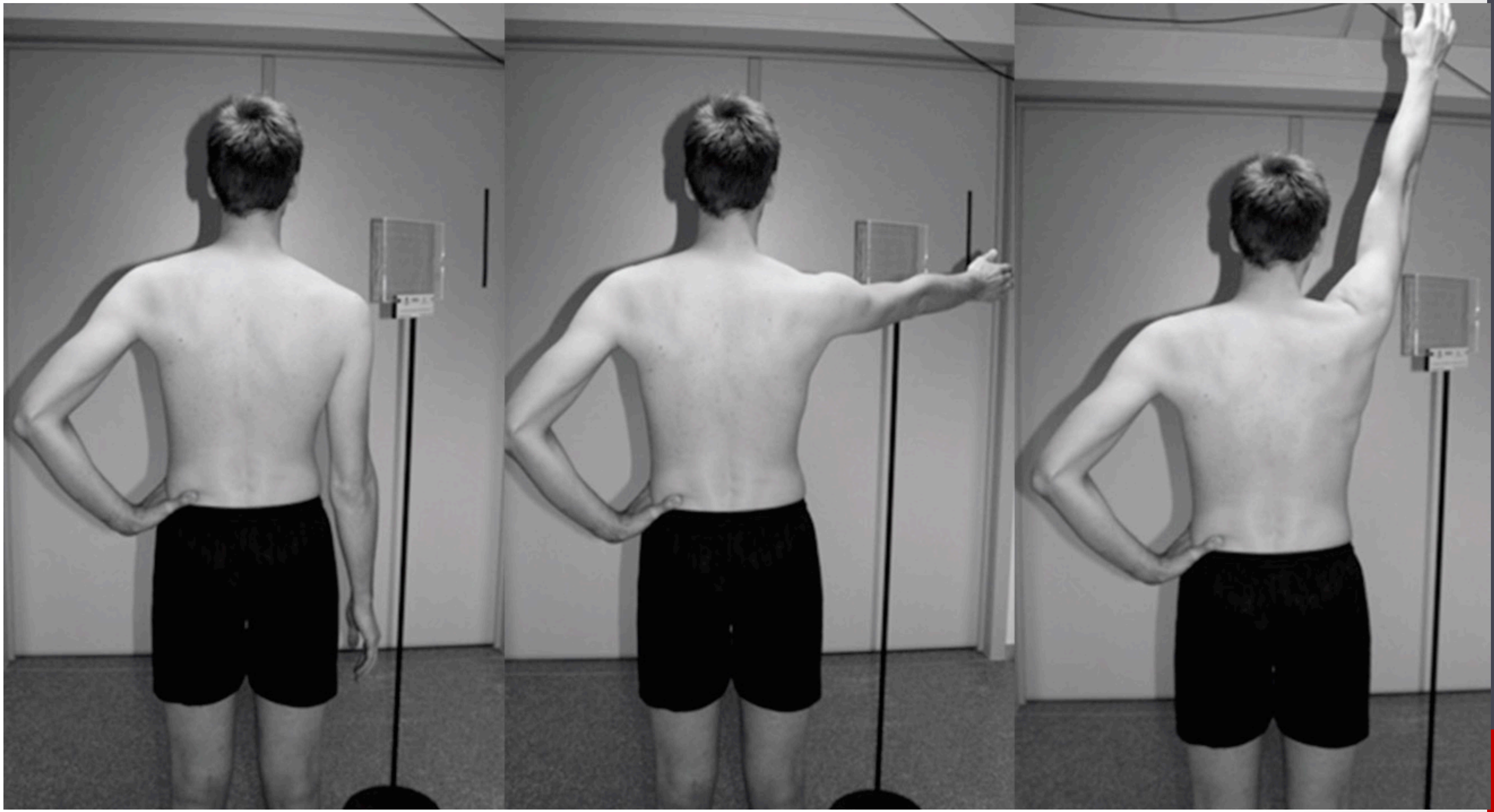


Ekstrom, Journal Electromyo Kines, 2005

Scapular EMG during 6 exercises

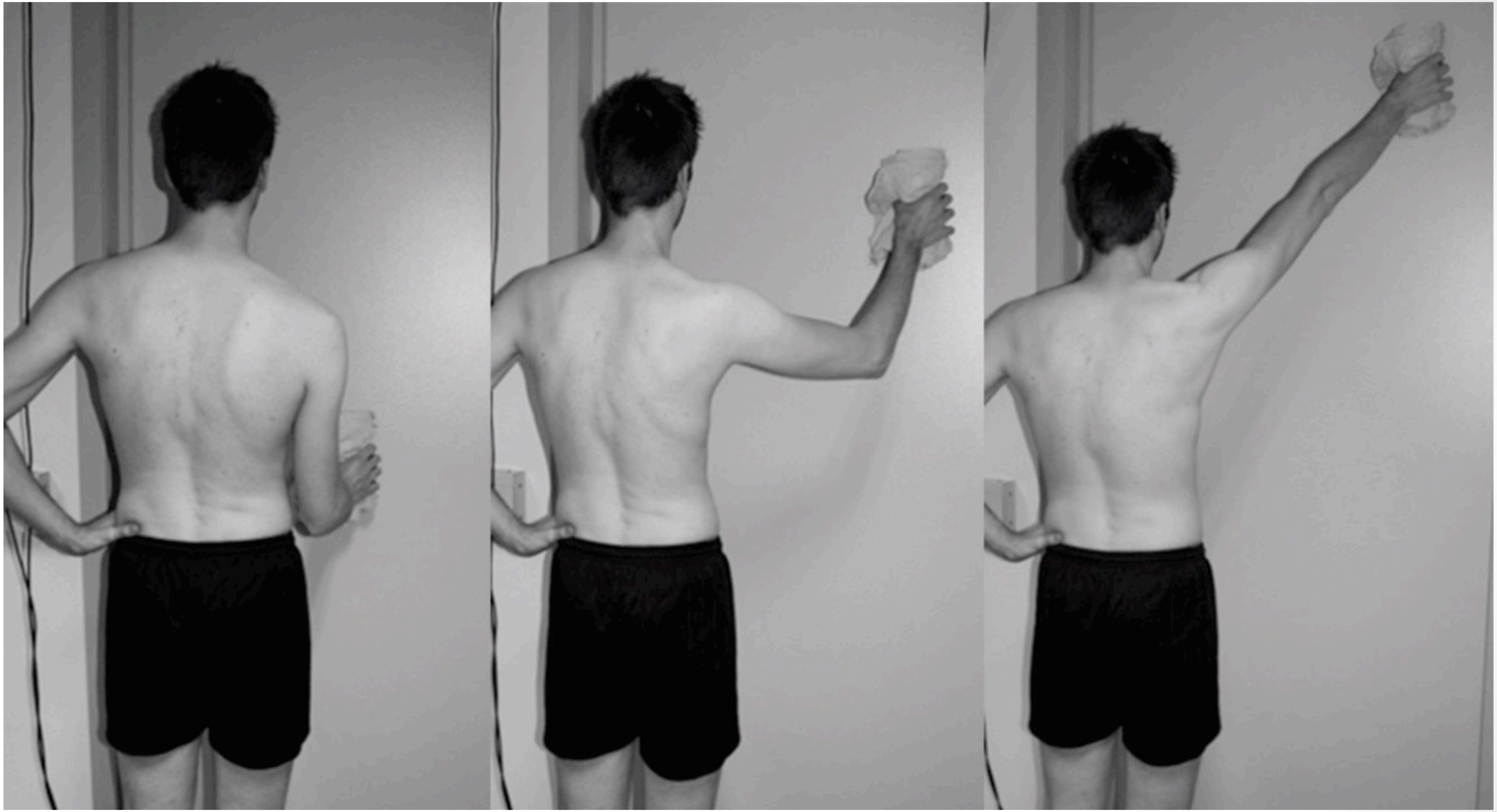
- N= 21 healthy subjects
- Fine wire: LS, PM, RM
- Surface EMG: UT, MT, LT and SA
- 3 exercises:
  - Scaption
  - Towel wall slide
  - Elevation with ER (Tband)
  - All exercises with and without load

Castelein, JOSPT, 2016



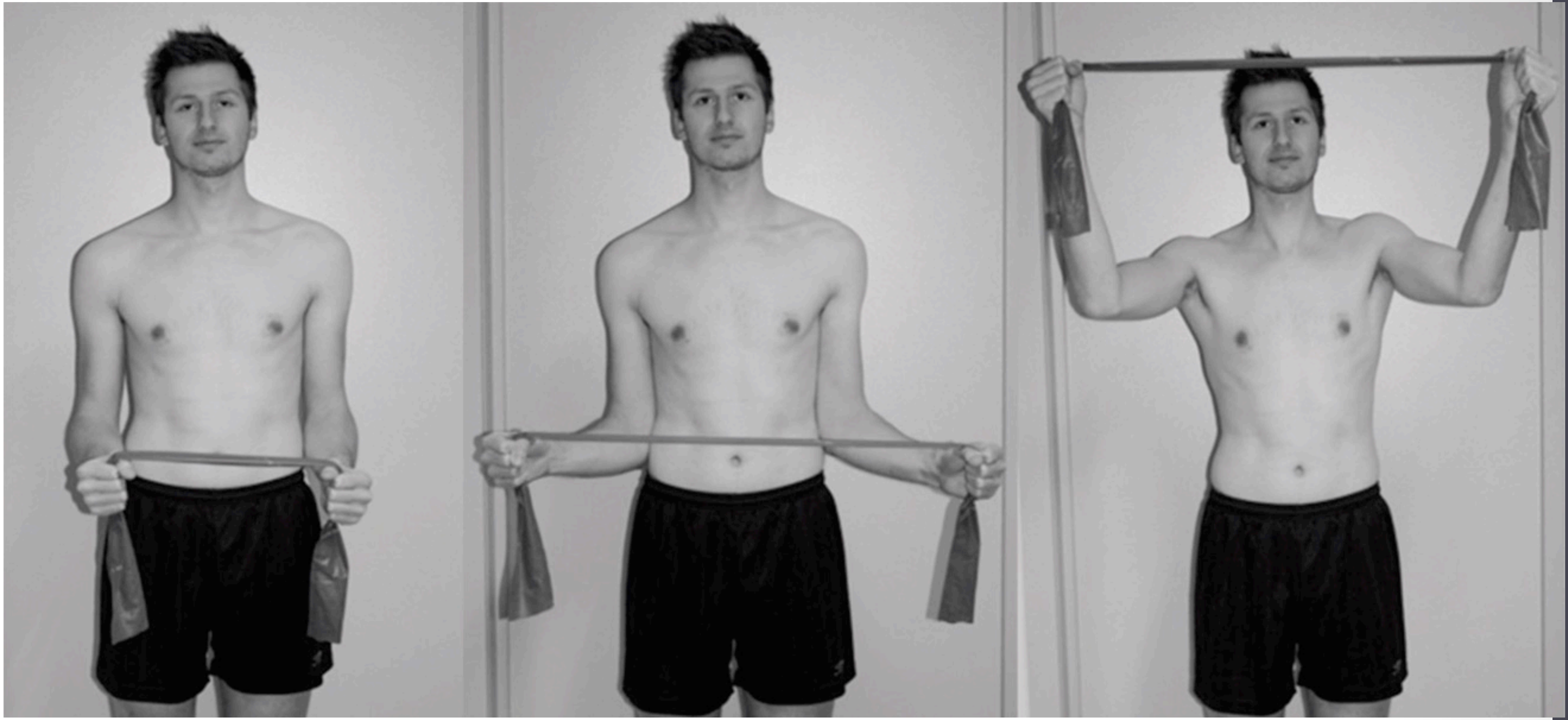
Scaption

Castelein, JOSPT, 2016



Towel wall slide

Castelein, JOSPT, 2016



Elevation with ER (Tband)

Castelein, JOSPT, 2016

External Load

- The external load was the same for every exercise
- The amount of load of the dumbbell was determined in a pilot study to find an external load that achieved a moderate load of ±15 repetition maximum for both male and female subjects (2 kg-5 kg)

Castelein, JOSPT, 2016

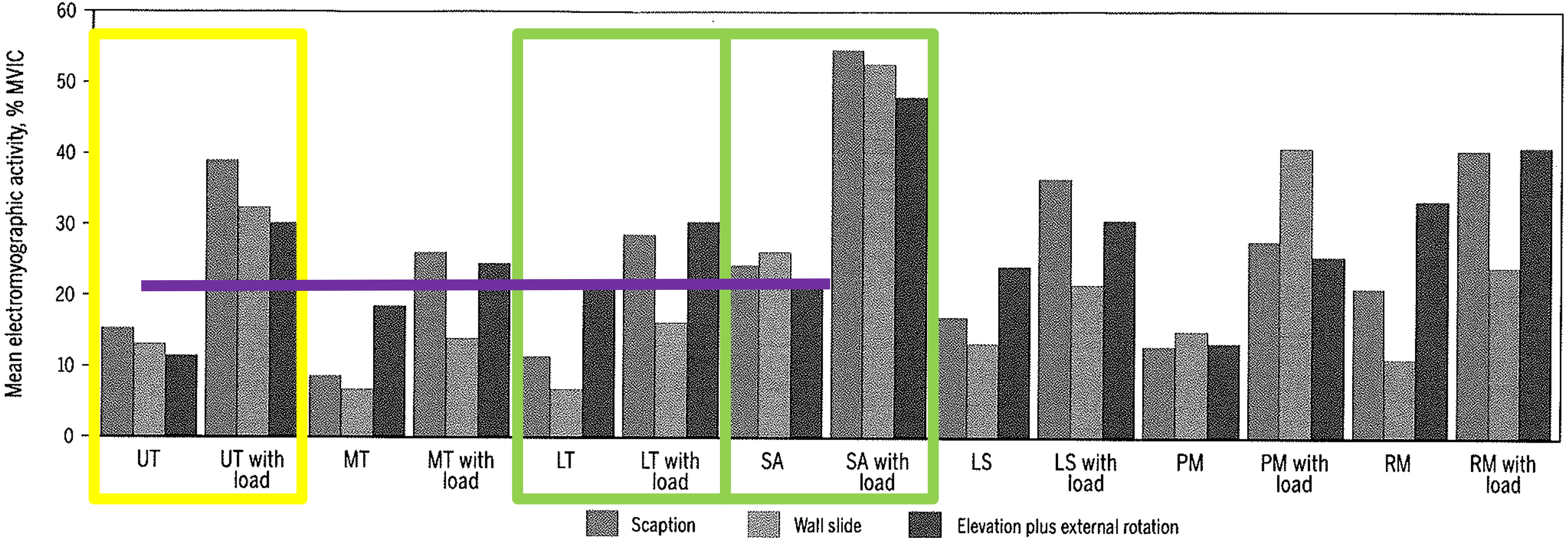


FIGURE 4. Visualization of mean electromyographic activity (percent MVIC) of each scapulothoracic muscle during the different elevation exercises for each load condition. For specific values, see **TABLE 2.** Abbreviations: LS, levator scapulae; LT, lower trapezius; MT, middle trapezius; MVIC, maximum voluntary isometric contraction; PM, pectoralis minor; SA, serratus anterior; RM, rhomboid major; UT, upper trapezius.

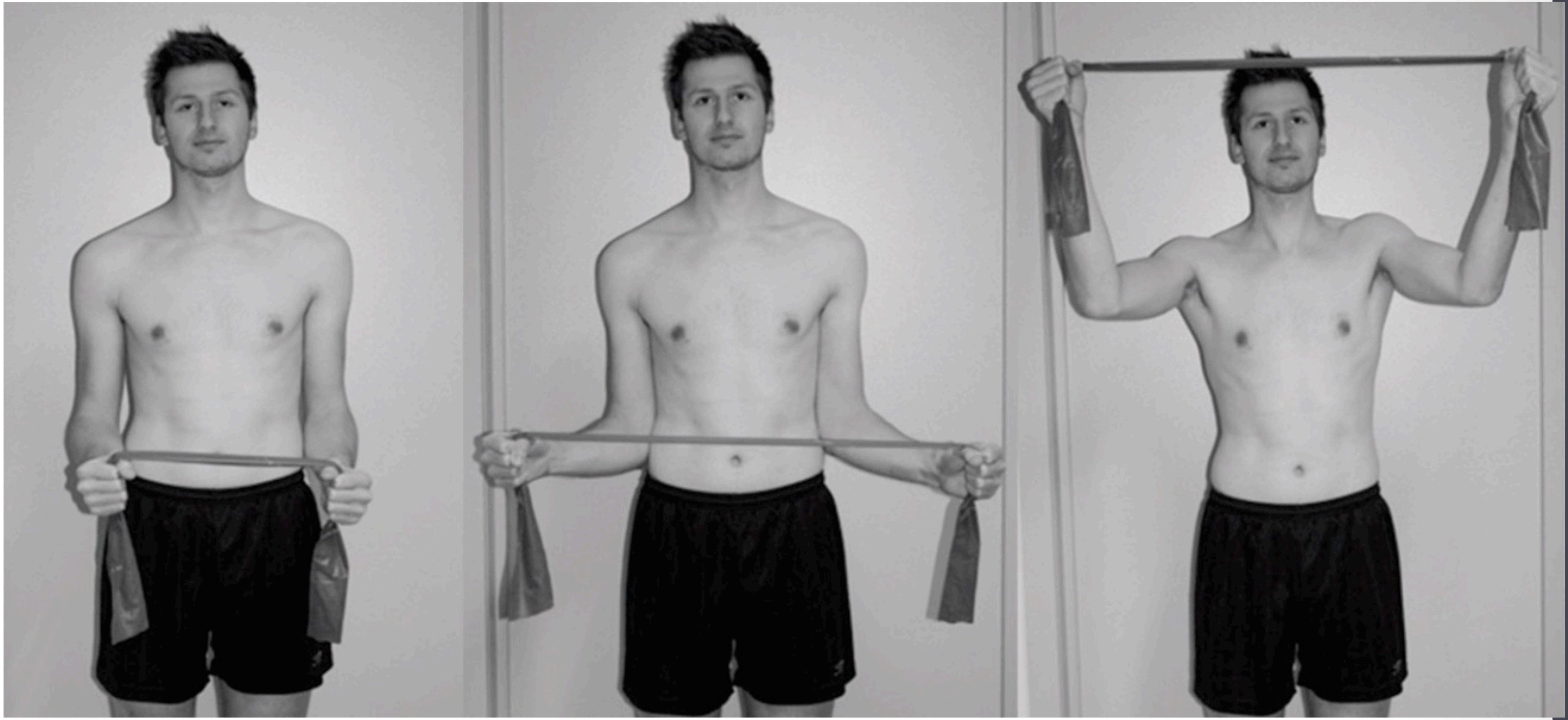
Castelein, JOSPT, 2016

TABLE 2 Electromyographic Activity of Each Scapulothoracic Muscle During the Different Exercises for Each Load Condition*

	No Additional Load			Additional Load		
	Scaption	Wall Slide	Elevation Plus External Rotation	Scaption	Wall Slide	Elevation Plus External Rotation
Upper trapezius	15.9 ± 4.0†	13.6 ± 4.7	12.0 ± 4.0	39.5 ± 10.2†	33.0 ± 10.0	30.9 ± 9.7
Middle trapezius	9.1 ± 4.0	7.3 ± 7.6	19.1 ± 12.2†	26.6 ± 12.9‡	14.6 ± 9.9	25.1 ± 13.7‡
Lower trapezius	12.0 ± 5.6	7.4 ± 4.5	22.5 ± 7.5†	29.2 ± 10.7‡	17.0 ± 7.6	31.0 ± 10.2‡
Serratus anterior	25.1 ± 12.2	26.8 ± 10.3	22.5 ± 11.4	55.2 ± 16.0	53.2 ± 11.9	48.6 ± 15.9
Levator scapulae	17.7 ± 10.5	13.9 ± 13.6	24.7 ± 17.1†	37.1 ± 17.6‡	22.4 ± 15.6	31.2 ± 16.2‡
Pectoralis minor	13.4 ± 6.7	15.7 ± 9.0†	13.7 ± 9.0	28.3 ± 13.5	41.3 ± 27.1†	26.2 ± 15.2
Rhomboid major	21.7 ± 12.9‡	11.6 ± 6.3	33.9 ± 25.0‡	41.1 ± 16.1‡	24.7 ± 9.2	41.2 ± 25.8‡

**Values are mean ± SD percent maximal voluntary isometric contraction.*
†*Exercises that show significantly higher activity than the other 2 exercises (P<.05).*
‡*Exercises that show significantly higher activity than the exercise with the lowest value (P<.05).*

Castelein, JOSPT, 2016



Elevation with ER (Tband)

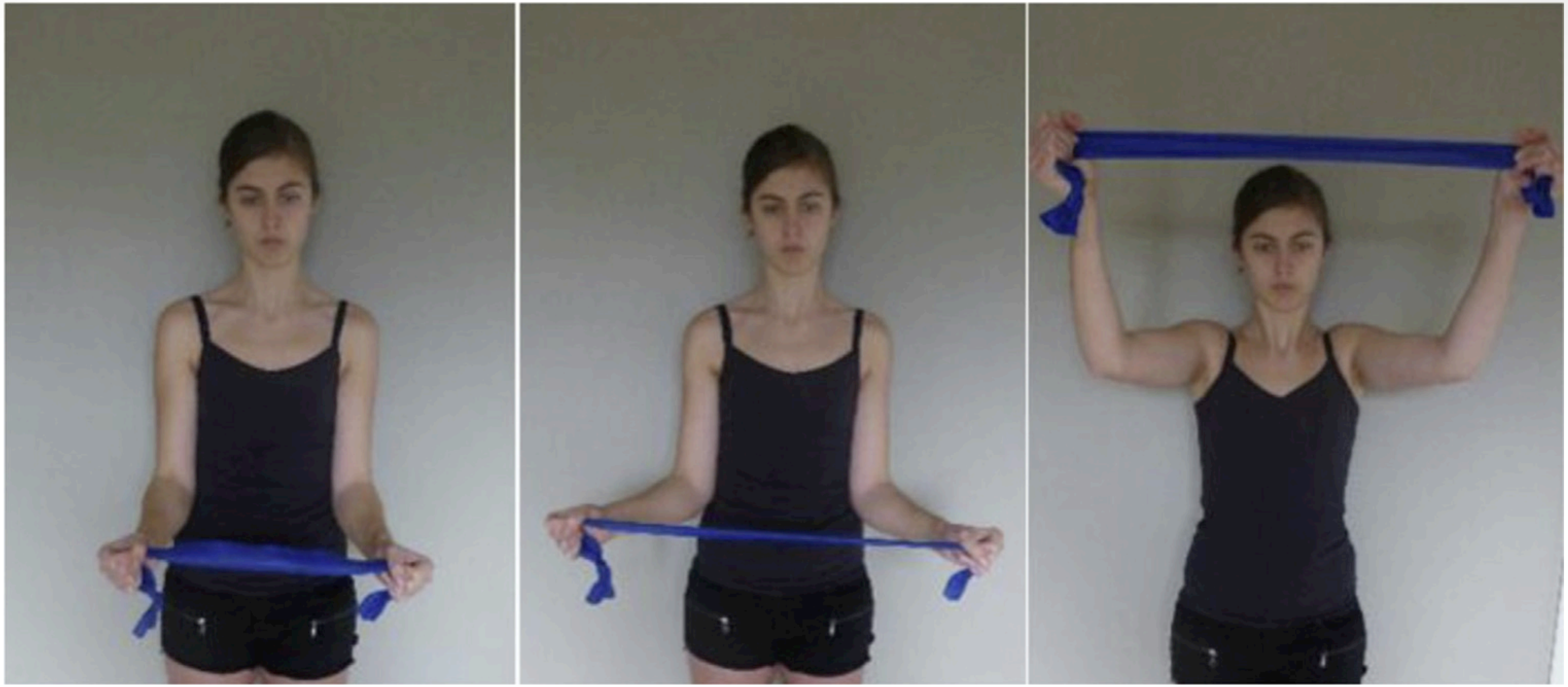
Castelein, JOSPT, 2016

Towel Wall Slide

- All scapular retractors (MT, LT, LS, RM) are activated to a lesser degree than during the other elevation exercises
- Pectoralis minor and SA showed the highest EMG activity, potentially caused by the "pushing" movement that is required to keep the towel against the wall

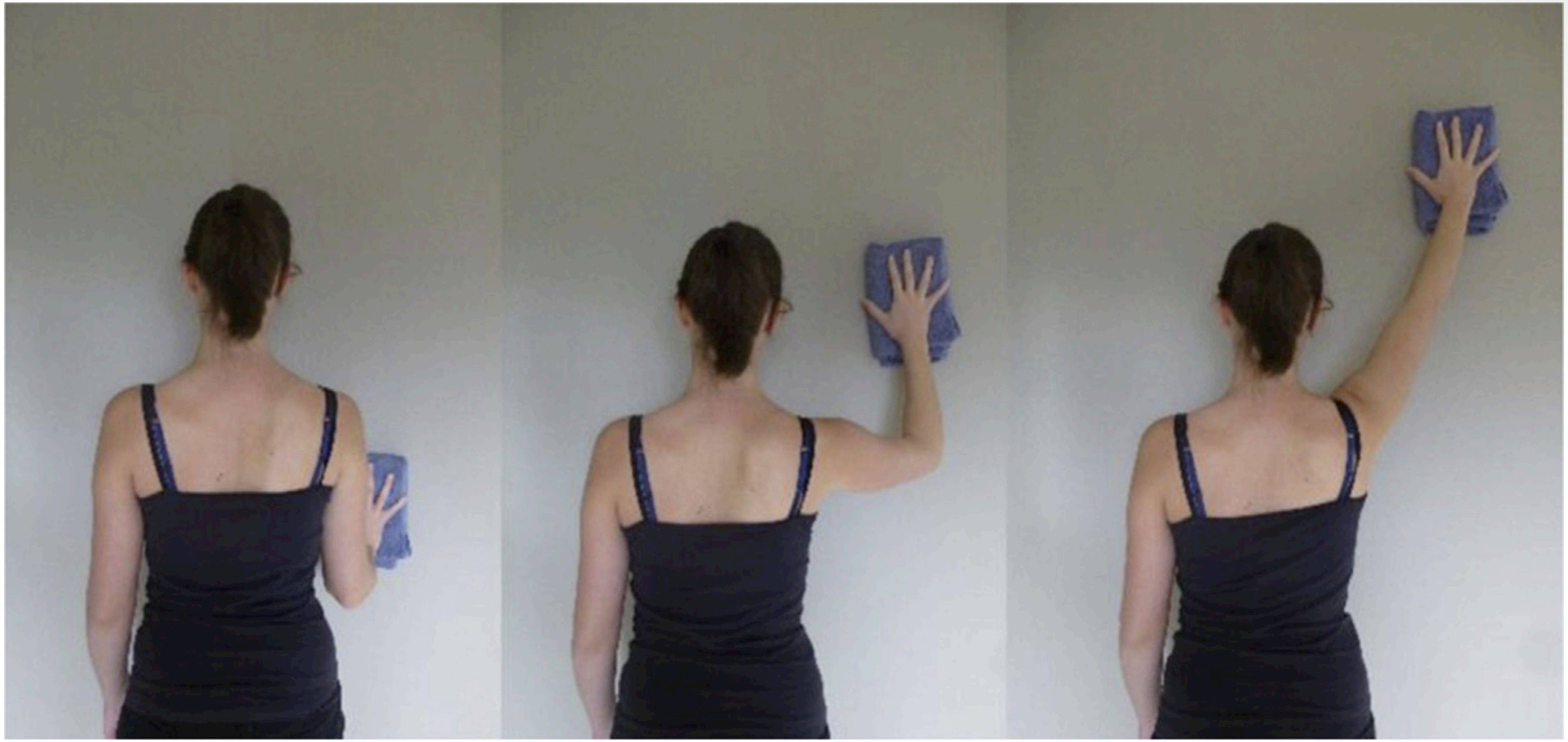
Castelein, JOSPT, 2016


AMERICAN
AVIATION
LEARN TO
FLY HERE!



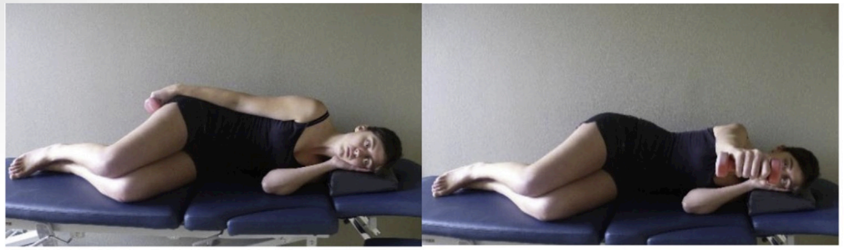
High SA and LT activity and low UT and PM.

Castelein, J Hand Ther, 2017

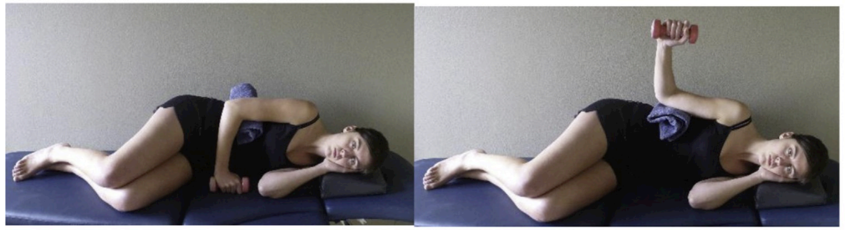


High SA and low UT activity.

Castelein, J Hand Ther, 2017



Sidelying forward flexion



Sidelying external rotation

Prone horizontal abduction with external rotation

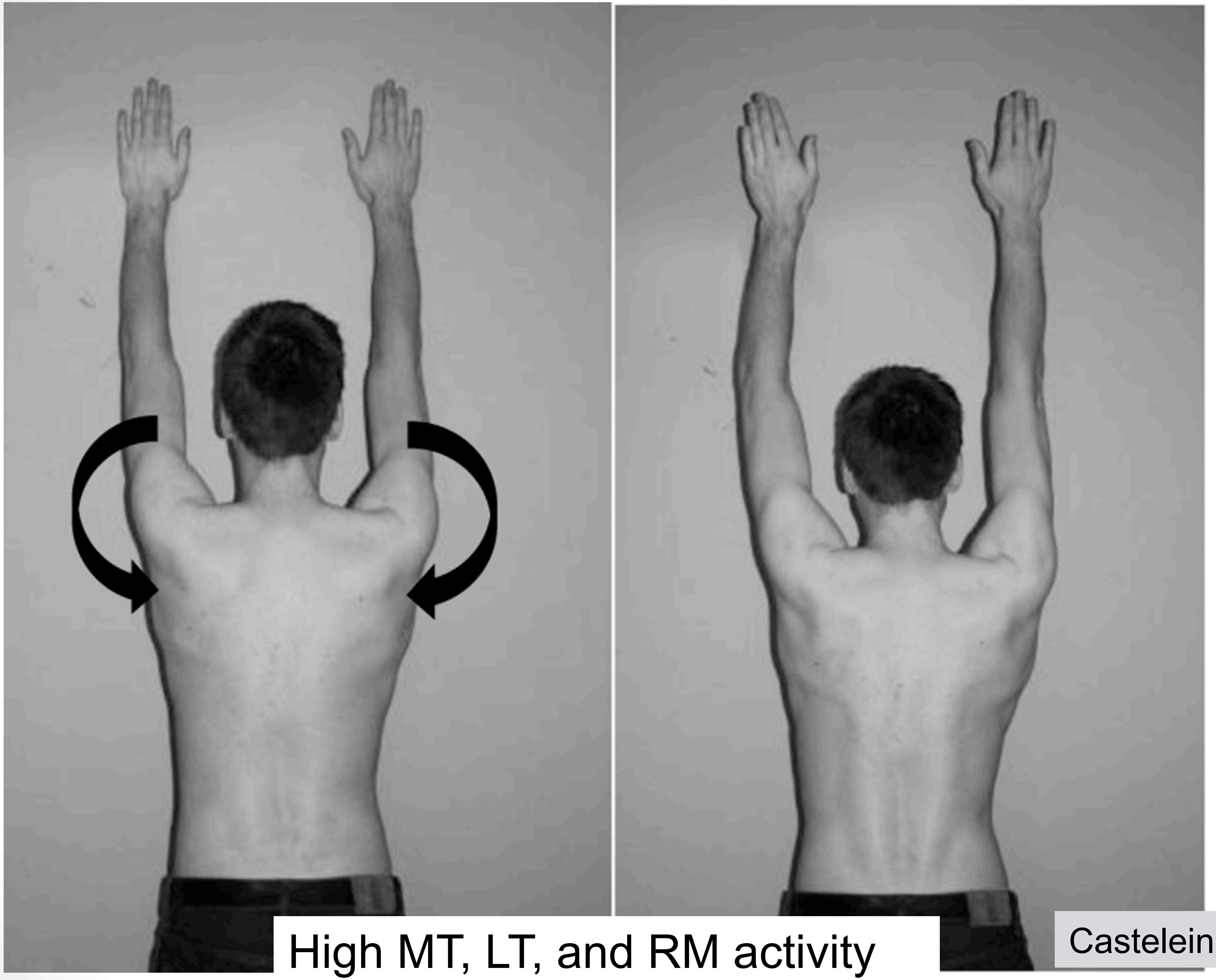
Prone extension

All have high MT and LT with low UT activity.

Castelein, J Hand Ther, 2017

High SA activity and low PM activity

Castelein, J Hand Ther, 2017



High MT, LT, and RM activity

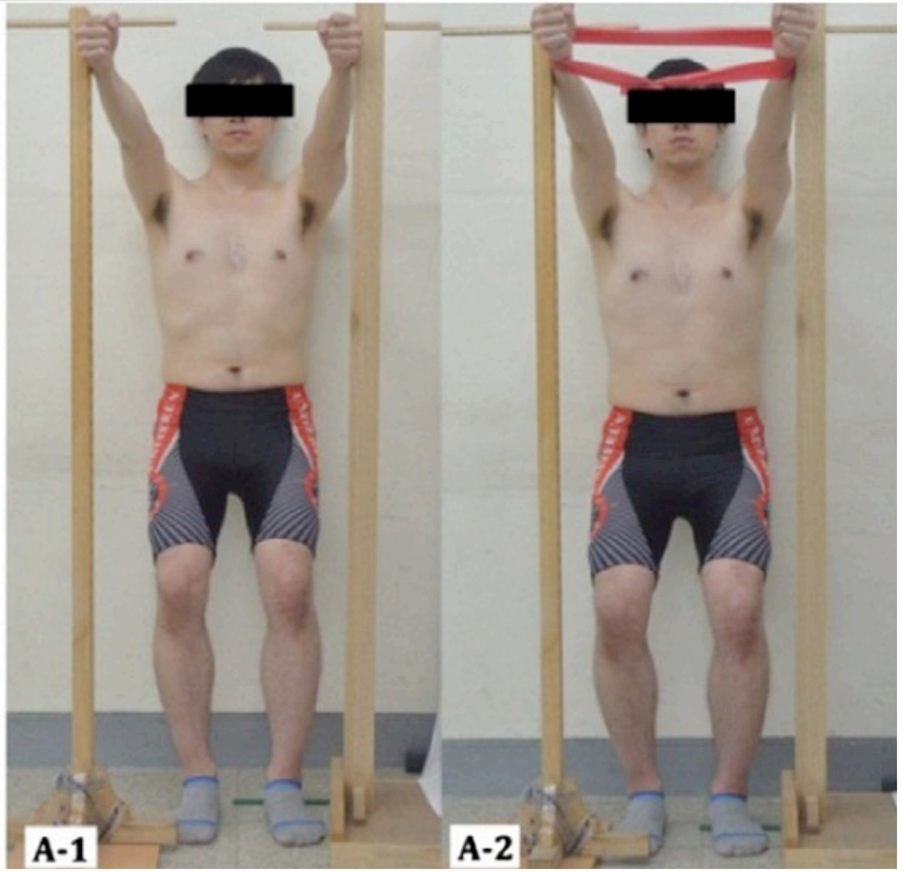
Castelein, J Hand Ther, 2017

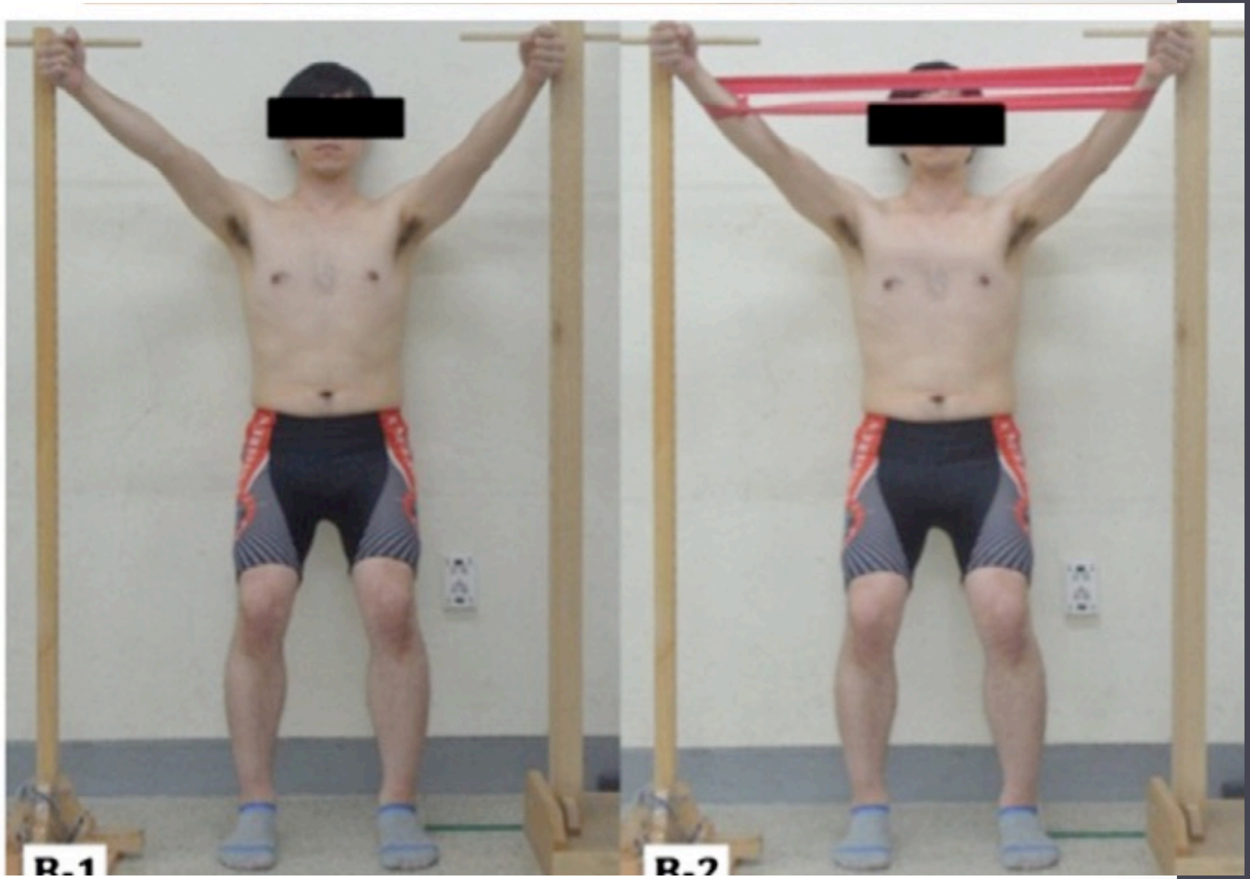

CAUTION
THIS SIGN HAS
SHARP EDGES
DO NOT TOUCH THE EDGES OF THIS SIGN

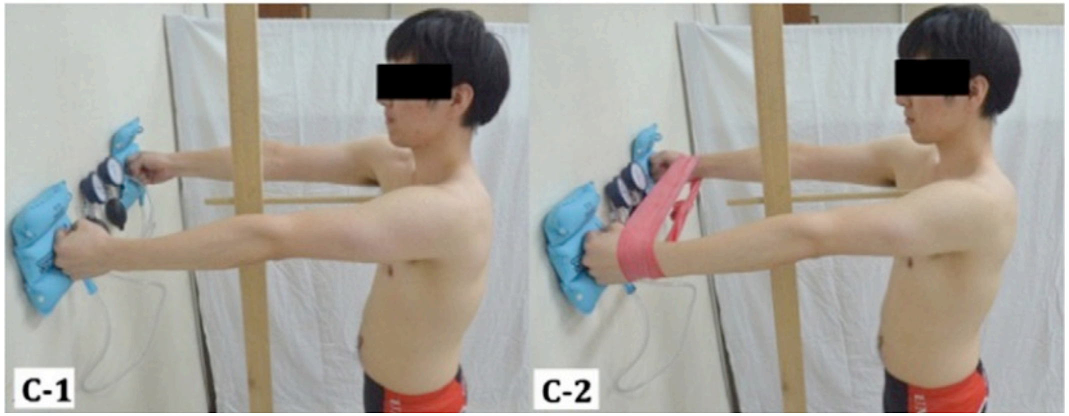
High SA activation with low PM(Major) activation

- 24 males with winging scapula
- Forward flexion, scaption, and wall push-up plus with and without isometric horizontal abduction using Thera-Band
- sEMG pectoralis major and serratus anterior
- Anytime you protract scapula for SA, you get PM firing. How can we quiet the PM?

Park, J Electromyo Kines, 2013







Park, J Electromyo Kines, 2013

Park, J Electromyo Kines, 2013

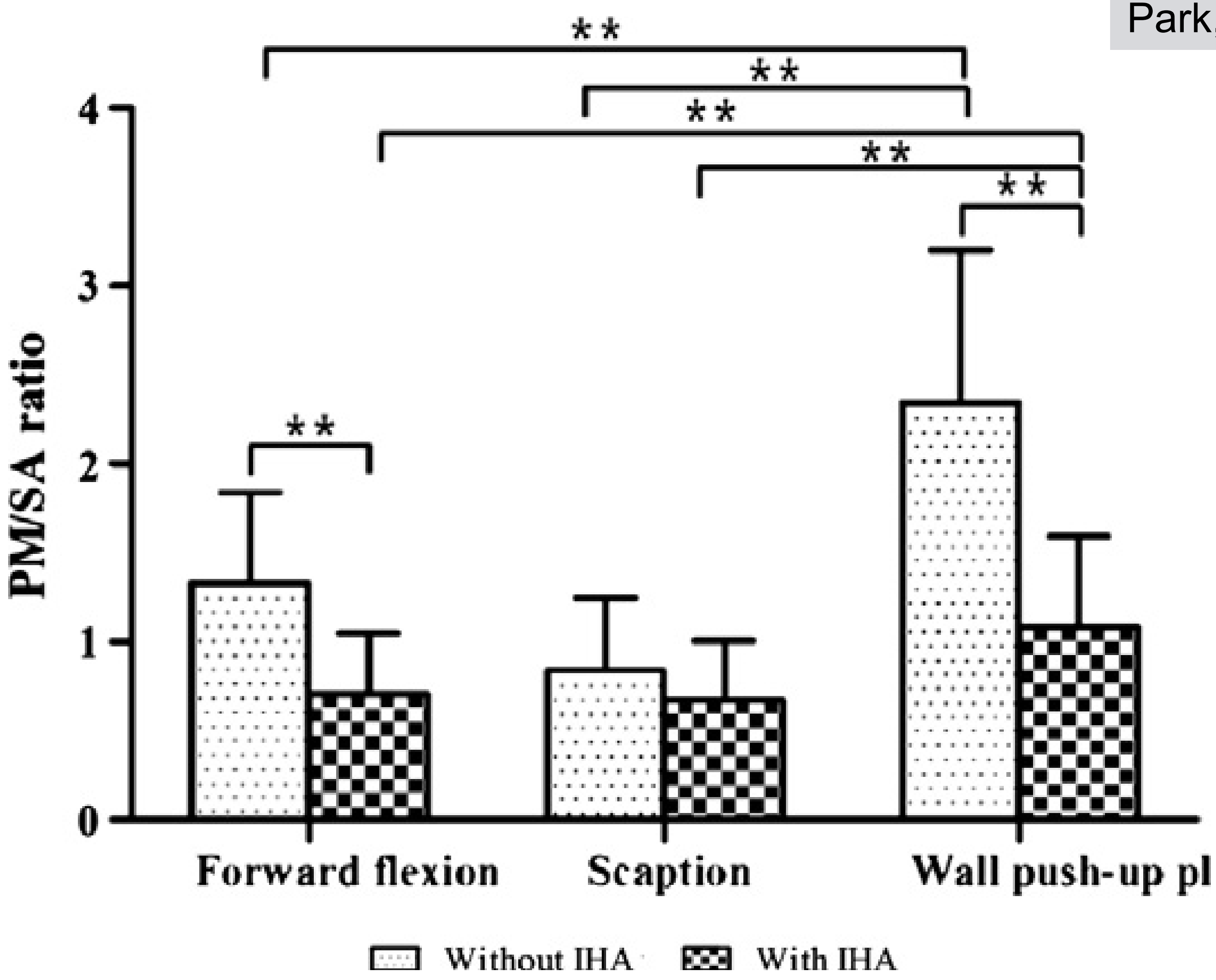
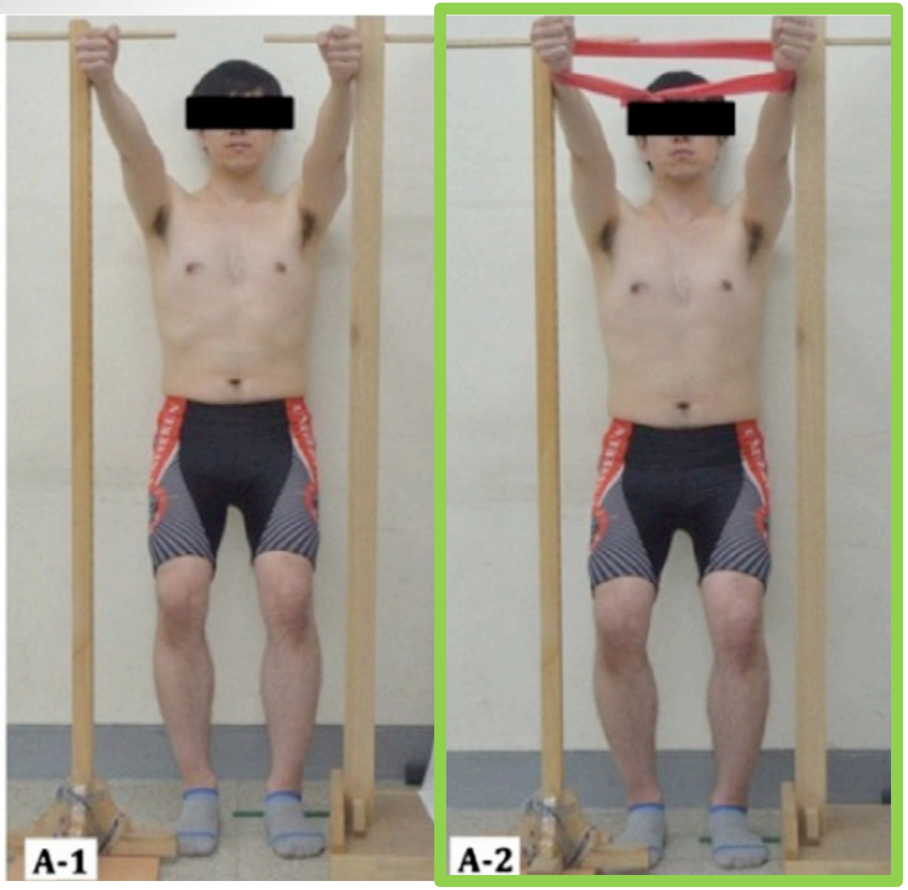


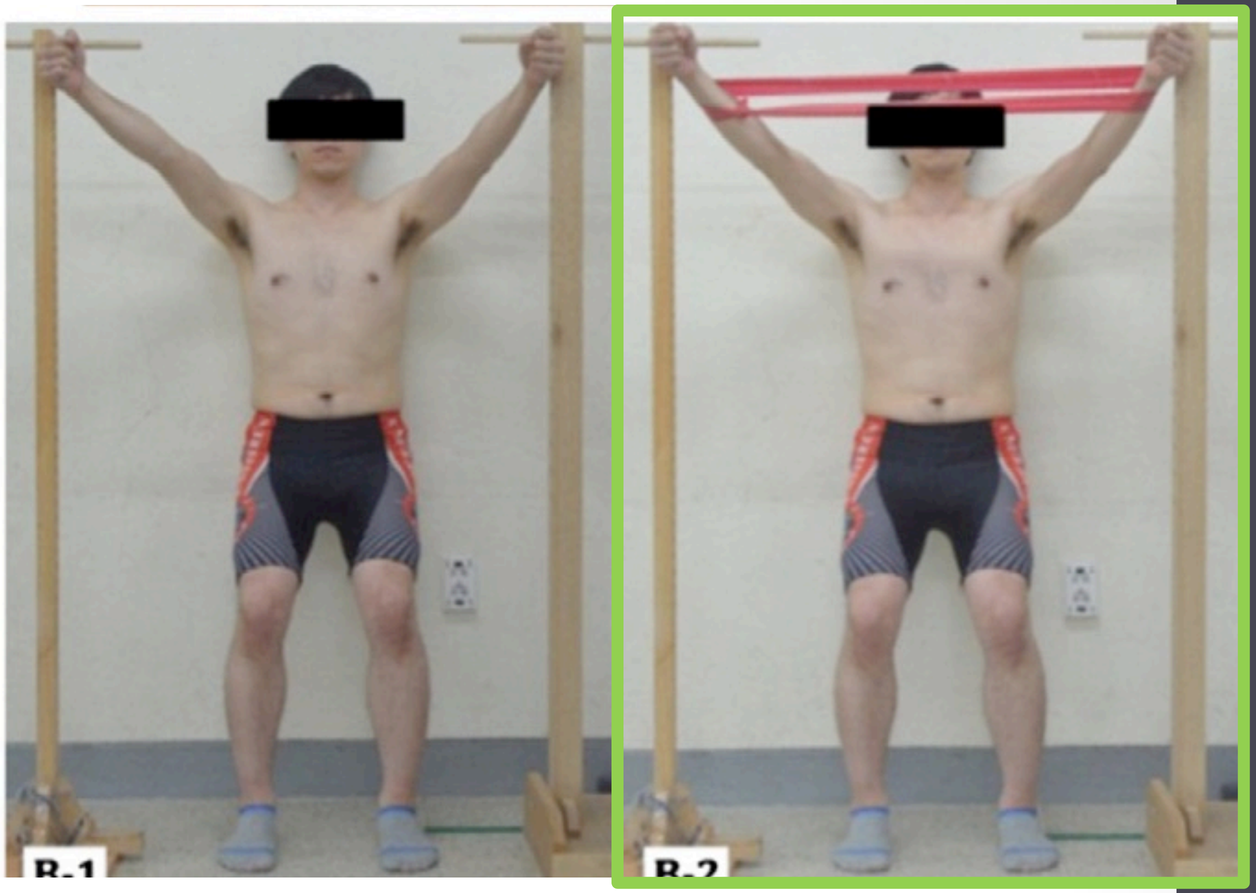
Fig. 4. Comparison of the PM/SA EMG activity ratio during the SA activation exercises with and without IHA (PM: pectoralis major, SA: serratus anterior, IHA: isometric horizontal abduction). $p < 0.008$. significant simple effect.

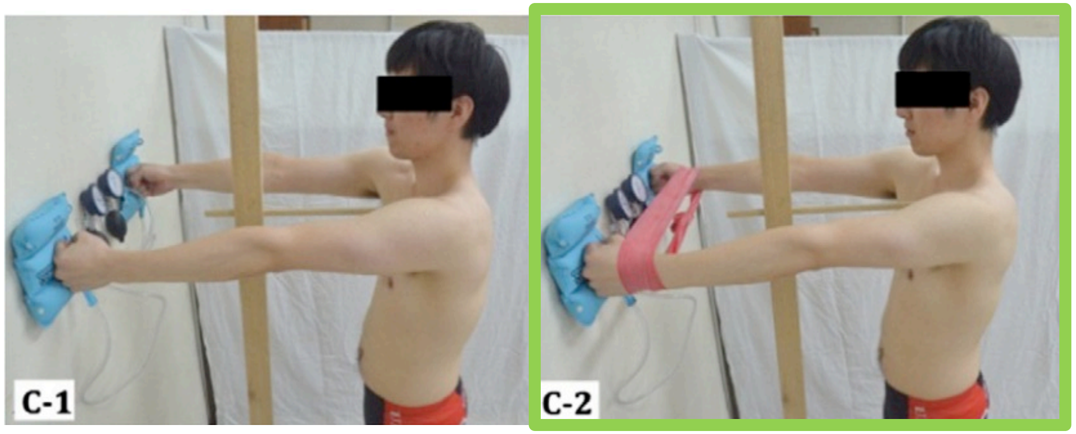
High SA activation with low PM(Major) activation

- + PM EMG activity was significantly lower during forward flexion and wall push-up plus with isometric horizontal abduction
- + SA EMG activity was significantly greater with isometric horizontal abduction
- THM: Use a Thera-band to facilitate SA activity and reduce PM activity during exercises for activating serratus anterior

Park, J Electromyo Kines, 2013







Park, J Electromyo Kines, 2013

Review Article

- 22 articles
- Exercises aimed to efficiently and maximally recruit rotator cuff and periscapular musculature
- Authors were able to establish a useful series of exercises to promote glenohumeral stability and foster normal scapulohumeral rhythm

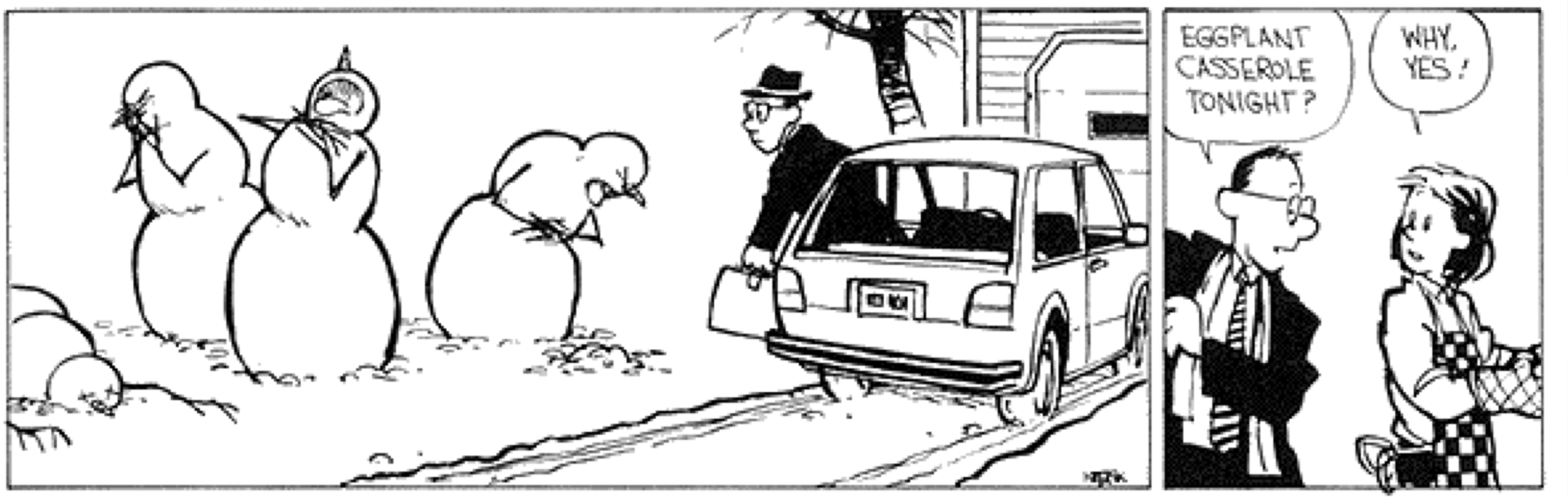
Cricchio, J Hand Ther, 2011

TABLE 3. **Periscapular Exercises**

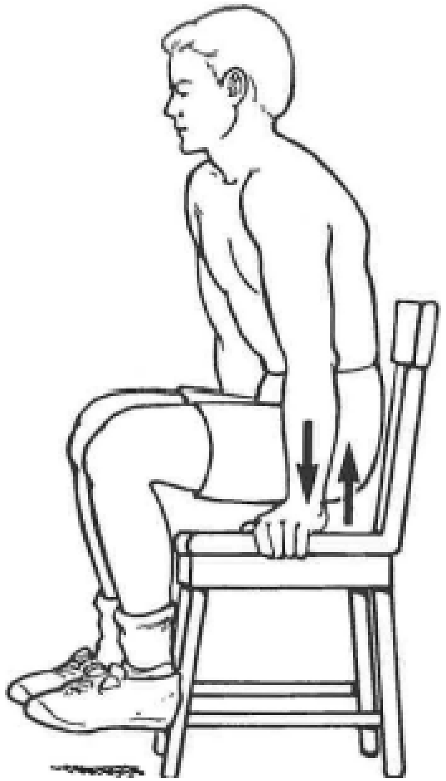
Exercise	Muscle(s)	Position
Prone extension[15,17,32]	Middle trapezius	Prone shoulder extension with elbow in full extension
Horizontal extension (abduction) with external rotation at 90°[29]	Middle trapezius	Prone horizontal abduction at 90° with full ER.
Overhead arm raise at 125°[29]	Middle and low trapezius	Prone horizontal abduction (extension) at 125° with full ER.
Inferior glide[24]	Low trapezius, serratus anterior	Seated with arm abducted to 90°, wrist neutral position, elbow extended, and fist clenched on a full supportive surface. Apply pressure in an adduction direction and inferiorly depress the scapula.
Isometric low row[24]	Low trapezius, serratus anterior	Subject stands in front of an immovable surface. The patient places hand on the edge of the surface with the palm facing posteriorly. Apply pressure to the surface; retract and depress the scapula.
Lawnmower[24]	Low trapezius, serratus anterior	Start with trunk flexed and rotated to the opposite side from the affected arm at the contralateral patella. Rotate trunk toward affected arm, while extending the hip and trunk to vertical. Affected arm then simultaneously retracts the scapula with elbow flexed.
Push-up plus[56]	Serratus anterior	Subject prone with hands shoulder width apart and chest near the ground; subject then extends elbows to a standard push-up position, then continue to rise up by protracting the scapula.
Dynamic hug[56]	Serratus anterior	Horizontal flexion of humerus at a constant 60° of humeral elevation while hands follow an imaginary arc until maximum protraction is attained.
Wall slide[30,61]	Serratus anterior	Subject stands facing wall with dominant foot at the base of the wall with opposite foot shoulder width and behind dominant foot. Ulnar portion of arms in contact with smooth wall with shoulder and elbow flexed at 90°; subject instructed to slide forearms up and down the wall.

Cricchio, J Hand Ther, 2011

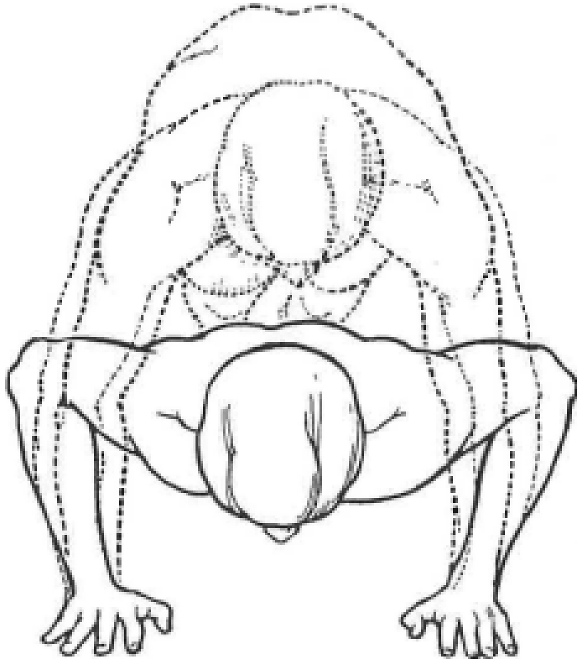
Let's wrap this up



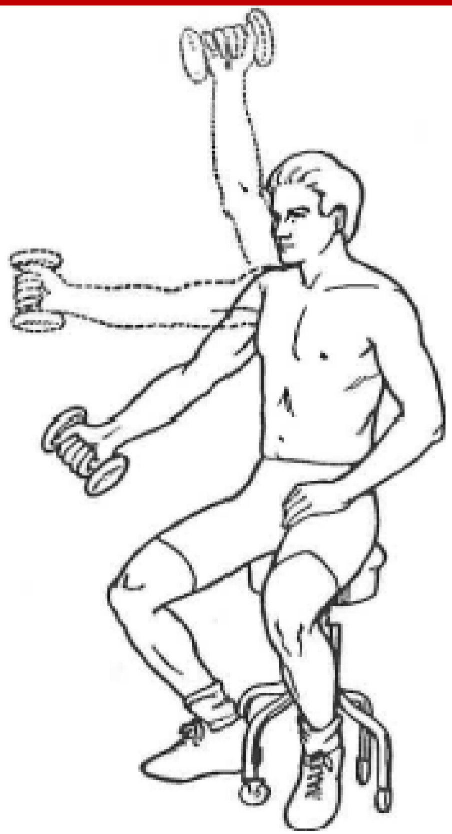
These are a good start!



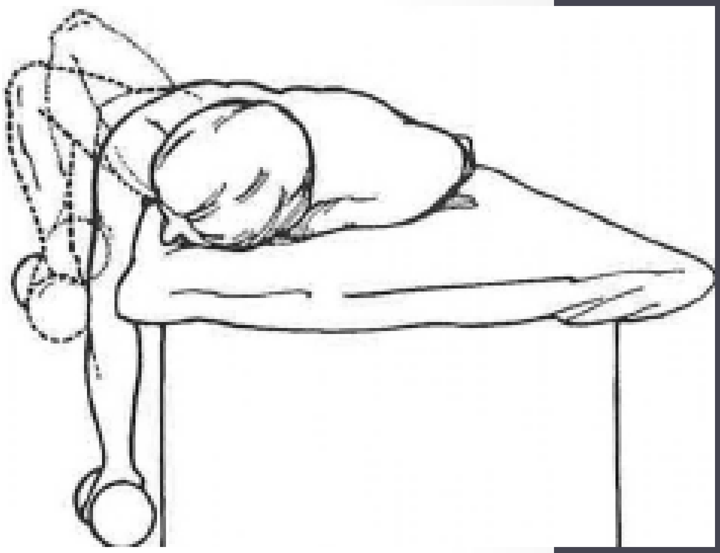
Press up



Push up with a plus



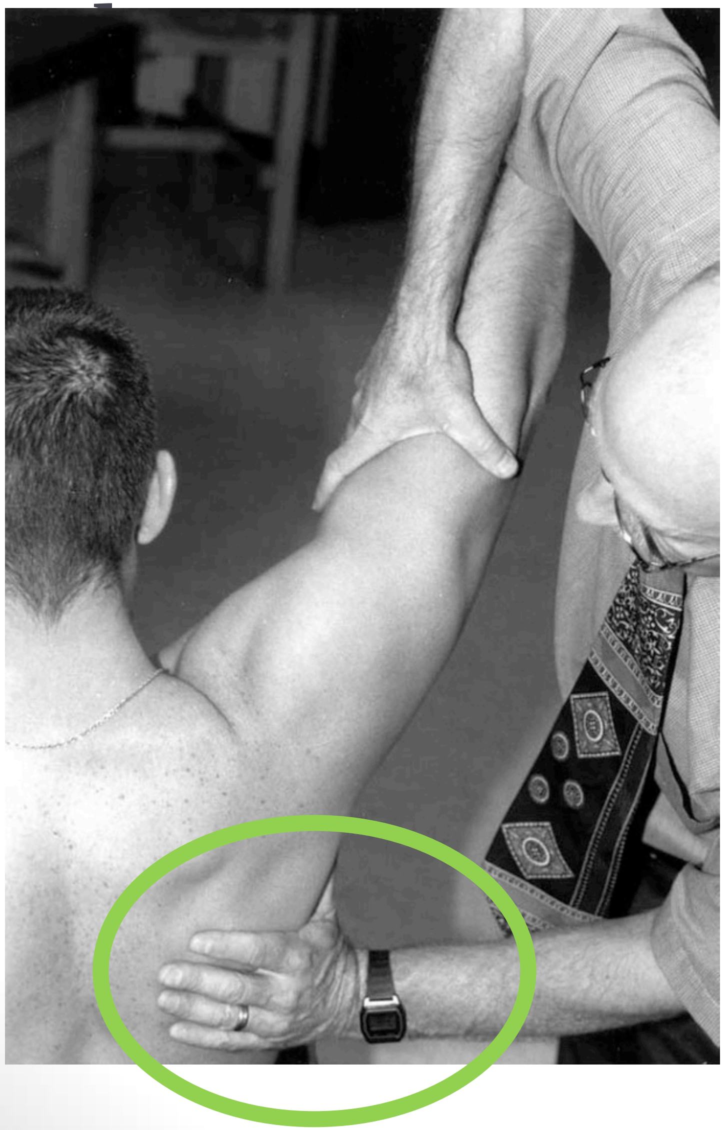
Elevation in scaption

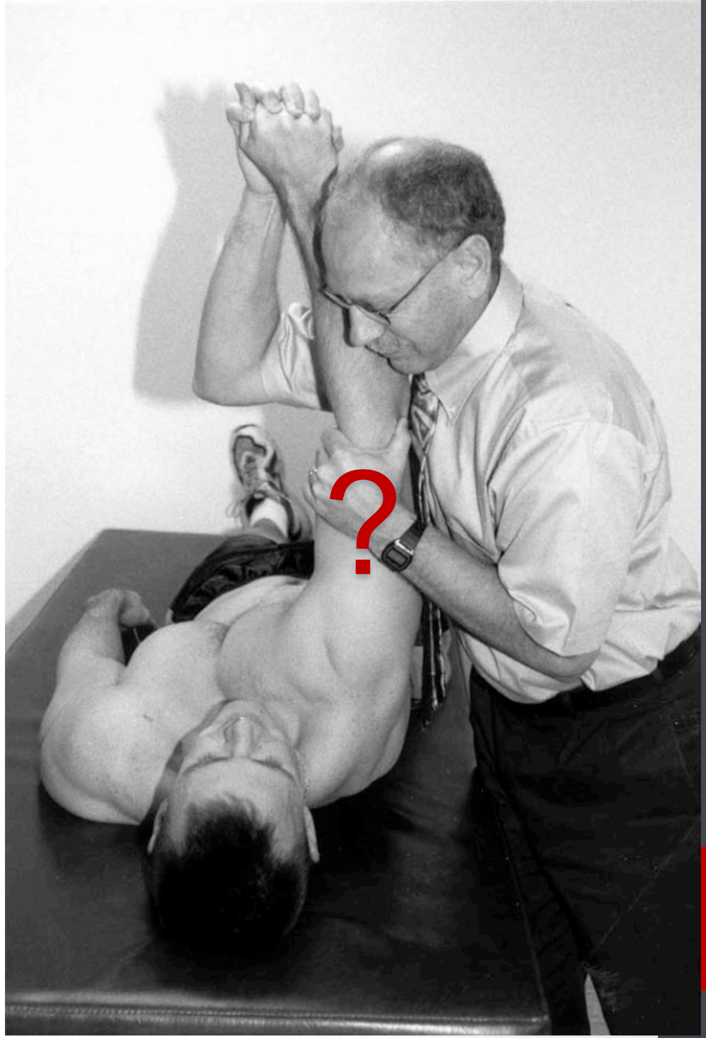


Rowing

Moseley, Am J Sports Med, 1992

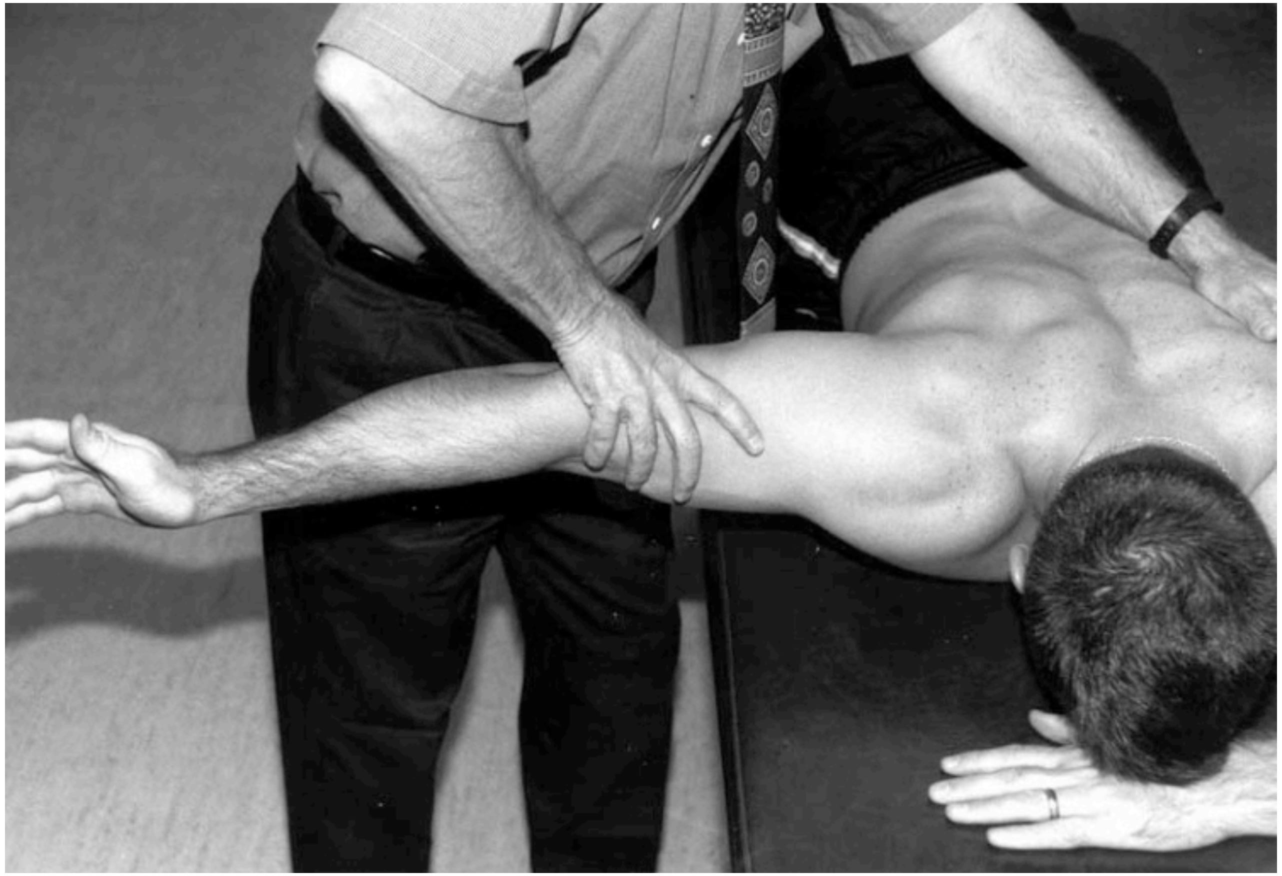
Serratus Anterior: think hand

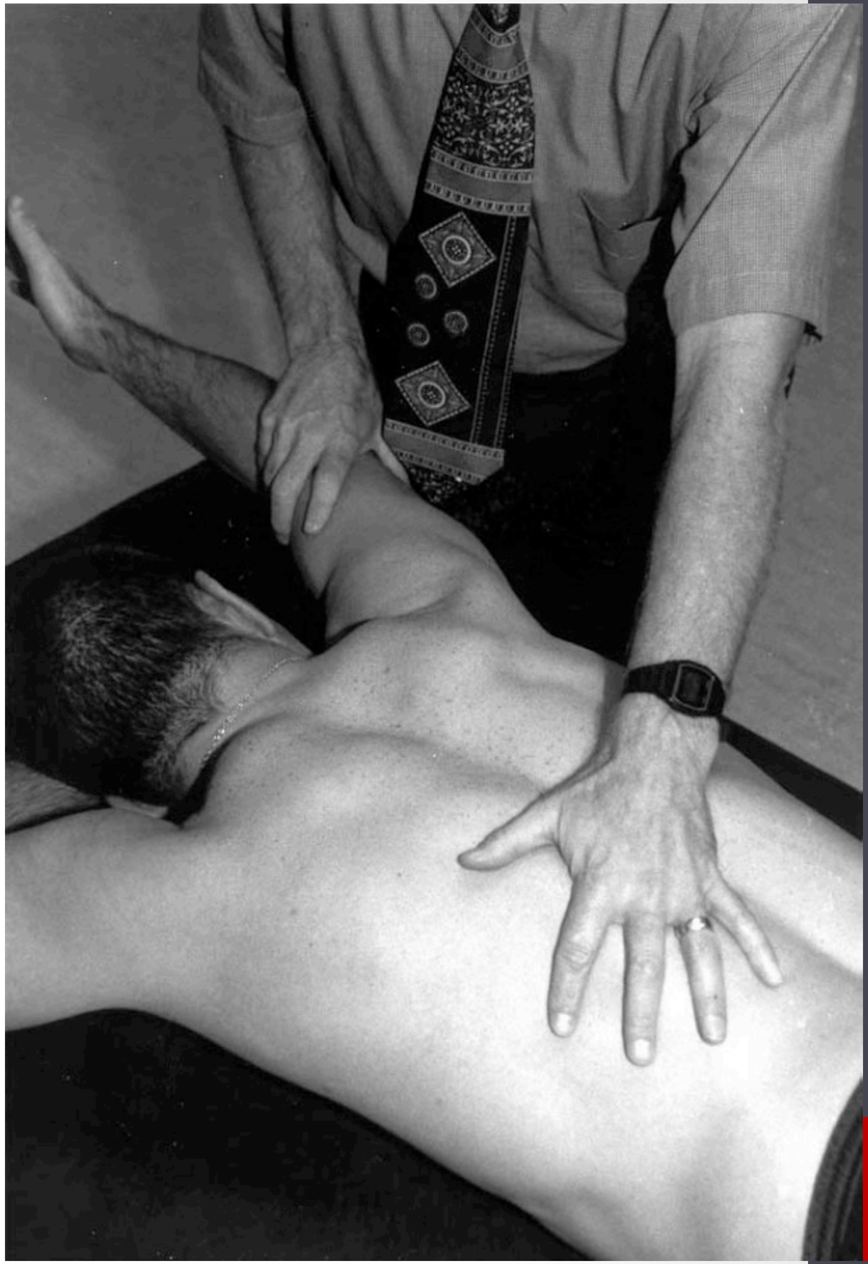




Ekstrom, Journal Electromyo Kines, 2005

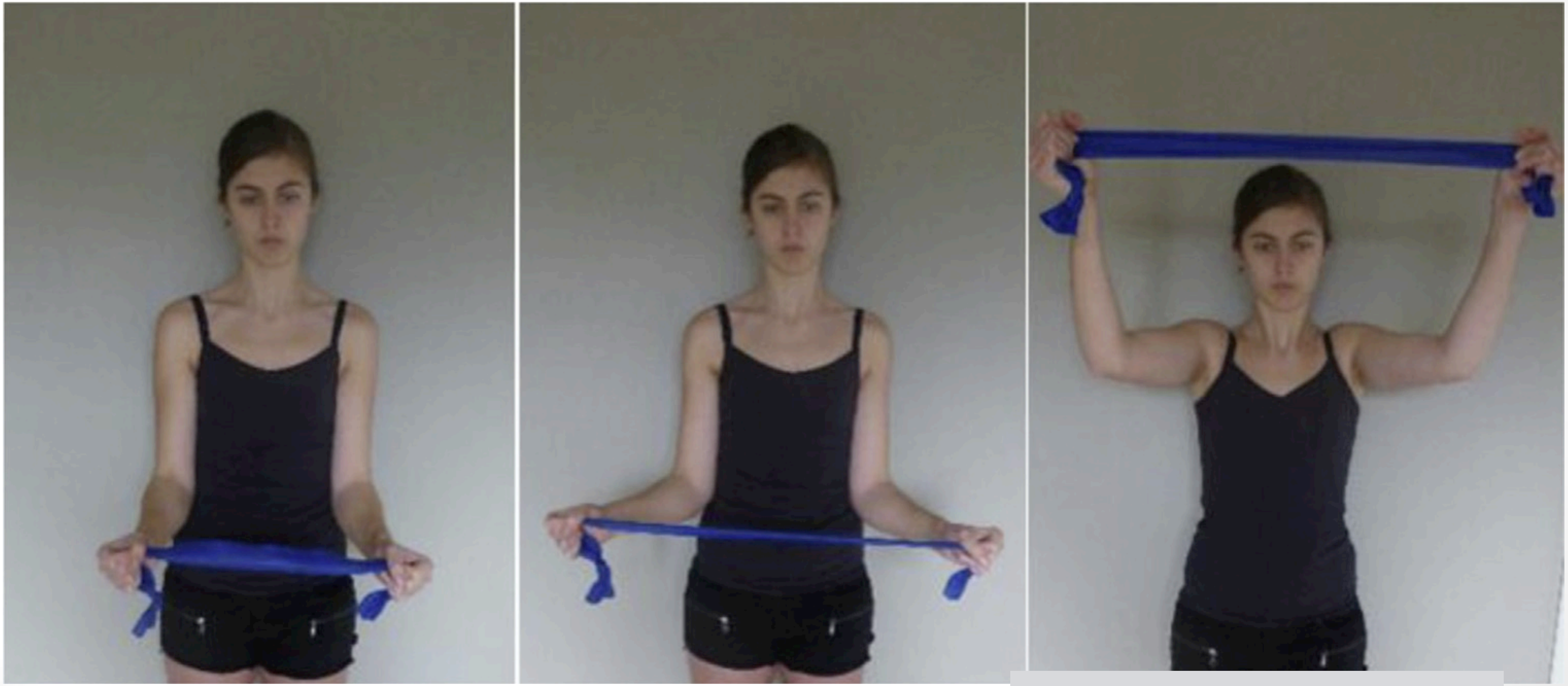
Middle Trap and Lower Trap: Getting both at the same time





Ekstrom, Journal Electromyo Kines, 2005

High SA and LT activity and low UT and PM

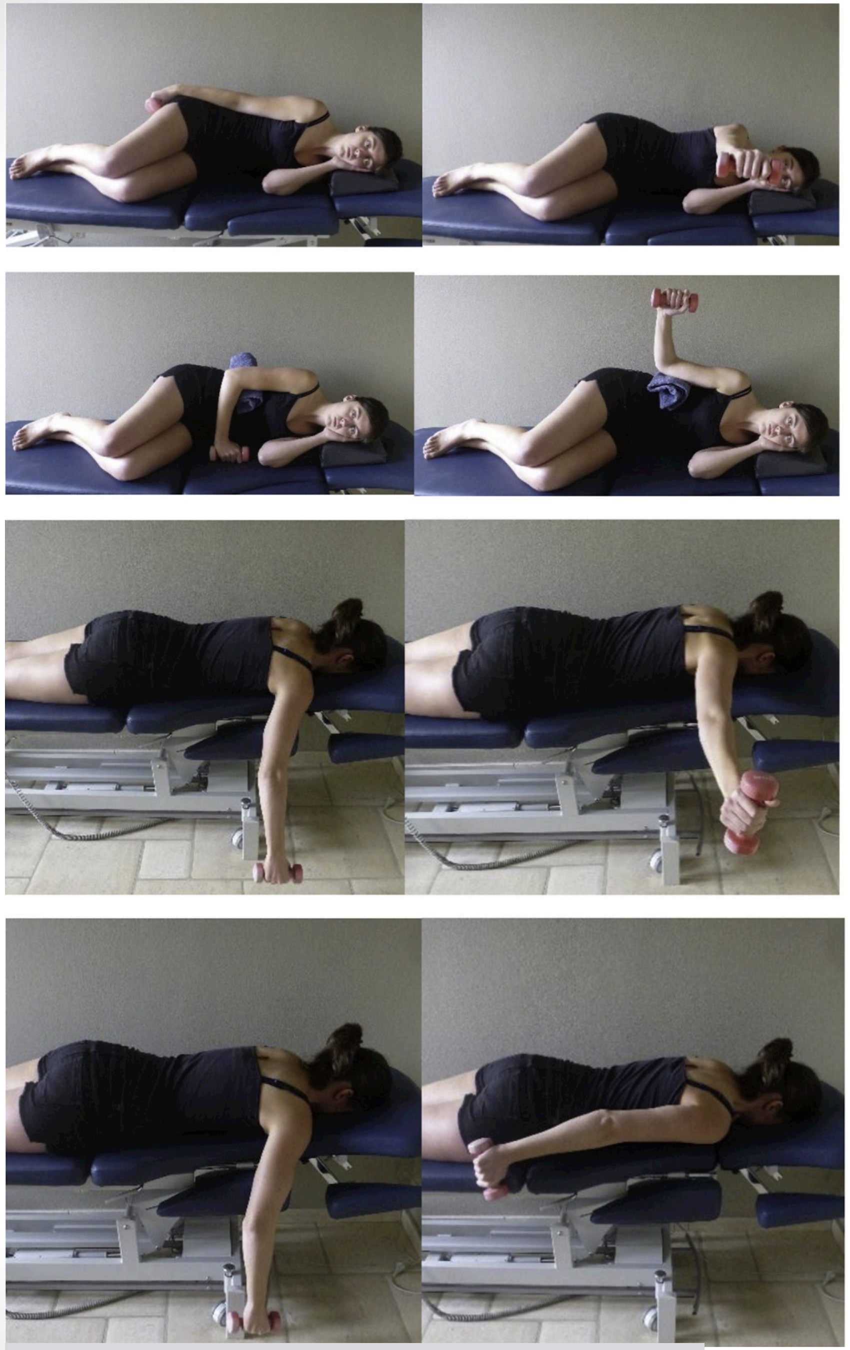


Castelein, J Hand Ther, 2017

High SA and low UT activity

Castelein, J Hand Ther, 2017

High MT and LT with low UT activity



Castelein, J Hand Ther, 2017

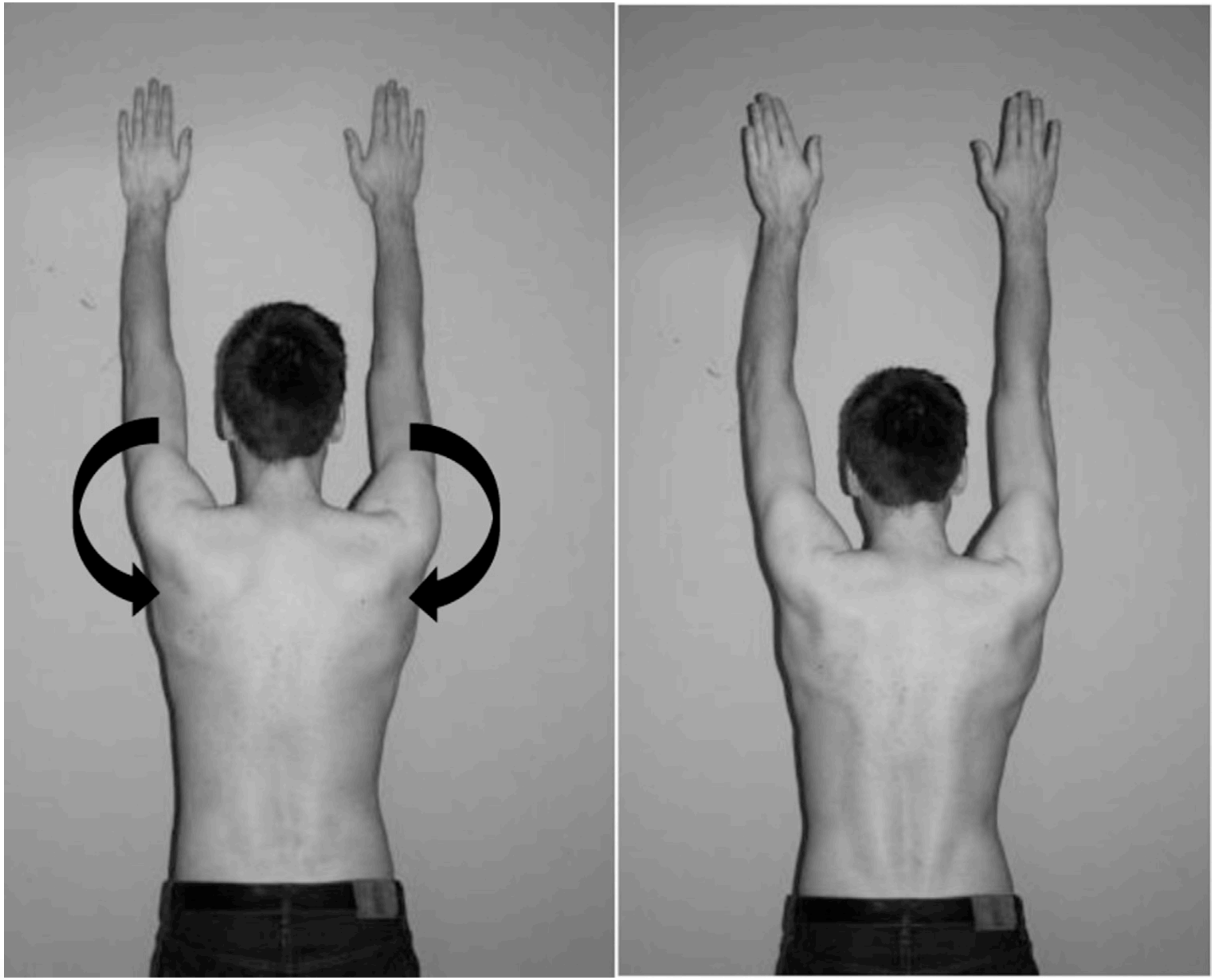
Sidelying forward flexion

Sidelying external rotation

Prone horizontal abduction with external rotation

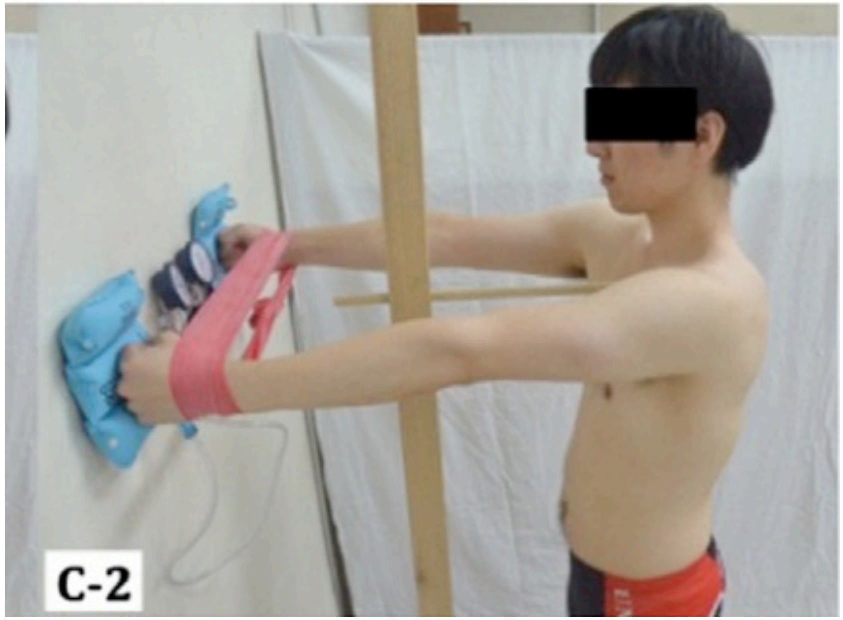
Prone extension

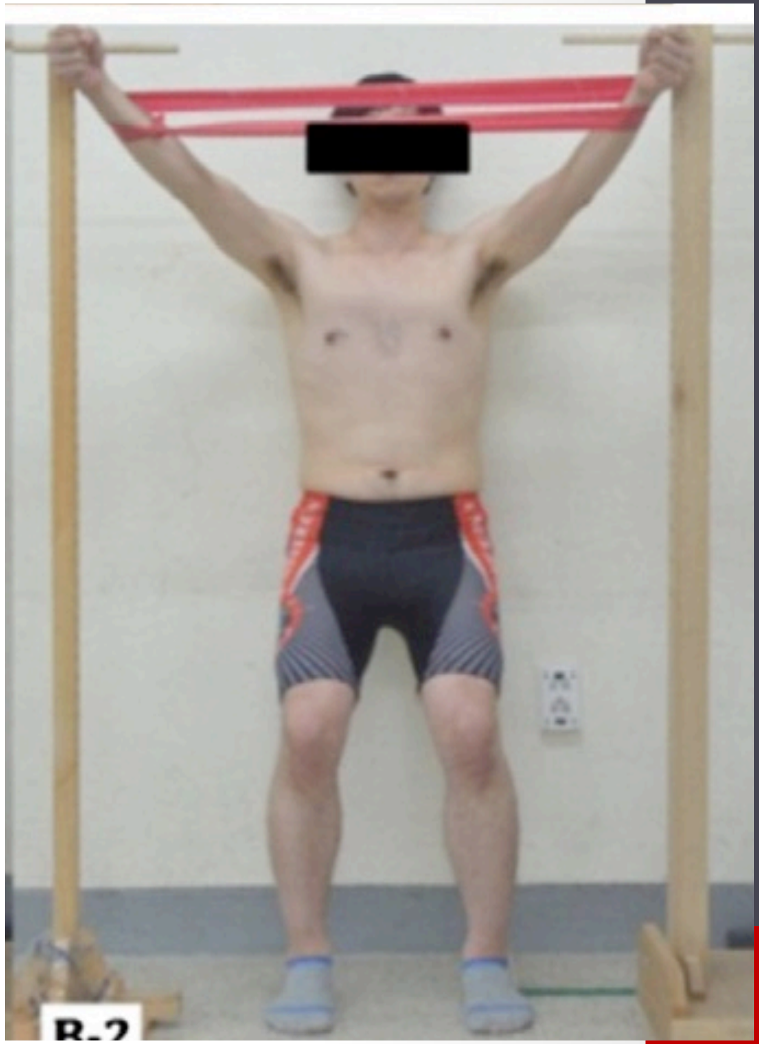
High MT, LT, and RM activity



Castelein, J Hand Ther, 2017

Use a Theraband to increase SA activity





Park, J Electromyo Kines, 2013

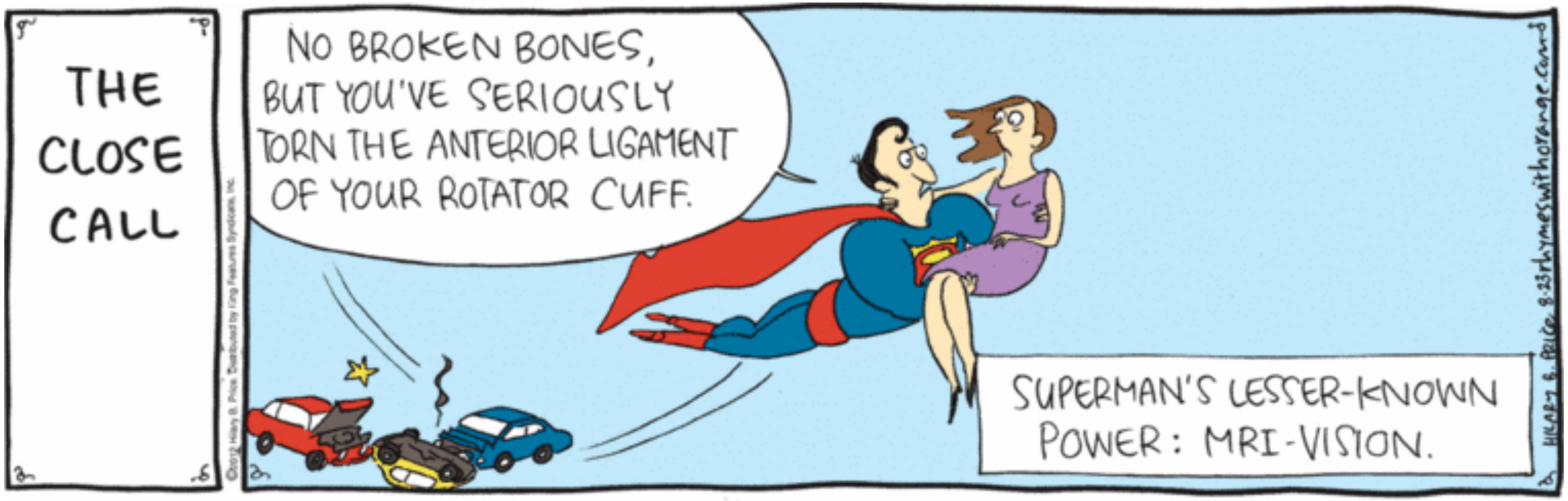
TABLE 3. **Periscapular Exercises**

Exercise	Muscle(s)	Position
Prone extension[15,17,32]	Middle trapezius	Prone shoulder extension with elbow in full extension
Horizontal extension (abduction) with external rotation at 90°[29]	Middle trapezius	Prone horizontal abduction at 90° with full ER.
Overhead arm raise at 125°[29]	Middle and low trapezius	Prone horizontal abduction (extension) at 125° with full ER.
Inferior glide[24]	Low trapezius, serratus anterior	Seated with arm abducted to 90°, wrist neutral position, elbow extended, and fist clenched on a full supportive surface. Apply pressure in an adduction direction and inferiorly depress the scapula.
Isometric low row[24]	Low trapezius, serratus anterior	Subject stands in front of an immovable surface. The patient places hand on the edge of the surface with the palm facing posteriorly. Apply pressure to the surface; retract and depress the scapula.
Lawnmower[24]	Low trapezius, serratus anterior	Start with trunk flexed and rotated to the opposite side from the affected arm at the contralateral patella. Rotate trunk toward affected arm, while extending the hip and trunk to vertical. Affected arm then simultaneously retracts the scapula with elbow flexed.
Push-up plus[56]	Serratus anterior	Subject prone with hands shoulder width apart and chest near the ground; subject then extends elbows to a standard push-up position, then continue to rise up by protracting the scapula.
Dynamic hug[56]	Serratus anterior	Horizontal flexion of humerus at a constant 60° of humeral elevation while hands follow an imaginary arc until maximum protraction is attained.
Wall slide[30,61]	Serratus anterior	Subject stands facing wall with dominant foot at the base of the wall with opposite foot shoulder width and behind dominant foot. Ulnar portion of arms in contact with smooth wall with shoulder and elbow flexed at 90°; subject instructed to slide forearms up and down the wall.

Cricchio, J Hand Ther, 2011

Thanks!

Let's talk Rotator Cuff



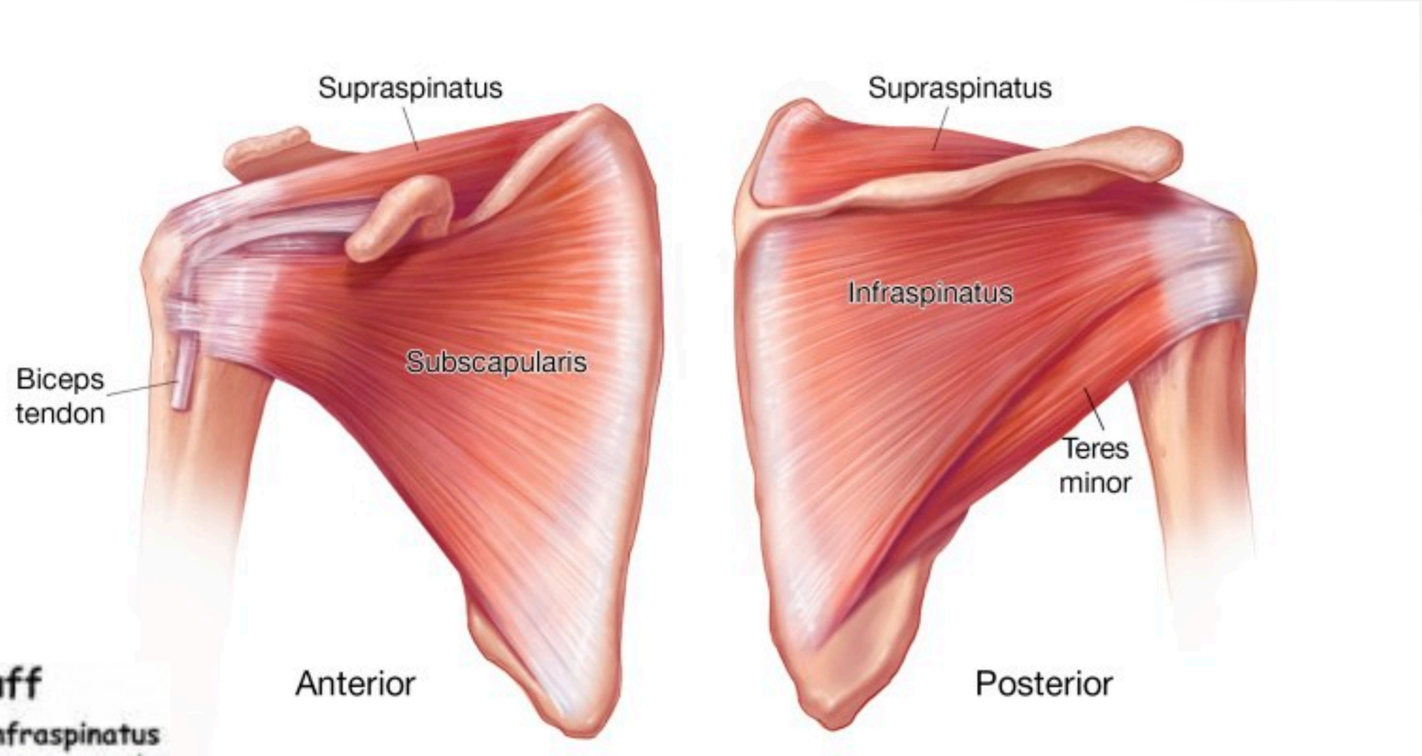
First…….

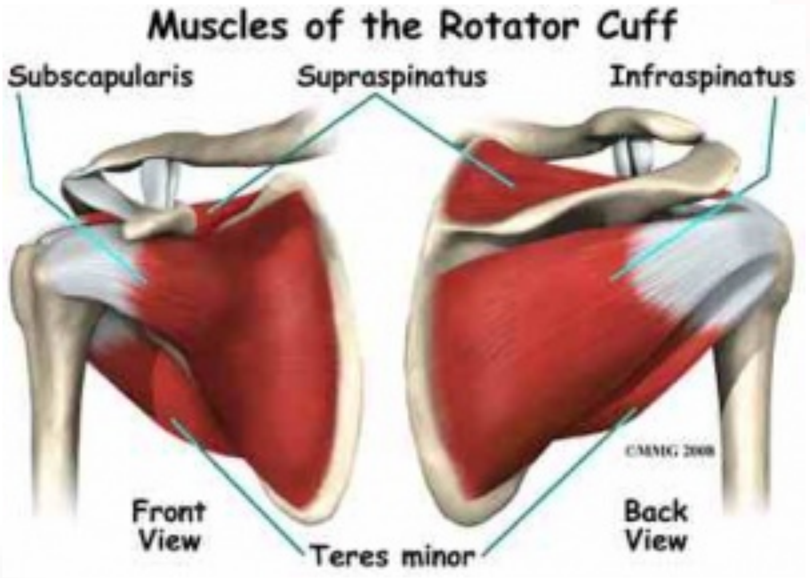
- EMG is typically expressed as a %MVIC (percentage of the maximal voluntary isometric contraction)
  - Low-level muscle activation: 0–20% MVIC
  - Moderate-level activation: 21–40% MVIC
  - High-level activation: 41–60% MVIC
  - Very high-level activation: > 60% MVIC

- Contaminate the desired muscle’s EMG signal with that of nearby muscles (i.e., cross-talk)

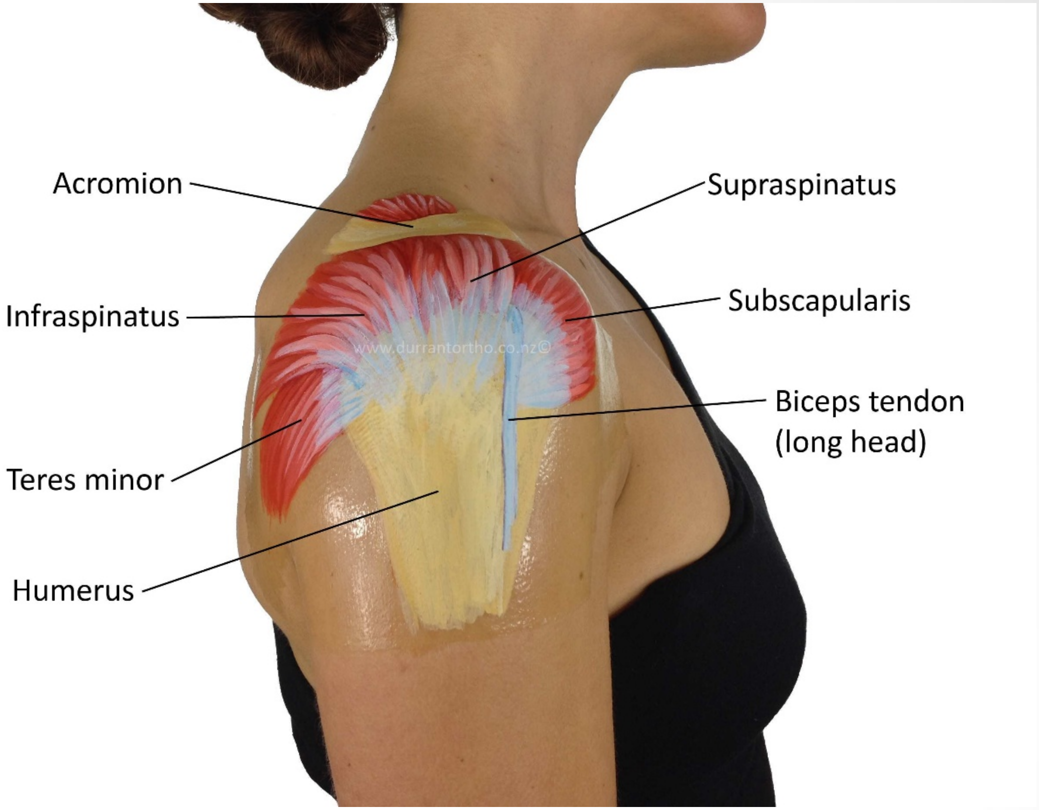
Escamilla, JOSPT, 2010

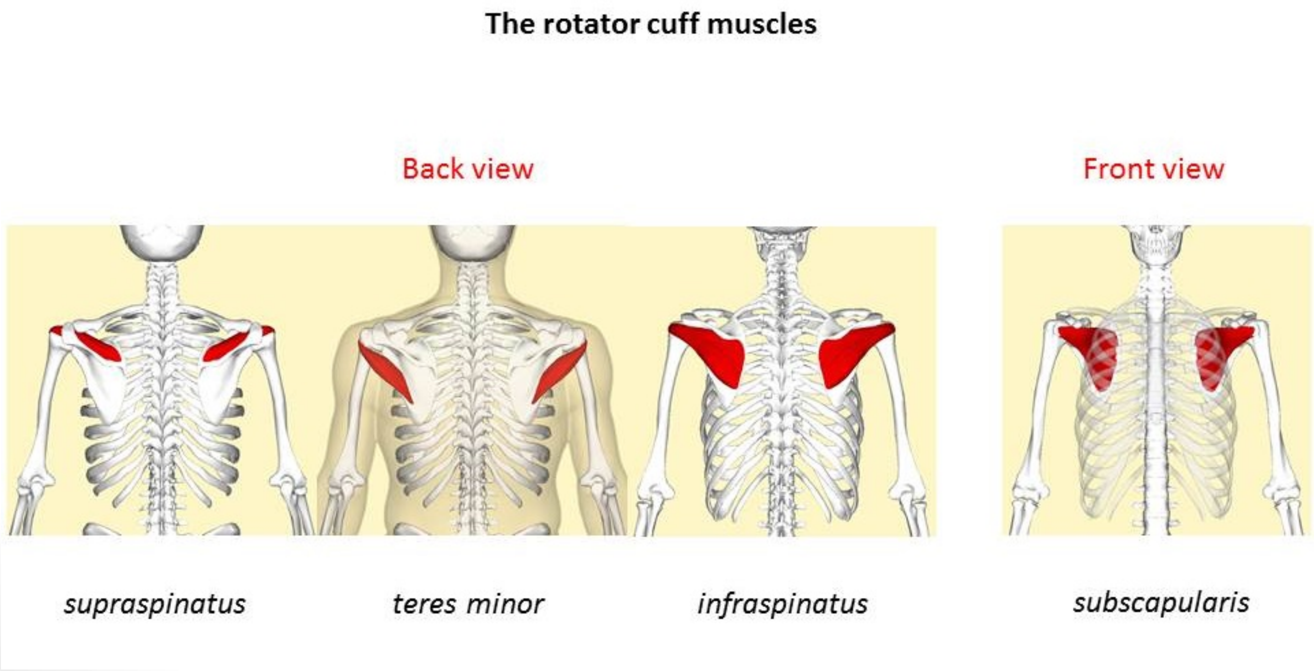
Rotator Cuff Muscles





Anatomy


Acromion
Supraspinatus
Infraspinatus
Subscapularis
Biceps tendon
(long head)
Teres minor
Humerus


The rotator cuff muscles
Back view
Front view
supraspinatus
teres minor
infraspinatus
subscapularis

Rotator Cuff Muscles: *Supraspinatus*

- **Medial Attachment:** Supraspinous fossa of scapula
- **Lateral Attachment:** Greater tubercle of humerus
- **Innervation:** Suprascapular nerve

- **Action:** Initially abducts the arm, stabilizes humeral head

https://rad.washington.edu/muscle-atlas/supraspinatus/

Rotator Cuff Muscles: *Infraspinatus*

- **Medial Attachment:** Infraspinous fossa of scapula
- **Lateral Attachment:** Greater tubercle of humerus
- **Innervation:** Suprascapular nerve
- **Action:** Laterally rotates arm; stabilizes humeral head

https://rad.washington.edu/muscle-atlas/supraspinatus/

Rotator Cuff Muscles: *Subscapularis*

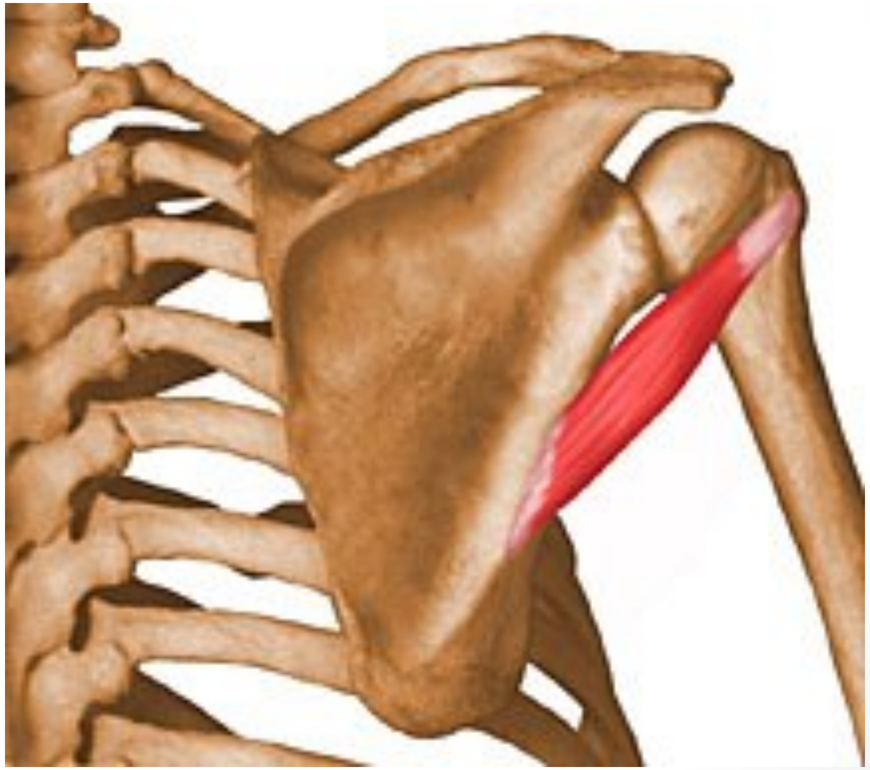
- **Medial Attachment:** Subscapular fossa of scapula
- **Lateral Attachment:** Lesser tuberosity of humerus
- **Innervation:** Subscapular nerve

- **Action:** Medially rotates arm and adducts; stabilizes humeral head

https://rad.washington.edu/muscle-atlas/supraspinatus/

Rotator Cuff Muscles: *Teres Minor*

- **Proximal Attachment:** Inferior facet on greater tuberosity of humerus
- **Distal Attachment:** Superior part of lateral border of scapula
- **Innervation:** Axillary nerve
- **Action:** Laterally rotates arm, stabilizes humeral head



https://rad.washington.edu/muscle-atlas/supraspinatus/

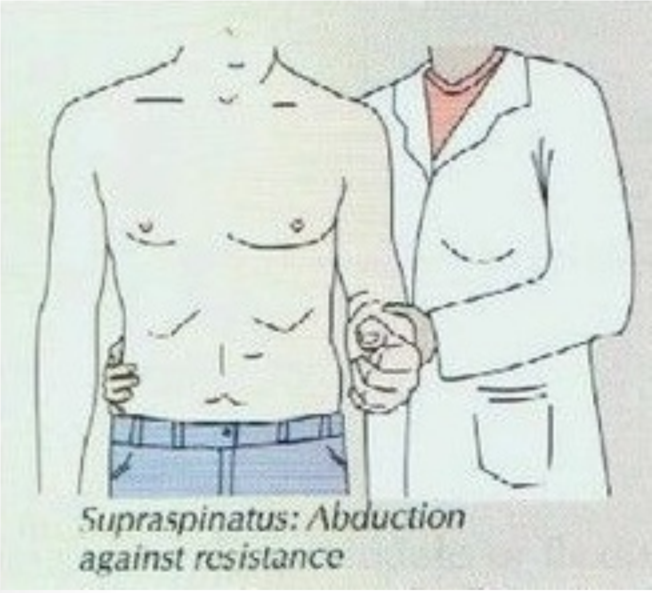
Rotator Cuff MMTs

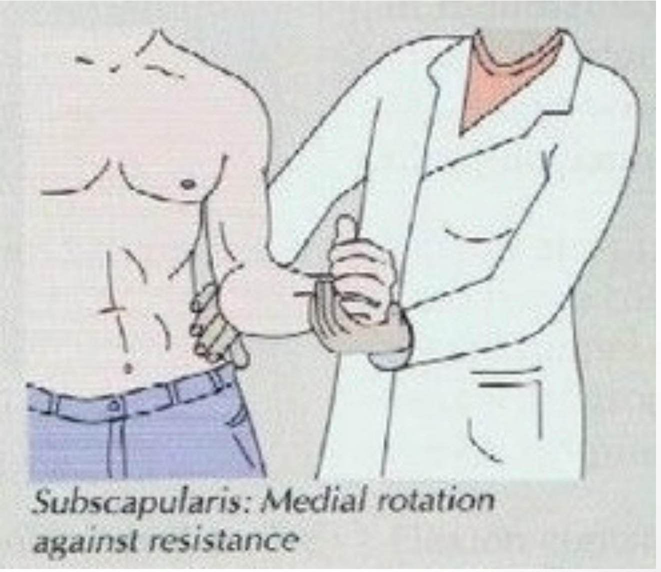
Supraspinatus: Abduction against resistance

Infraspinatus: Lateral rotation against resistance

Subscapularis: Medial rotation against resistance

Teres Minor: Lateral rotation against resistance





Clinical Pearl

Sciascia et al, Br J Sport Med, 2010 AND Hurov et al, J of Hand Therapy, 2009

- Compared to other body regions which often rely on *ligamentous* and passive support from *bony structures*, scapular stability is achieved actively by supporting musculature
- This includes the upper, middle and lower trapezius and the serratus anterior (UT, MT, LT and SERR, respectively).
- **AND,** the rotator cuff which is critical in maintaining glenohumeral stability by compressing the humeral head congruently against the scapular glenoid.

These two muscle groups (rotator cuff and periscapular muscles) work concurrently to create a functional kinetic chain.

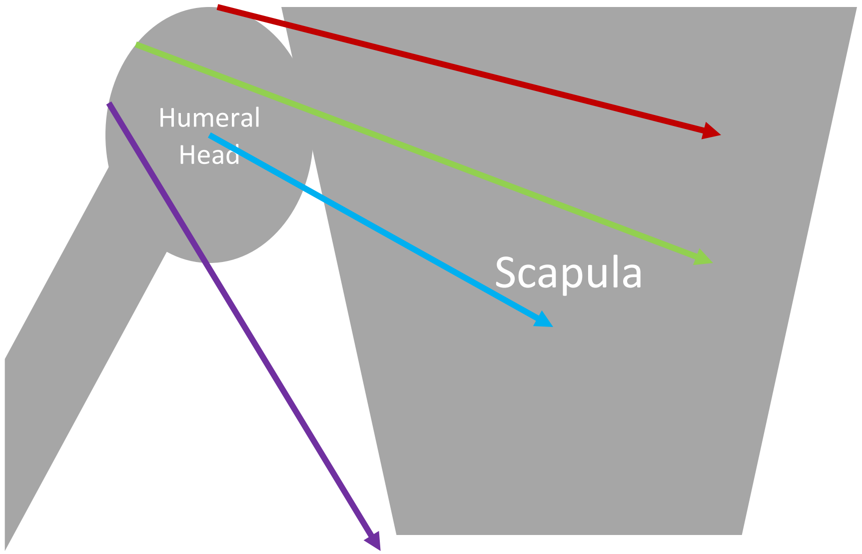
- Rotator Cuff Muscles account for **66-85%** of all shoulder cases evaluated.

De Oliveria et al, J Elect and Kines, 2017

Rotator Cuff Importance

Rotator cuff muscle provide dynamic compressive forces to keep the humeral head seated in the concave glenoid fossa.

- Supraspinatus
- Infraspinatus
- Subscapularis
- Teres Minor



Cricchio et al, J Hand Ther, 2011

Which Exercises?

Reminder…….

- EMG is typically expressed as a %MVIC (percentage of the maximal voluntary isometric contraction)
  - Low-level muscle activation: 0–20% MVIC
  - Moderate-level activation: 21–40% MVIC
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Escamilla, JOSPT, 2010

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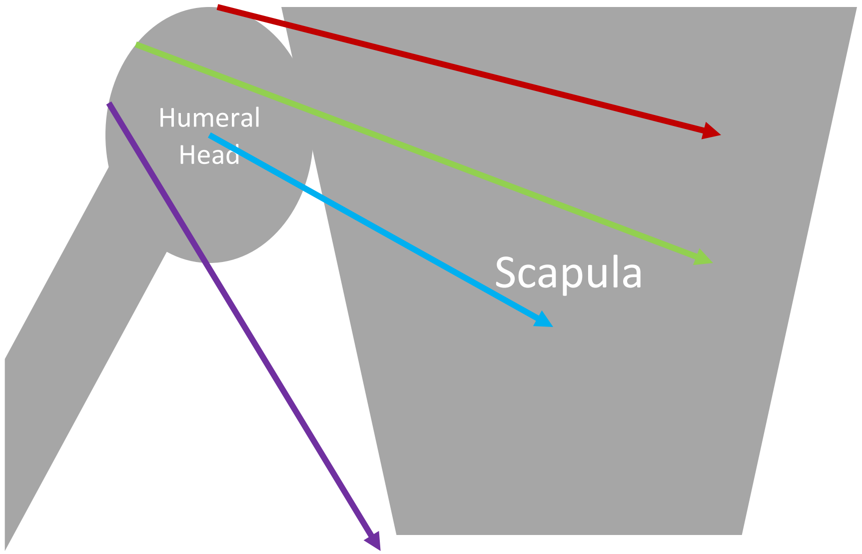


Cricchio et al, J Hand Ther, 2011

Rotator Cuff Muscles: *Supraspinatus*

- 4 pairs of fine wire EMG electrodes
- 31 healthy participants

Arm posture influences on regional supraspinatus and infraspinatus activation in isometric arm elevation efforts☆

Talia Alenabi[a], Rachel L. Whittaker[a], Soo Y. Kim[b], Clark R. Dickerson[a,*]

[a] University of Waterloo, Faculty of Applied Health Sciences, Department of Kinesiology, Digital Industrial Ergonomics and Shoulder Evaluation Laboratory (DIESEL), Waterloo, Ontario, Canada
[b] School of Physical Therapy, College of Medicine, University of Saskatchewan, Saskatoon, Canada

- 18 isometric resistance exercises against a force cube in flexion, scaption and abduction at 30, 90 and 150 degrees

Supraspinatus "Anterior" was significantly more active during abduction and scaption and in higher elevation angles.

Alenabi et al, J Electromyogr Kinesiol, 2018

Rotator Cuff Muscles: *Supraspinatus*

- 15 MVIC, randomized order, held for 5s with 1-2min rest in between
- 9 testing postures were examined at 3 elevations
- Participants completed 1 maximum voluntary force (MVF) and 1 submaximal force (50% MVF) at each posture

Table 1
MVIC tests: explanation of the test positions*

Test Name	Description
Flexion (90°)	Seated, arm flexion in 90° is resisted
Abduction (90°)	Seated, arm abduction in 90°is resisted
Prone Ext (90°)	Prone lying, arm abducted 90°, externally rotated, palm up, and arm elevation is resisted
Fullcan (60°)	Seated, arm elevated 60° in scapular plane, thumb is up; resistance is applied downward on the arm
Fullcan (90°)	Seated, arm elevated 90° in scapular plane, thumb up; resistance is applied downward on the arm
Emptycan (60°)	Seated, arm elevated 60° in scapular plane, thumb down; resistance is applied downward on the arm
Emptycan (90°)	Seated, arm elevated 90° in scapular plane, thumb down; resistance is applied downward on the arm
Sit ER (0°)	Seated, arm beside the body, elbow flexed 90°, external rotation is resisted
Sit ER (45°)	Seated, arm in 45°abduction, elbow flexed 90°, external rotation is resisted
Sit ER (90°)	Seated, arm in 90°abduction, elbow flexed 90°, external rotation is resisted
Sit ER (110°)	Seated, arm in 90°abduction, elbow flexed 90°, external rotation is resisted
Prone ER (90°)	Prone lying, arm abducted 90°, palm facing the floor; external rotation is resisted
Side ER (0°)	Left side lying, arm close to the body, elbow flexed 90, external rotation is resisted
Side Abduction (10°)	Left side lying, arm abducted 10°, resistance applied downward on the right arm
Side Abduction (45°)	Left side lying, arm abducted 45°, resistance applied downward on the right

ER = external rotation, Ext = extension.
* = reported by Alenabi et al. (2018).

Alenabi et al, J Electromyogr Kinesiol, 2018

Rotator Cuff Muscles: *Supraspinatus*

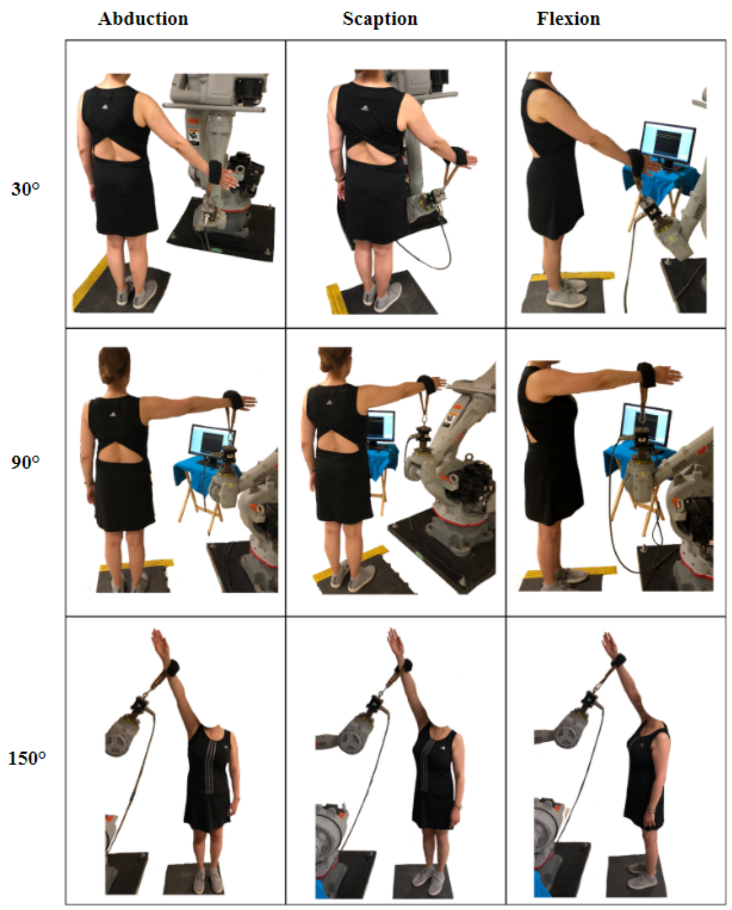


Fig. 1. Experiment design with robotic arm. The participants exerted force perpendicular to the midpoint of the force transducer.

Alenabi et al, J Electromyogr Kinesiol, 2018

Rotator Cuff Muscles: *Supraspinatus*

Table 3
Mean rotator cuff muscle activation (%MVE) at 50% MVF collapsed across planes and angles. A significant difference between means is shaded in grey and further noted by a letter. The bolded values indicate the means that are significantly higher, the letter "a" indicates a significantly larger mean than that at 30° of elevation. The letter "b" indicate [illegible] at in the abduction plane.

“High” Category

Muscle	Angle			Plane		
	30°	90°	150°	Abduction	Flexion	Scaption
Supraspinatus Anterior	28 (1.8)	**41.9 (2.[illegible])** [a]	[illegible] [a]	[illegible]	[illegible]	[illegible]
Supraspinatus Posterior	38.4 (2.6)	42.6 (2[illegible]				
Infraspinatus Superior	22.5 (2.1)	27.9 (2[illegible]				
Infraspinatus Middle	26.6 (2.9)	28.7 ([illegible]				

T. Alenabi et al. *Journal of Electromyography and Kinesiology 44 (2019) 108–116*

Table 4
Mean rotator cuff muscle activation (%MVE) at 100% MVF collapsed across planes and angles. A significant difference between means is shaded in grey and further noted by a letter. The bolded values indicate the means that are significantly higher, the letter "a" indicates a significantly larger mean than that at 30° of elevation. The letter "b" indicates a significantly larger mean than that in the abduction plane.

Muscle	Angle			Plane		
	30°	90°	150°	Abduction	Flexion	Scaption
Supraspinatus Anterior	47.4 (2.9)	**66.7 (3.3)** [a]	**65.4 (3.9)** [a]	60.9 (2.5)	56.8 (2.9)	61.8 (3.5)
Supraspinatus Posterior	63 (4.7)	65.8 (4.1)	60.3 (3.9)	64.1 (3.9)	61.9 (3.2)	63.1 (3.6)
Infraspinatus Superior	44.1 (4)	52.2 (3.3)	47.4 (4.[illegible]	[illegible]	[illegible]	49.2 (3.6)
Infraspinatus Middle	41.2 (3.7)	51.4 (4.5)	54.9 (4.3)	43.9 (3.6)	**52.6 (3.8)** [b]	50.9 (3.8)

“Very High” Category

Alenabi et al, J Electromyogr Kinesiol, 2018

Rotator Cuff Muscles: *Supraspinatus*

- Take Home:
  - Anterior region of the Supraspinatus accounts for over 75% of the supraspinatus muscle
  - More relative activation at 90% elevation
  - Abduction and scaption could generate more activation than flexion

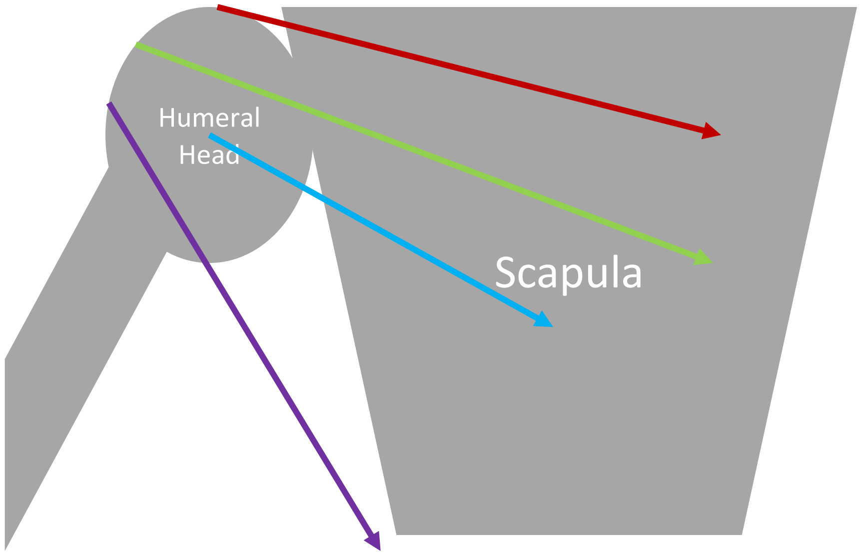
Maximally resisted abduction or scaption at 90 degrees (Full Can Posture) can better elicit more supraspinatus anterior activation.

Alenabi et al, J Electromyogr Kinesiol, 2018

Rotator Cuff Importance

Rotator cuff muscle provide dynamic compressive forces to keep the humeral head seated in the concave glenoid fossa.

- Supraspinatus
- Infraspinatus
- Subscapularis
- Teres Minor



Cricchio et al, J Hand Ther, 2011

Rotator Cuff Muscles: *Supraspinatus and Infraspinatus*

- Intramuscular EMG for supraspinatus (anterior and posterior) and infraspinatus (superior and middle)
- 27 right handed healthy volunteers
- 4 elastic band exercises (Y, T, W and L)

American Journal of Physical Medicine & Rehabilitation Articles Ahead of Print
DOI: 10.1097/PHM.0000000000001116

Activation of Supraspinatus and Infraspinatus Partitions and Periscapular Musculature during Rehabilitative Elastic Resistance Exercises

Ranjit Joseph, MSc,[1] Talia Alenabi, MD, PhD,[1] Tea Lulic, MSc,[1] Clark R. Dickerson, PhD[1]

Joseph et al, Am J of Phy Med & Rehab, 2018

Rotator Cuff Muscles: *Supraspinatus and Infraspinatus*

"High" Category

- Mean activations of all rotator cuff partitions (supraspinatus anterior and posterior AND infraspinatus superior and middle) were all over 40% MVIC.

- *EXCEPT*: Infraspinatus Middle during T-exercise.

Joseph et al, Am J of Phy Med & Rehab, 2018

Rotator Cuff Muscles: *Supraspinatus and Infraspinatus*

Figure 1

Joseph et al, Am J of Phy Med & Rehab, 2018

Rotator Cuff Muscles: *Supraspinatus and Infraspinatus*

"High" Category

Table 2. Mean peak activation of shoulder musculature (%MVIC ± SD) during Y, T, W and L Theraband exercises. Bold numbers indicate the activations that are significantly different from the superscripted exercises (y, t, w and l), * indicates that the values were not normally distributed and Wilcoxon non-parametric tests were used for analysis.

Muscle	Y	T	W	L
Supraspinatus Anterior	50.5 ± 23.8	41.0 ± 27.5	48.1 ± 22.7	48.4 ± 23.3
Supraspinatus Posterior	50.5 ± 34.3	42.3 ± 23.5	42.3 ± 23.2	49.9 ± 27.5
Infraspinatus Superior	42.0 ± 28.7	41.0 ± 27.5	48.8 ± 34.6	50.6 ± 31.4
Infraspinatus Middle	**41.9 ± 24.7** F=7.16, df = 22 (p= 0.002)^t	**29.3 ± 20.9** F=7.16, df = 22 (p=0.002)^y, (p = 0.006)^l	38.9 ± 23.4	**44.2 ± 23.9** F=7.16, df = 22 (p =0.006)^t
Upper Trapezius	**64.6 ± 26.0** F=19.5, df = 23 (p < 0.008)^w, (p < 0.008)^l	**59.8 ± 21.0** F=19.5, df = 23 (p < 0.008)^w, (p = 0.005)^l	**39.5 ± 20.0** F=19.5, df = 23 (p < 0.008)^y , (p = 0.005)^t	**44.6 ± 17.9** F=19.5, df = 23 (p < 0.008)^y, (p = 0.005)^t
Middle Trapezius*	**56.6 ± 19.0** (p = 0.006)^t	**68.3 ± 16.0** (p = 0.006)^y, (p < 0.008)^w, (p = 0.001)^l	**52.1 ± 15.0** (p < 0.008)^t	**56.1 ± 19.1** (p=0.001)^t
Lower Trapezius	94.9 ± 29.0	88.3 ± 26.3	83.6 ± 33.2	91.5 ± 26.5

Joseph et al, Am J of Phy Med & Rehab, 2018

Rotator Cuff Muscles: *Supraspinatus* and *Infraspinatus*

- <u>Take Home:</u>
  - All four exercises highly activated both partitions within supraspinatus muscles and the superior partition of infraspinatus.
  - The middle partition of infraspinatus showed high activation in Y and L exercises.

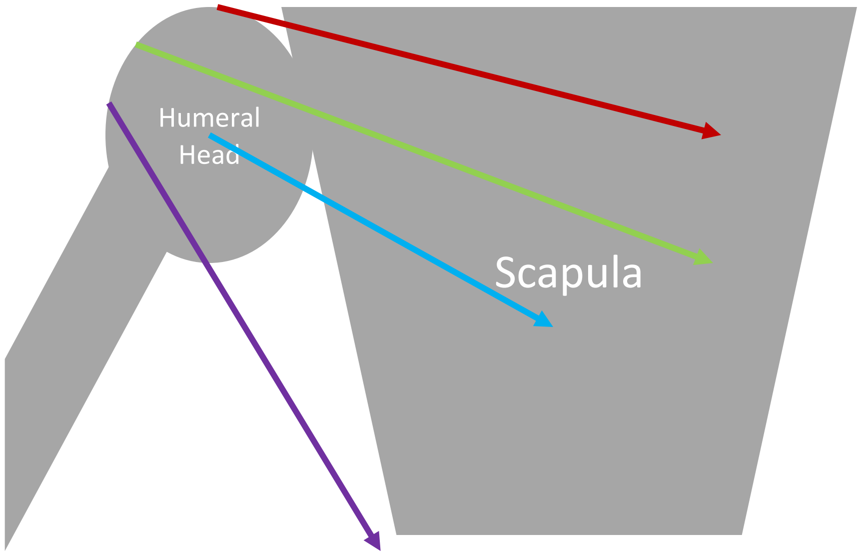
YTWL banded exercises induce high activation in supraspinatus and infraspinatus partitions. YTWL exercises are appropriate for strengthening of some rotator cuff for late stages of shoulder rehabilitation.

Joseph et al, Am J of Phy Med & Rehab, 2018

Rotator Cuff Importance

Rotator cuff muscle provide dynamic compressive forces to keep the humeral head seated in the concave glenoid fossa.

- Supraspinatus
- Infraspinatus
- Subscapularis
- Teres Minor



Cricchio et al, J Hand Ther, 2011

Rotator Cuff Muscles: *Infraspinatus*

- 4 pairs of fine wire EMG electrodes
- 31 healthy participants

Arm posture influences on regional supraspinatus and infraspinatus activation in isometric arm elevation efforts☆

Talia Alenabi[a], Rachel L. Whittaker[a], Soo Y. Kim[b], Clark R. Dickerson[a,*]

[a] University of Waterloo, Faculty of Applied Health Sciences, Department of Kinesiology, Digital Industrial Ergonomics and Shoulder Evaluation Laboratory (DIESEL), Waterloo, Ontario, Canada
[b] School of Physical Therapy, College of Medicine, University of Saskatchewan, Saskatoon, Canada

- 18 isometric resistance exercises against a force cube in flexion, scaption and abduction at 30, 90 and 150 degrees

Infraspinatus Middle activation was higher at 90 degrees during flexion.

Alenabi et al, J Electromyogr Kinesiol, 2018

Rotator Cuff Muscles: *Infraspinatus*

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Mean rotator cuff muscle activation (%MVE) at 50% MVF collapsed across planes and angles. A significant difference between means is shaded in grey and further noted by a letter. The bolded values indicate the means that are significantly higher, the letter "a" indicates a significantly larger mean than that at 30° of elevation. The letter "b" indicate [illegible] bduction plane.

"Moderate" Category

Muscle	Angle			Plane		
	30°	90°	150°	Abduction	Flexion	Scaption
Supraspinatus Anterior	28 (1.8)	**41.9 (2.3)** [a]	**45.3 (3.2)** [a]	38.9 (2.2)	35.5 (2.3)	40.7 (2.4)
Supraspinatus Posterior	38.4 (2.6)	42.6 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Infraspinatus Superior	22.5 (2.1)	27.9 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Infraspinatus Middle	26.6 (2.9)	28. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]

T. Alenabi et al. Journal of Electromyography and Kinesiology 44 (2019) 108–116

Table 4
Mean rotator cuff muscle activation (%MVE) at 100% MVF collapsed across planes and angles. A significant difference between means is shaded in grey and further noted by a letter. The bolded values indicate the means that are significantly higher, the letter "a" indicates a significantly larger mean than that at 30° of elevation. The letter "b" indicates a significantly larger mean than that in the abduction plane.

Muscle	Angle			Plane		
	30°	90°	150°	Abduction	Flexion	Scaption
Supraspinatus Anterior	47.4 (2.9)	**66.7 (3.3)** [a]	**65.4 (3.9)** [a]	60.9 (2.5)	56.8 (2.9)	61.8 (3.5)
Supraspinatus Posterior	63 (4.7)	65.8 (4.1)	60.3 (3.9)	[illegible]	[illegible].2)	63.1 (3.6)
Infraspinatus Superior	44.1 (4)	52.2 (3.3)	47.4 (4.7)	42.8 (3.8)	51.8 (3.3)	49.2 (3.6)
Infraspinatus Middle	41.2 (3.7)	51.4 (4.5)	54.9 (4.3)	43.9 (3.6)	**52.6 (3.8)** [b]	50.9 (3.8)

"High" Category

Alenabi et al, J Electromyogr Kinesiol, 2018

Rotator Cuff Muscles: *Infraspinatus*

- <u>Take Home:</u>
  - More relative activation at 90% flexion
  - Consider shoulder flexion at 90 degrees another exercise to use to strengthen the Infraspinatus Middle.
  - More research to look specifically at infraspinatus tendon during flexion.

Infraspinatus Middle muscle assists in shoulder flexion (although primarily an ext rotator) due to its tendon overlapping the Supaspinatus anatomically.

Alenabi et al, J Electromyogr Kinesiol, 2018

Rotator Cuff Muscles: *Infraspinatus*

Int J Sports Phys Ther. 2018 Aug;13(5):896-904.

TESTING INFRASPINATUS AND DELTOID MUSCLES WITH NEW TECHNIQUE TO DECREASE DELTOID ACTIVITY DURING TESTING USING EMG ANALYSIS.

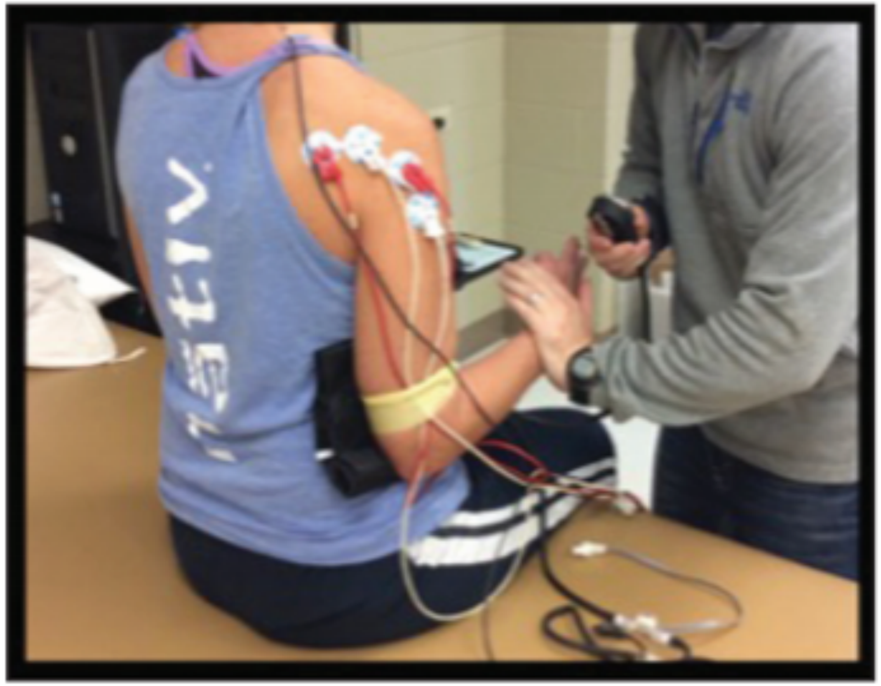
Forbush SW[1], Bandy WD[1], Garrison MK[1], Graves LC[1], Roberts R[1].

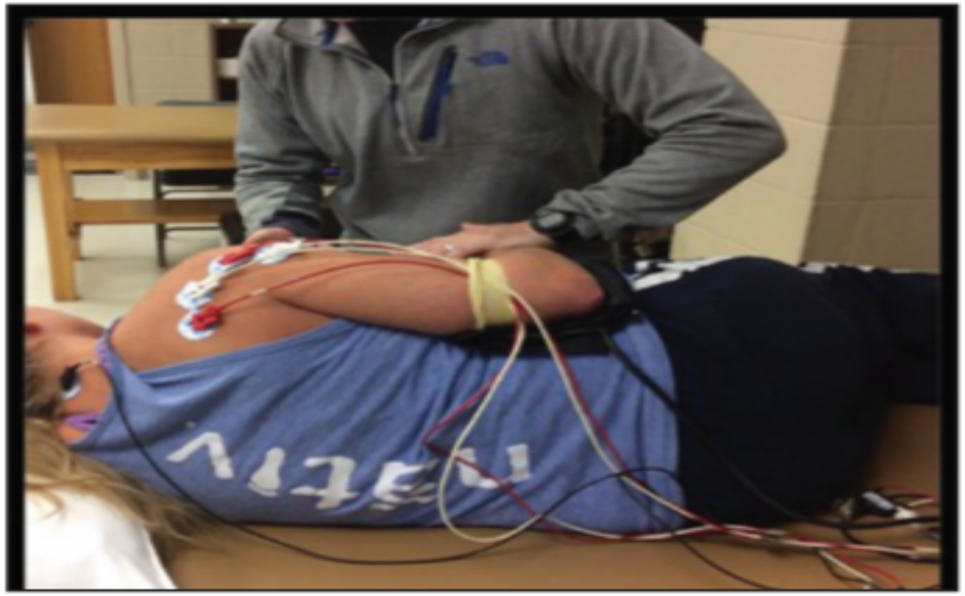
- Describe a testing method for the infraspinatus while decreasing signal of the posterior deltoid
- 34 right handed healthy volunteers
- Surface electrodes

- EMG was recorded during resisted ER in 4 different testing positions
  - Seated active adduction
  - Seated passive adduction
  - Side-lying active adduction
  - Side-lying passive adduction

Forbush et al, Int J Sports Phys Ther, 2018

Rotator Cuff Muscles: *Infraspinatus*





Forbush et al, Int J Sports Phys Ther, 2018

Rotator Cuff Muscles: *Infraspinatus*

- Take Home:

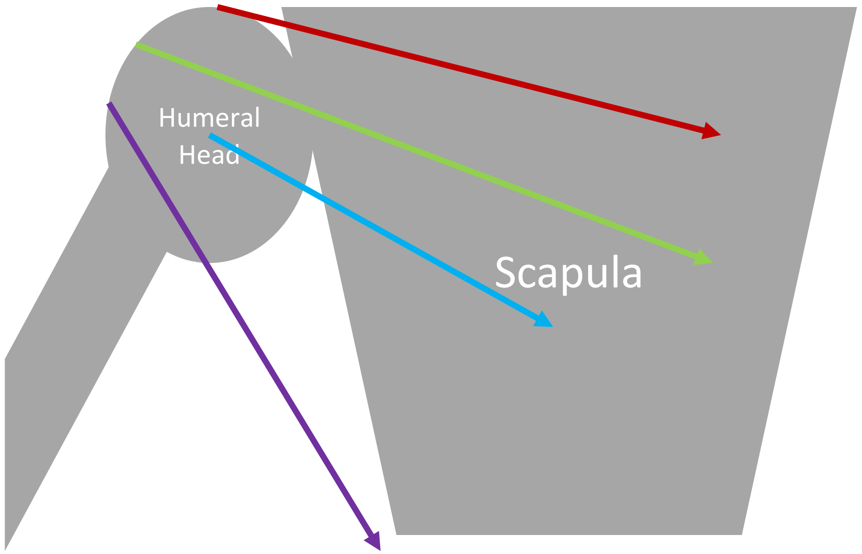
Increased activation of the Infraspinatus (with quieting of the posterior deltoid concurrently) was achieved with 0 degrees of adduction with resisted external rotation in BOTH side-lying and seated testing positions.

Forbush et al, Int J Sports Phys Ther, 2018

Rotator Cuff Importance

Rotator cuff muscle provide dynamic compressive forces to keep the humeral head seated in the concave glenoid fossa.

- Supraspinatus
- Infraspinatus
- Subscapularis
- Teres Minor



Cricchio et al, J Hand Ther, 2011

Rotator Cuff Muscles: *Supraspinatus*, and *Infraspinatus*

- Out of 13 active-assisted exercises, 9 were identified as suitable to load the supraspinatus and 10 as suitable to load the infraspinatus early after surgery.
- All exercises were placed in a theoretical-continuum model
- Recommendations could be made for prescription in patient's post rotator cuff repair in early stages of rehab.

A Systematic Review of Electromyography Studies in Normal Shoulders to Inform Postoperative Rehabilitation Following Rotator Cuff Repair

- AUTHORS

Peter K. Edwards, MSc[1], Jay R. Ebert, PhD[1], Chris Littlewood, PhD[2], Tim Ackland, PhD[1], Allan Wang, FRACS, PhD[3,4]

+ AFFILIATIONS

Published: *Journal of Orthopaedic & Sports Physical Therapy*, 2017 **Volume:**47 **Issue:**12 **Pages:**931–944 **DOI:** 10.2519/jospt.2017.7271

Edwards et al, J Ortho S Phys Ther, 2017

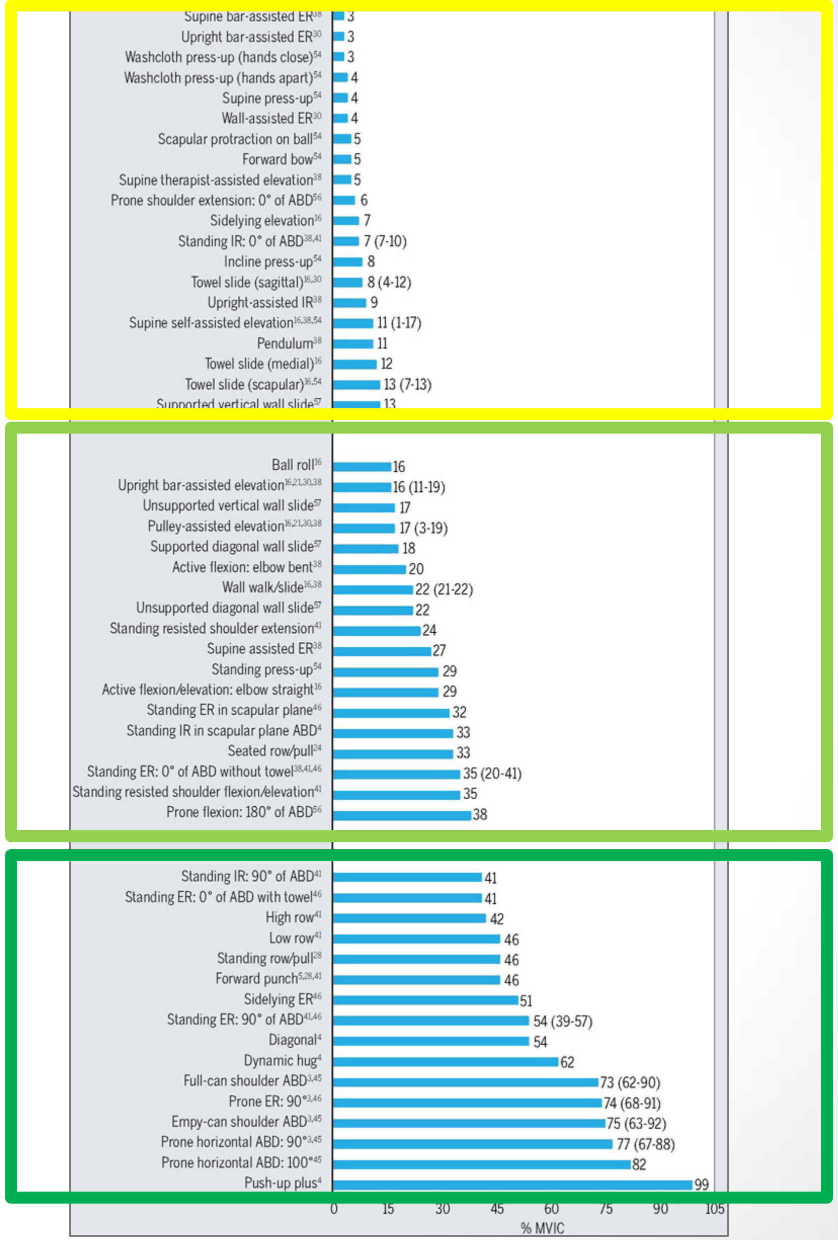
Rotator Cuff Muscles: *Supraspinatus*

“Low-Moderate” Category

“High” Category

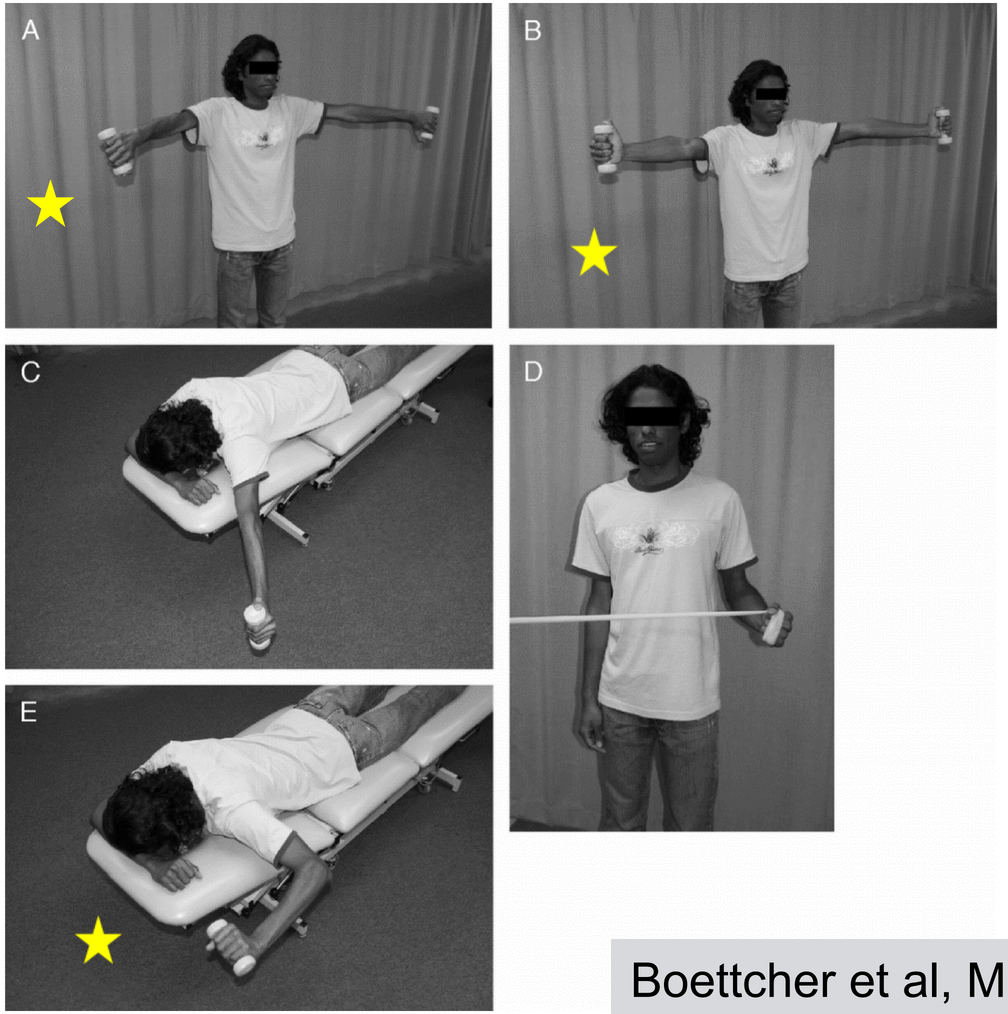
“ Very High” Category

FIGURE 2. Supraspinatus pooled means (range) of percent MVIC ranking of exercises. Abbreviations: ABD, abduction; ER, external rotation; IR, internal rotation; MVIC, maximal voluntary isometric contraction.



Edwards et al, J Ortho S Phys Ther, 2017

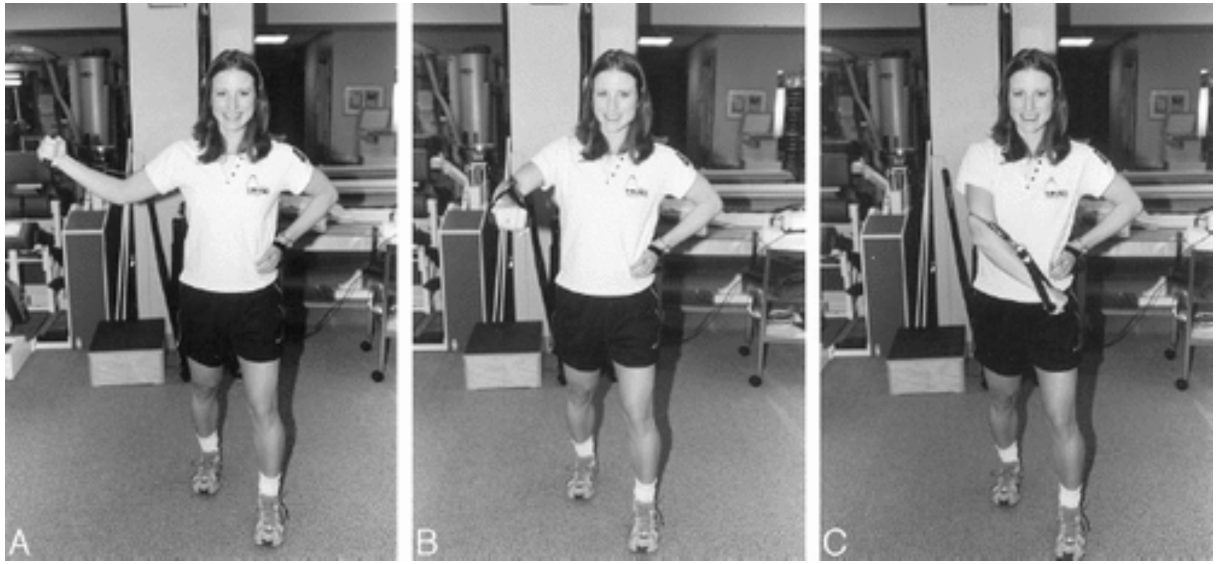
Rotator Cuff Muscles: *Supraspinatus*



Boettcher et al, Med Sci Sports Exerc, 2009

Rotator Cuff Muscles: *Supraspinatus*

Dynamic Hug



Diagonal

Decker et al, Am J Sport Med, 2003

Rotator Cuff Muscles: *Supraspinatus*

Push Up Plus/Forward Punch

Decker et al, Am J Sport Med, 2003

Rotator Cuff Muscles: *Supraspinatus*

Prone horizontal abduction at approximately 100°

Reinhold et al, J Orthop Sports Phys Ther, 2004

Rotator Cuff Muscles:
Infraspinatus

"Low-Moderate" Category

"High" Category

" Very High" Category

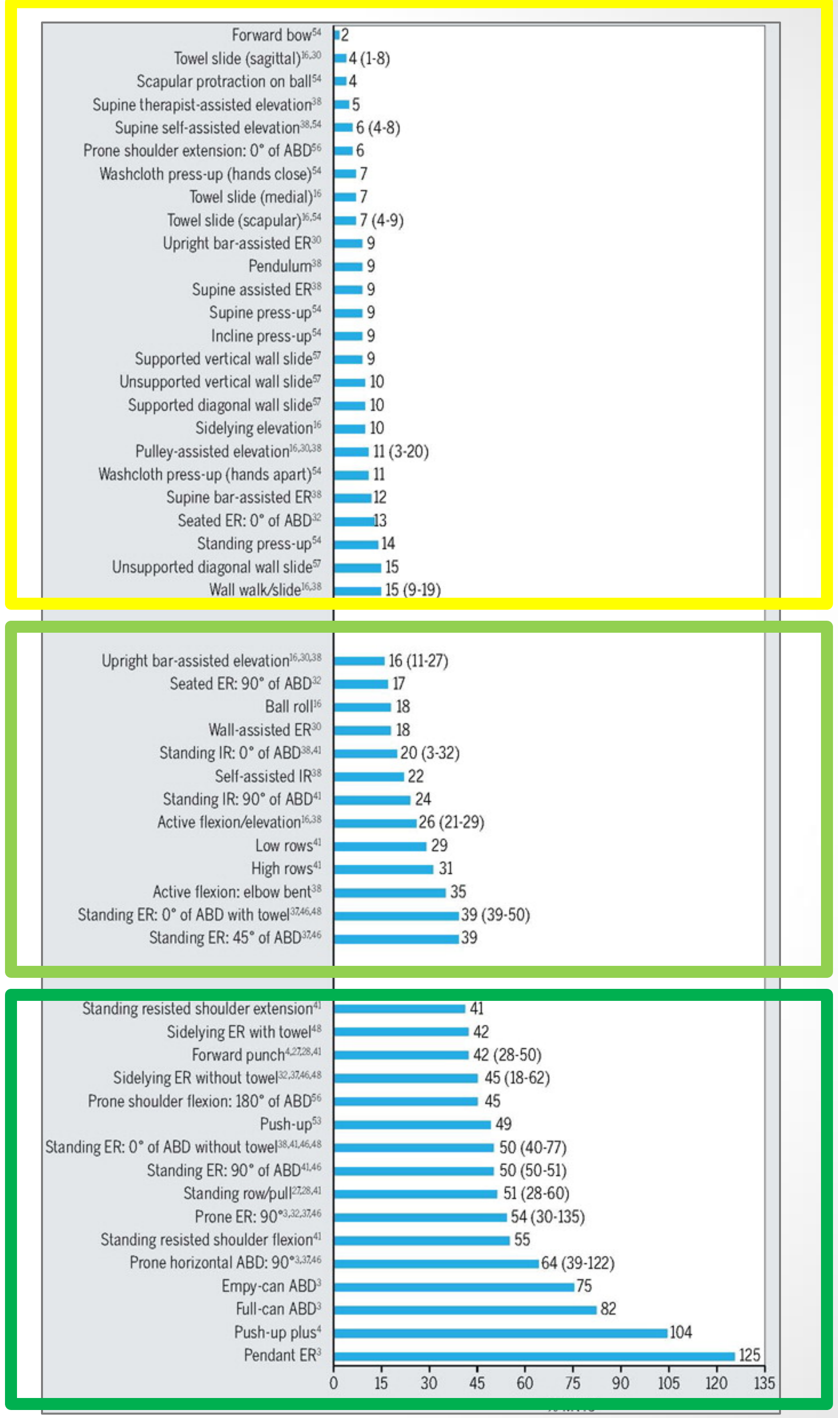
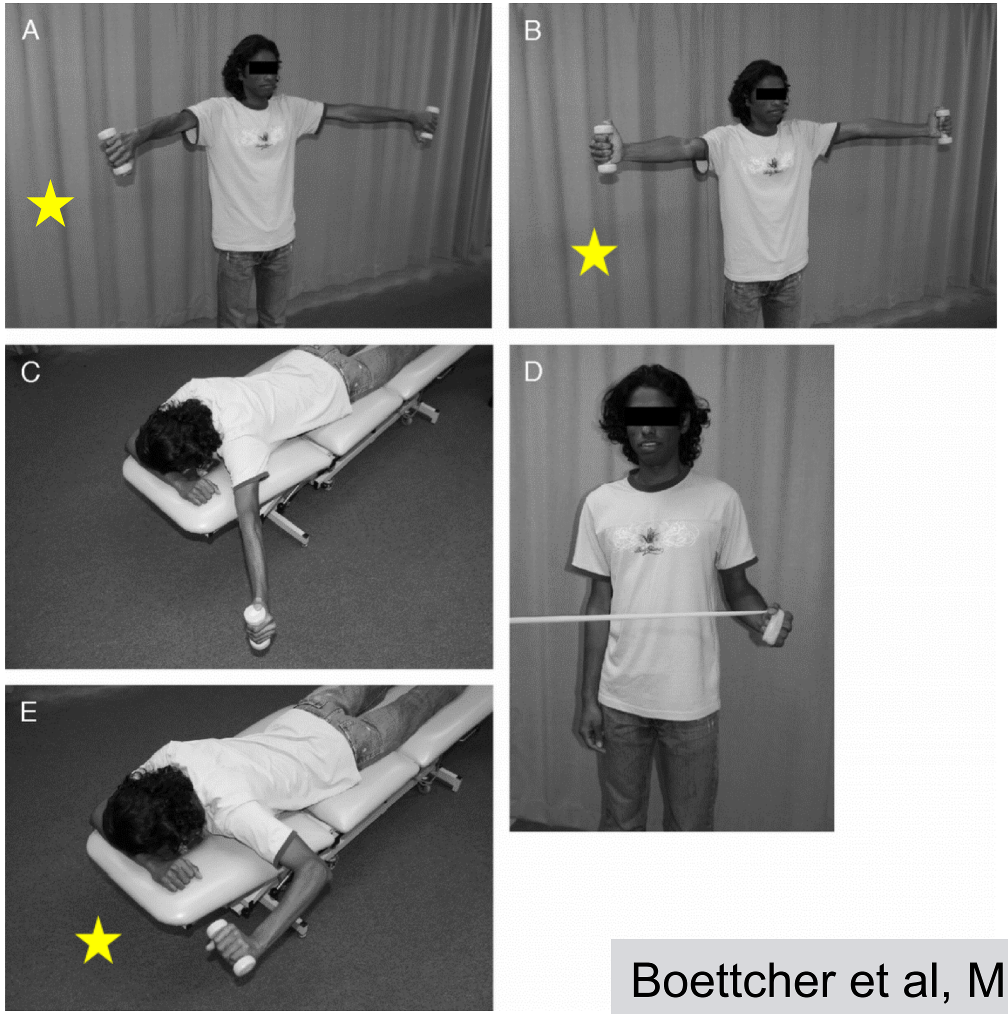


FIGURE 3. Infraspinatus pooled means (range) of percent MVIC ranking of exercises. Abbreviations: ABD, abduction; ER, external rotation; IR, internal rotation; MVIC, maximal voluntary isometric contraction.

Edwards et al, J Ortho S Phys Ther, 2017

Rotator Cuff Muscles: *Infraspinatus*

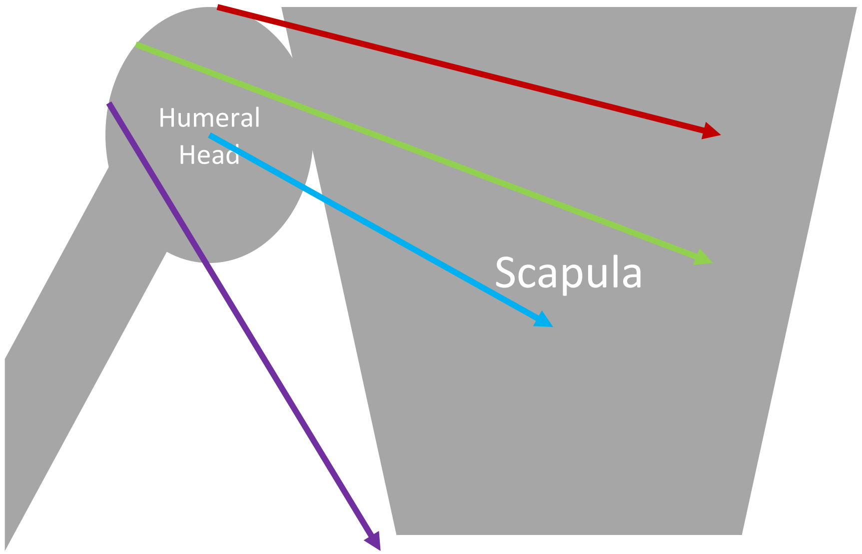


Boettcher et al, Med Sci Sports Exerc, 2009

Rotator Cuff Importance

Rotator cuff muscle provide dynamic compressive forces to keep the humeral head seated in the concave glenoid fossa.

- Supraspinatus
- Infraspinatus
- Subscapularis
- Teres Minor



Cricchio et al, J Hand Ther, 2011

Rotator Cuff Muscles: *Subscapularis* and *Teres Minor*

- All exercises were placed in a theoretical-continuum model
- Majority of studies were looking specifically at the supra/infraspinatus. Few looked at the subscap or teres minor
- The following are the studies that included subscap and teres minor

A Systematic Review of Electromyography Studies in Normal Shoulders to Inform Postoperative Rehabilitation Following Rotator Cuff Repair

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Edwards et al, J Ortho S Phys Ther, 2017

Rotator Cuff Muscles:

Subscapularis

“Low-Moderate” Category

“High” Category

“ Very High” Category

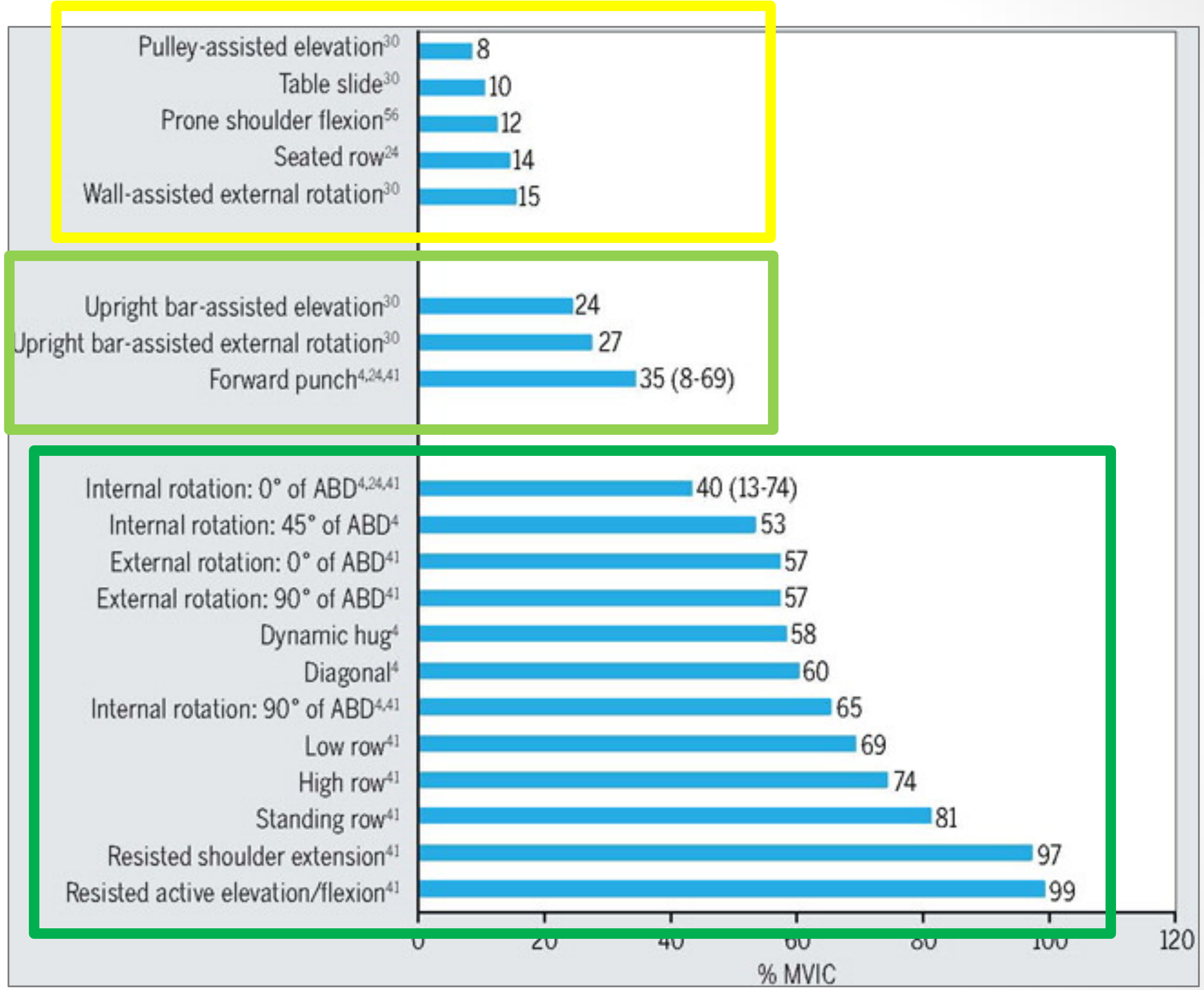


FIGURE 5. Subscapularis pooled means (range) of percent MVIC ranking of exercise. Abbreviations: ABD, abduction; MVIC, maximal voluntary isometric contraction.

Edwards et al, J Ortho S Phys Ther, 2017

Rotator Cuff Muscles:

Teres Minor

“Low-Moderate” Category

“High” Category

“ Very High” Category

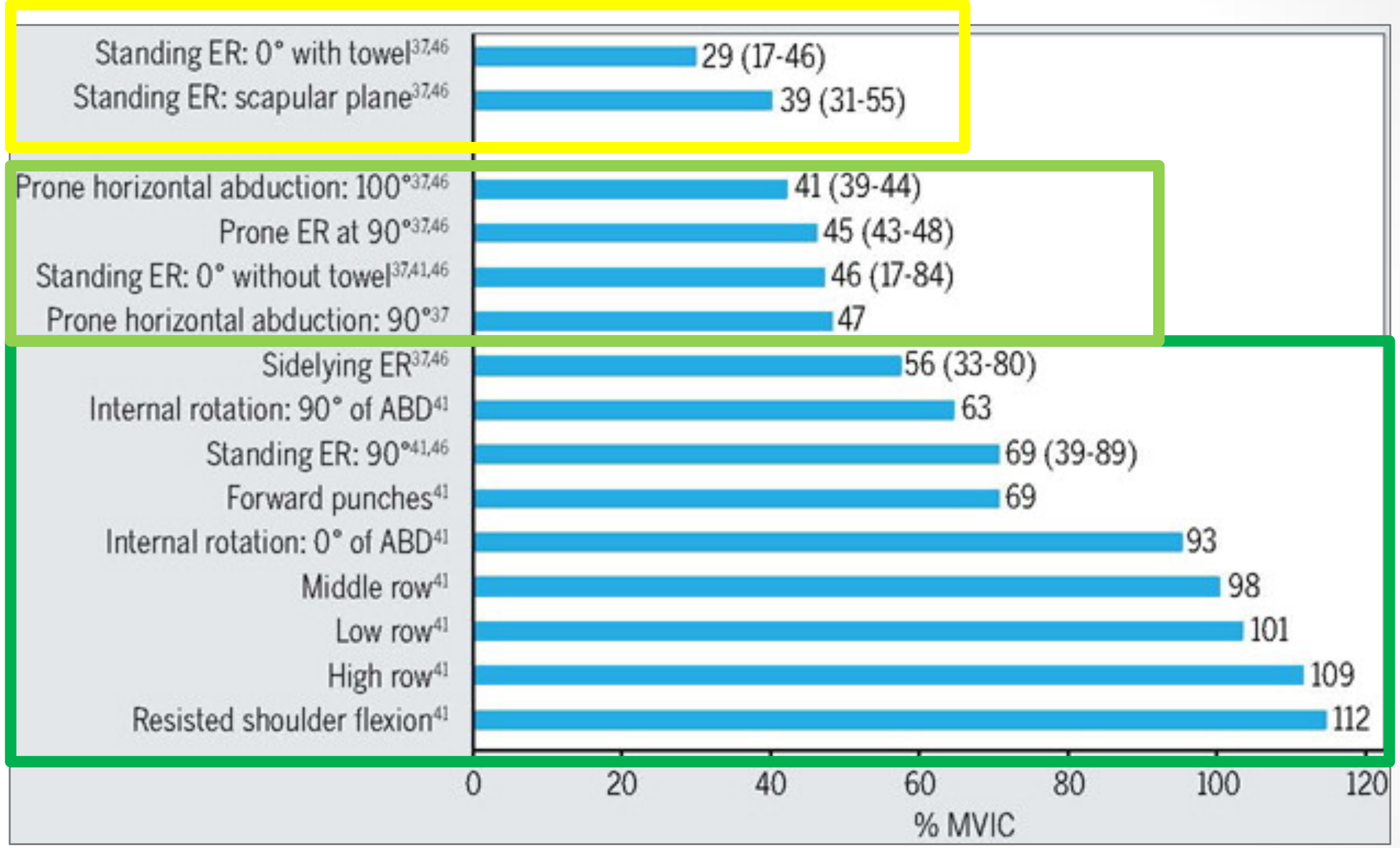


FIGURE 4. Teres minor pooled means (range) of percent MVIC ranking of exercises. Abbreviations: ABD, abduction; ER, external rotation; MVIC, maximal voluntary isometric contraction.

Edwards et al, J Ortho S Phys Ther, 2017

Rotator Cuff Muscles:

Take Home:

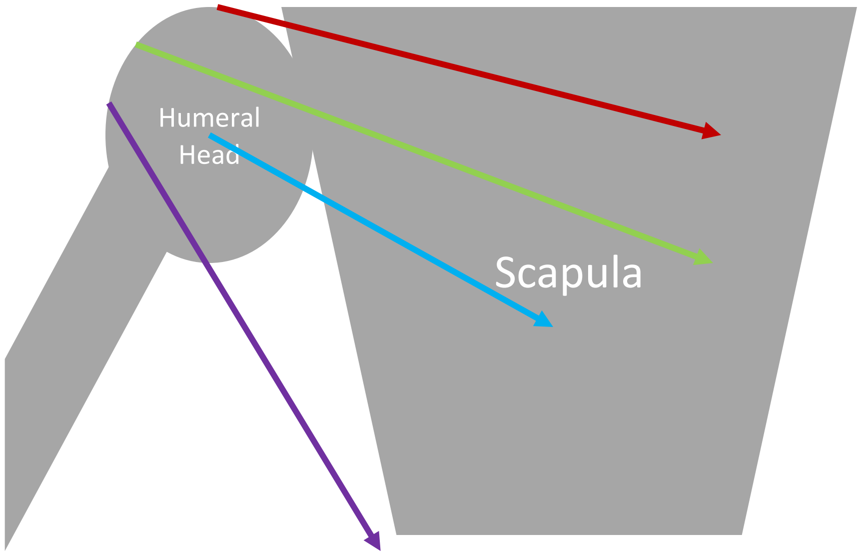
- This review highlights the large variety of studies that have investigated strengthening exercises in the shoulder
- Many of the studies included in this review evaluated primarily the supraspinatus and infraspinatus, and very few evaluated the subscapularis and the teres minor muscles.
- Therefore, caution must be taken when applying the guidelines in this review to patients presenting with repairs of the subscapularis and teres minor.

Edwards et al, J Ortho S Phys Ther, 2017

Rotator Cuff Importance

Rotator cuff muscle provide dynamic compressive forces to keep the humeral head seated in the concave glenoid fossa.

- Supraspinatus
- Infraspinatus
- Subscapularis
- Teres Minor



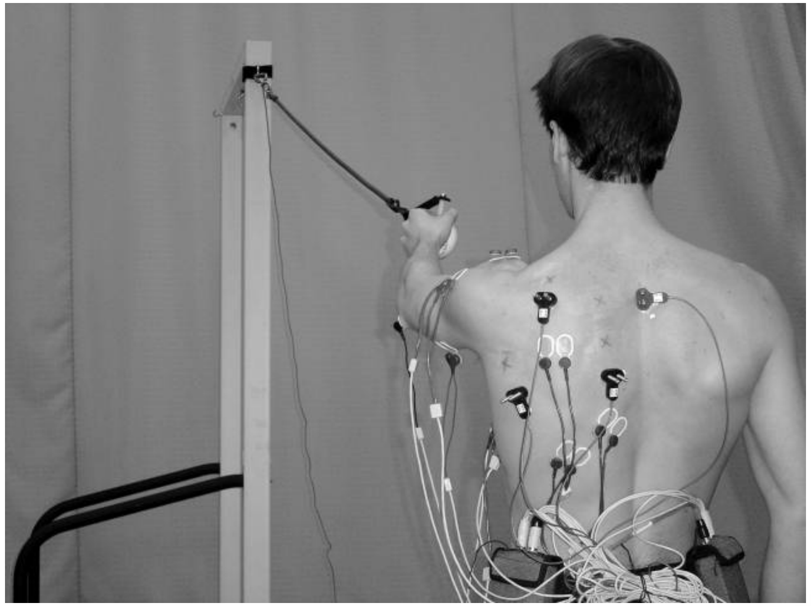
Cricchio et al, J Hand Ther, 2011

Rotator Cuff Muscles: *Subscapularis* and *Teres Minor*

On-the-Field Resistance-Tubing Exercises for Throwers: An Electromyographic Analysis

Joseph B Myers, Maria R Pasquale, Kevin G Laudner, Timothy C Sell, James P Bradley, and Scott M Lephart

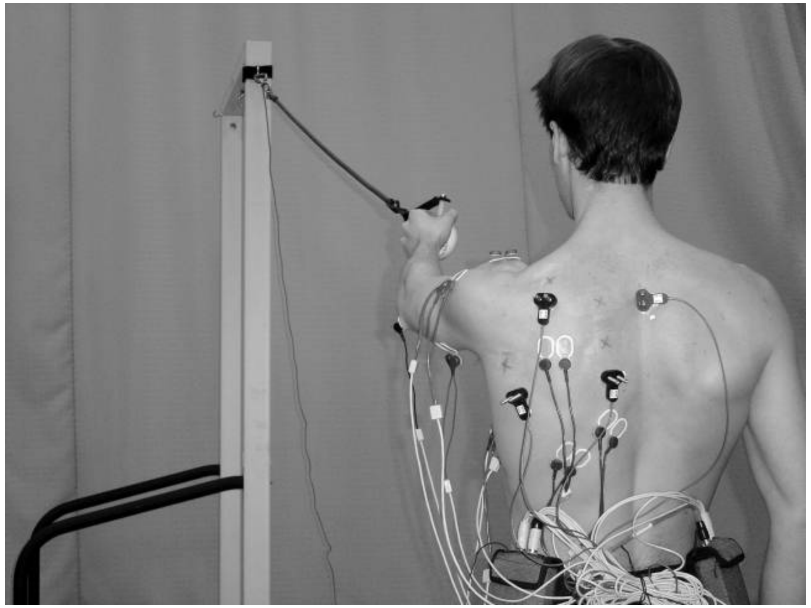
- Surface and fine-wire EMG
- 15 physically active healthy males
- Performed 12 rubber-tubing exercises in random order



Myers et al, J Athl Train, 2005

Rotator Cuff Muscles: *Subscapularis* and *Teres Minor*

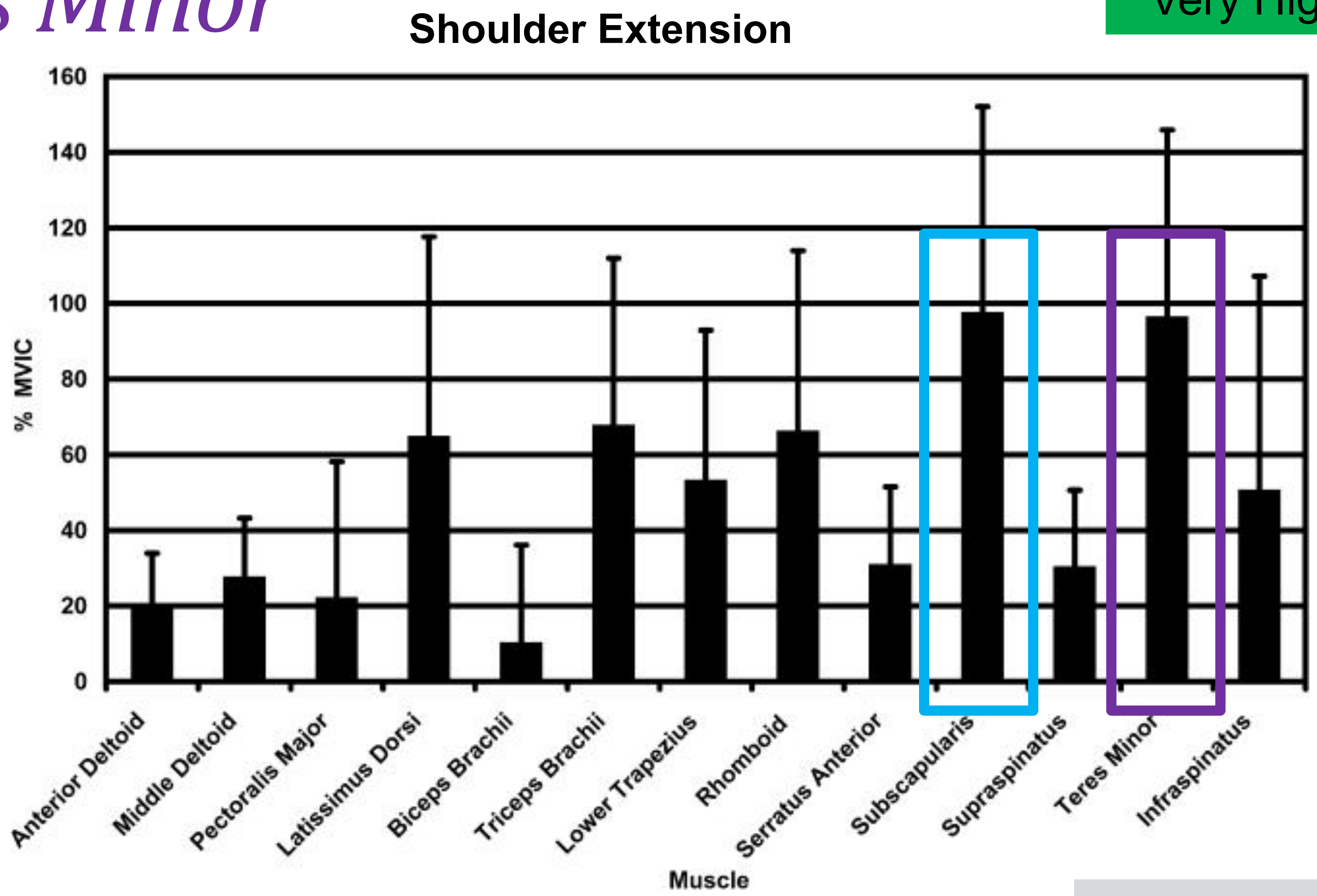
- Shoulder EXT, shoulder FLEX
- Throwing acceleration, throwing deceleration
- External rotation at 90° of abduction, scapular punches
- High or low scapular rows



Myers et al, J Athl Train, 2005

Rotator Cuff Muscles: *Subscapularis* and *Teres Minor*

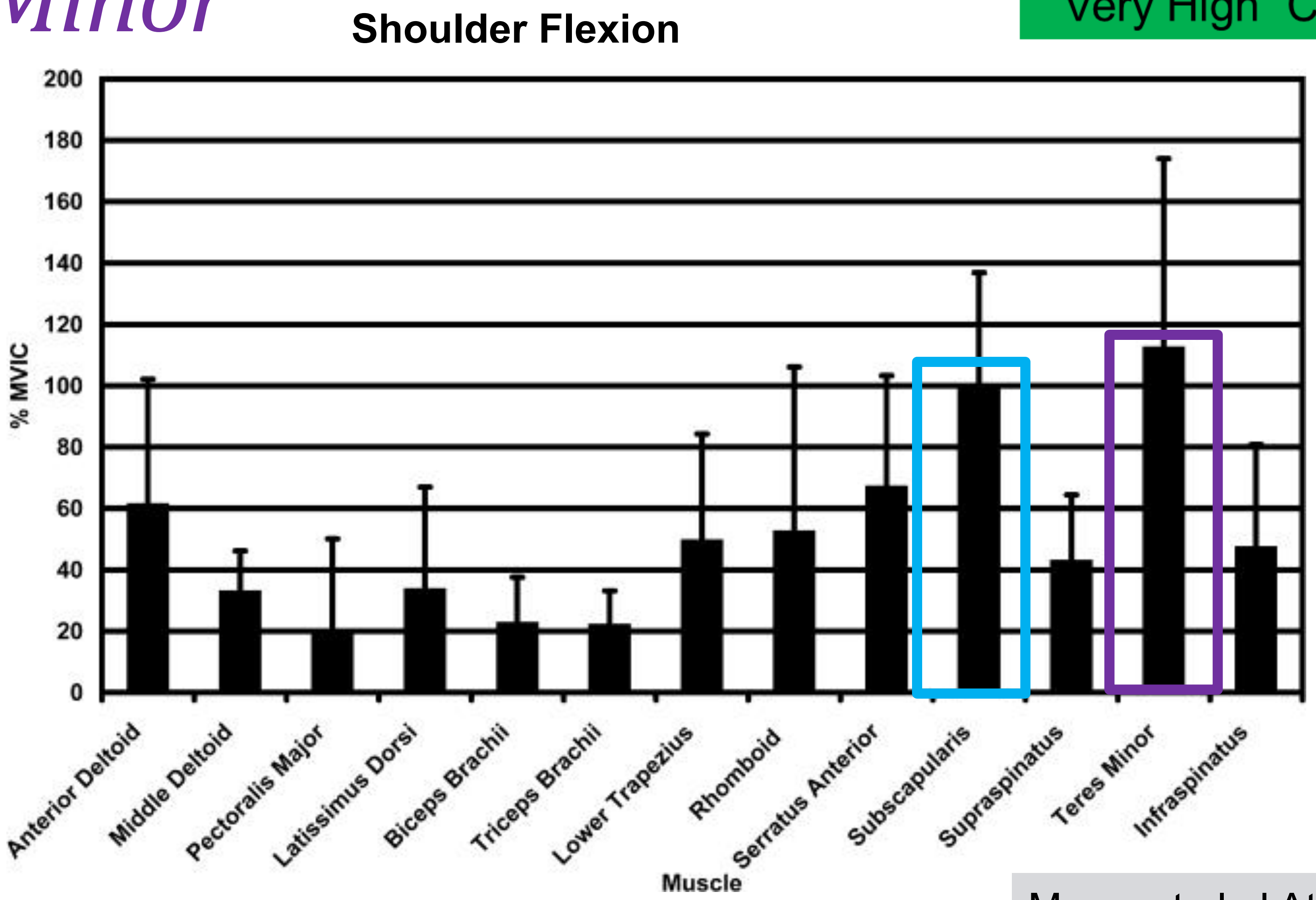
“ Very High” Category



Myers et al, J Athl Train, 2005

Rotator Cuff Muscles: *Subscapularis* and *Teres Minor*

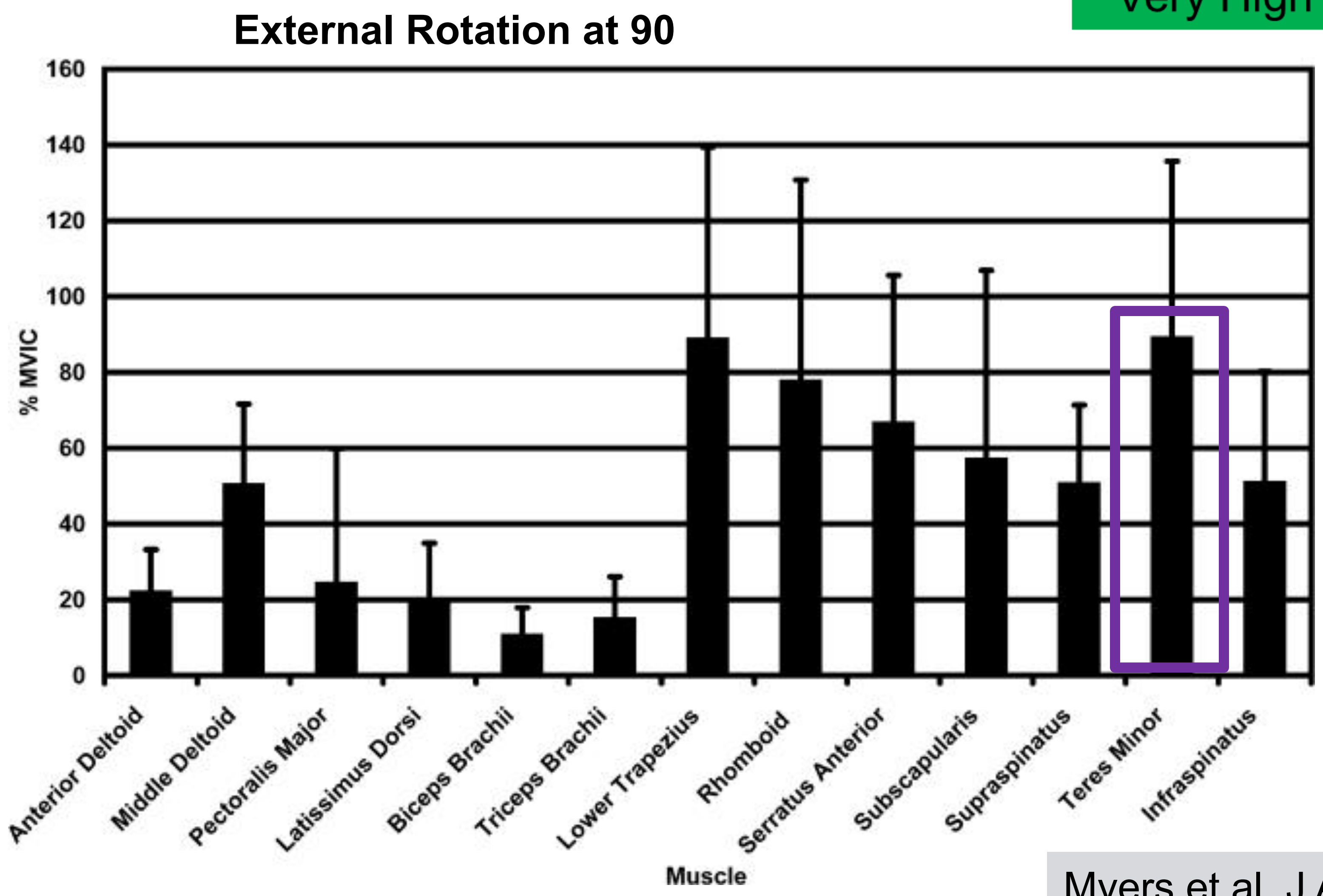
“ Very High” Category



Myers et al, J Athl Train, 2005

Rotator Cuff Muscles: *Teres Minor*

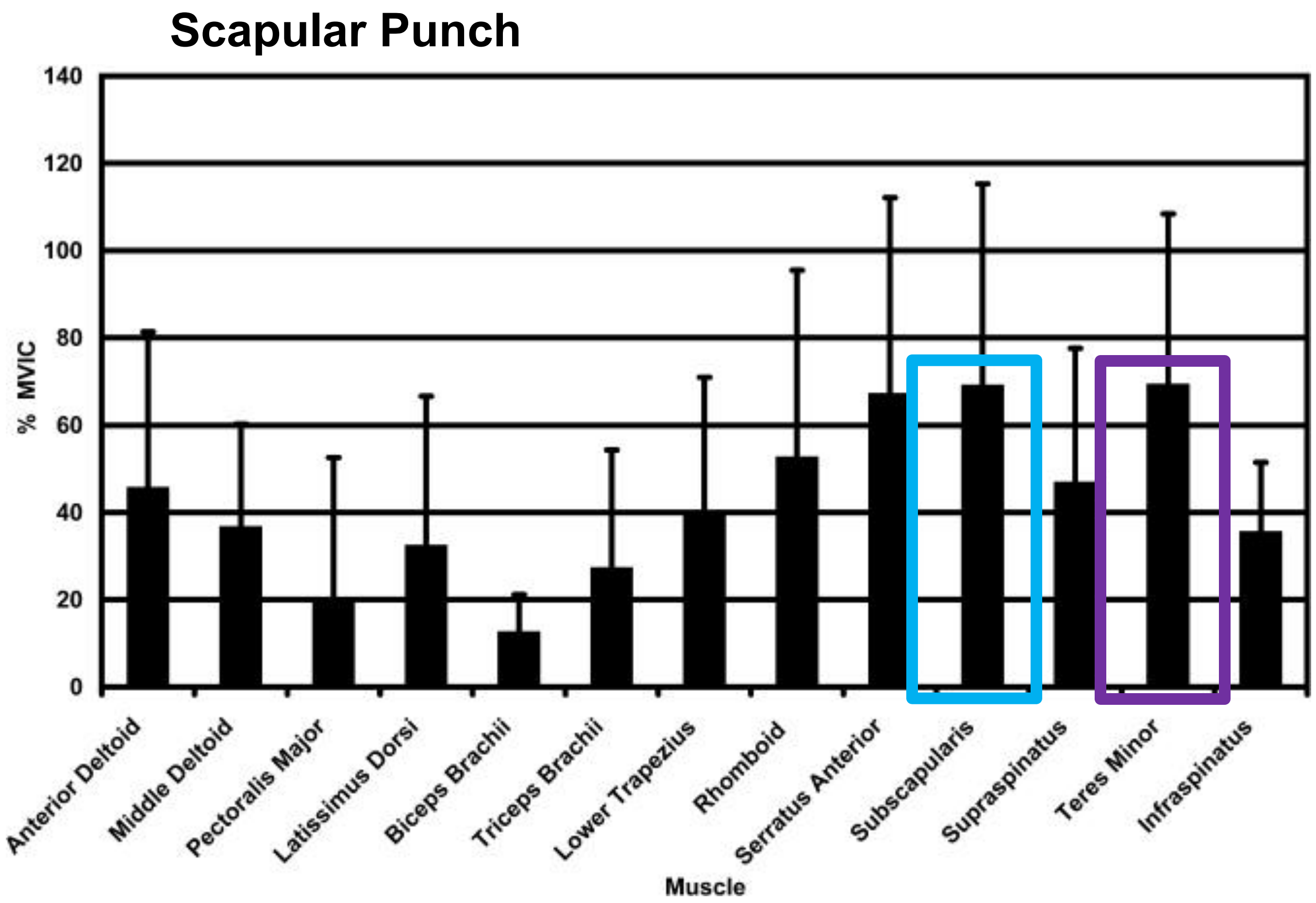
" Very High" Category



Myers et al, J Athl Train, 2005

Rotator Cuff Muscles: *Subscapularis* and *Teres Minor*

"Very High" Category

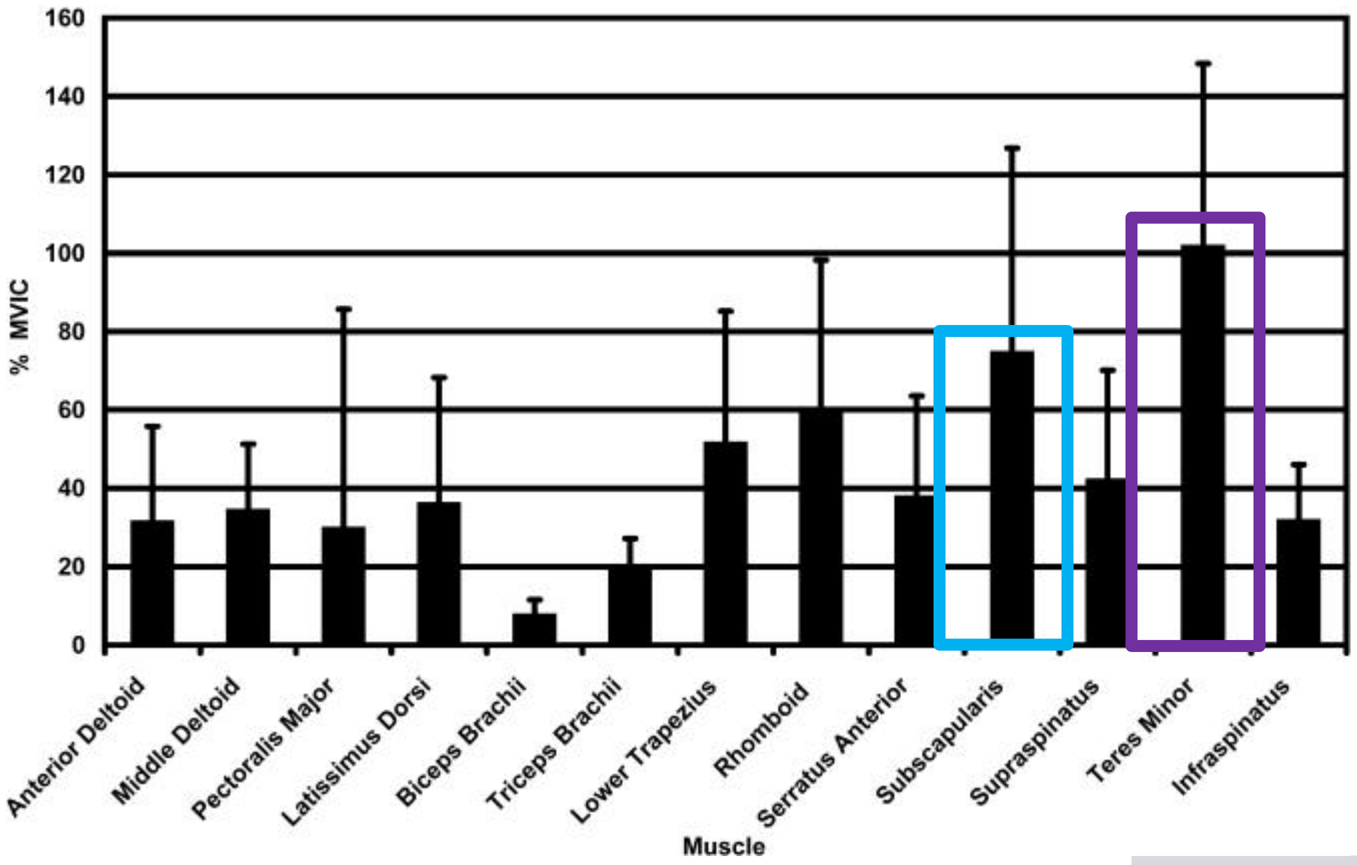


Myers et al, J Athl Train, 2005

Rotator Cuff Muscles: *Subscapularis* and *Teres Minor*

" Very High" Category

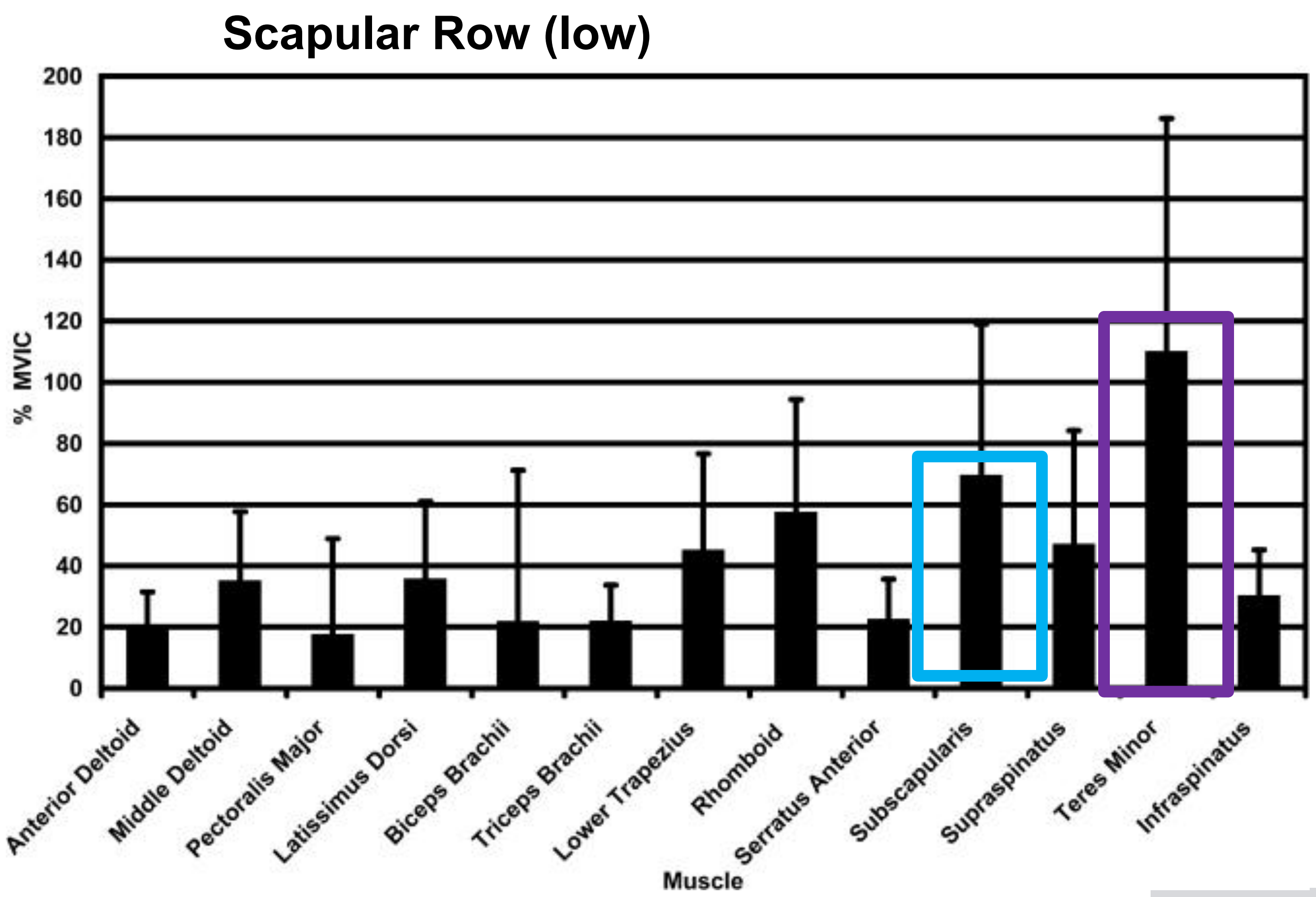
Scapular Row (high)



Myers et al, J Athl Train, 2005

Rotator Cuff Muscles: *Subscapularis* and *Teres Minor*

“ Very High” Category



Myers et al, J Athl Train, 2005

Rotator Cuff Muscles: *Subscapularis* and *Teres Minor*

- Take Home:
  - These 7 exercises (for timing purposes only showed 5 or 7) could be used for a warm up throwing or overhead athlete.

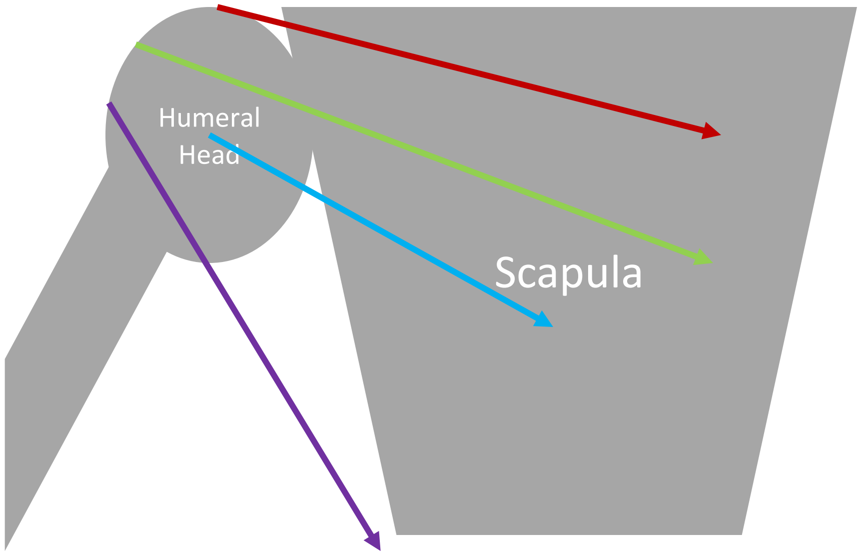
More research needs to be completed but preliminary results suggest that these exercises are very effective in activating rotator cuff muscles.

Myers et al, J Athl Train, 2005

Rotator Cuff Importance

Rotator cuff muscle provide dynamic compressive forces to keep the humeral head seated in the concave glenoid fossa.

- Supraspinatus
- Infraspinatus
- Subscapularis
- Teres Minor



Cricchio et al, J Hand Ther, 2011

Rotator Cuff Muscles: *Subscapularis*

- IM fine-wire EMG
- 20 healthy participants
- Subscapularis Muscle
  - Upper Subscapularis
  - Lower Subscapularis

The upper and lower segments of subscapularis muscle have different roles in glenohumeral joint functioning

Sangeeta Rathi [a, c], Nicholas F. Taylor [b], Rodney A. Green [a]

Rathi et al, J Biomechanics, 2017

Rotator Cuff Muscles: *Subscapularis*

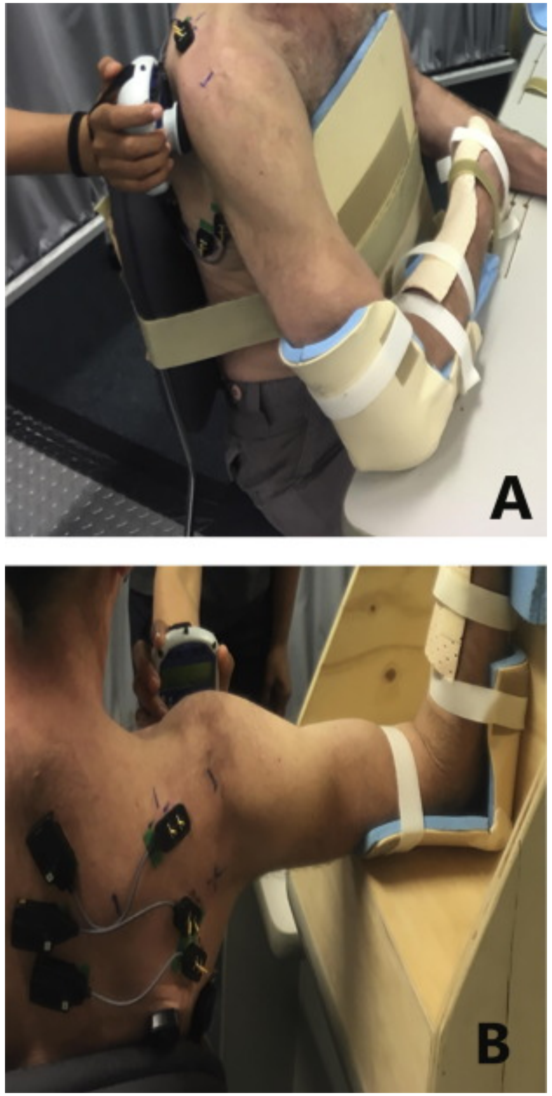


Fig. 1. Testing positions; (A) shoulder in neutral position with examiner applying anterior directed force at the humerus; (B) shoulder in 90° abducted position with examiner applying posterior directed force at the humerus.

Rathi et al, J Biomechanics, 2017

Rotator Cuff Muscles: *Subscapularis*

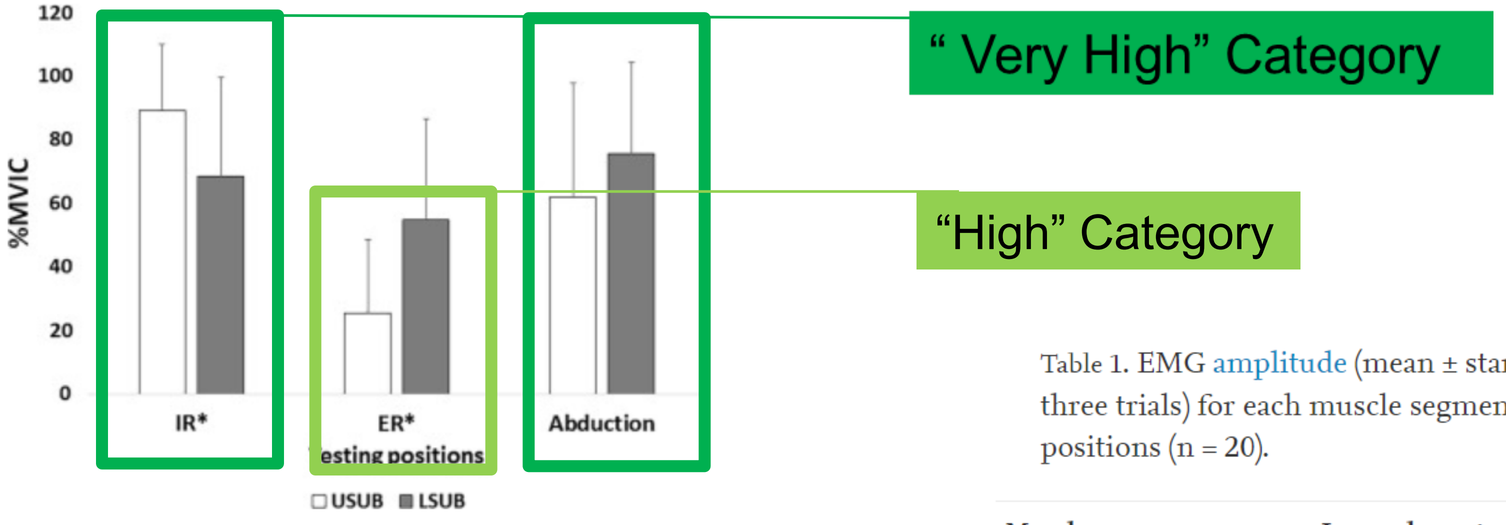


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Fig. 2. EMG activity (%MVIC) during maximum voluntary isometric contraction trials for two muscle segments in three testing positions. Interaction effect for testing position × muscle segment, *$p < 0.05$. IR, isometric internal rotation; ER, isometric external rotation.

Table 1. EMG amplitude (mean ± standard deviation) (%MVIC, maximal of three trials) for each muscle segment in each of three MVIC testing positions (n = 20).

Muscles	Internal rotation*	External rotation*	Abduction
Upper subscapularis	89.2 ± 20.8	25.3 ± 23.2	61.8 ± 36.0
Lower subscapularis	68.4 ± 31.2	54.9 ± 31.7	75.5 ± 28.9

%MVIC, percentage maximum voluntary isometric contraction.

Rathi et al, J Biomechanics, 2017

Rotator Cuff Muscles: *Subscapularis*

- **Take Home:**
  - High MVIC for USUB in IR contractions and its lack of response to ANT/POST----reinforces the notion that this muscle may have a greater role as an ***agonist for internal rotation rather than as a stabilizer.***
  - Higher MVIC of LSUB during all ER conditions can only be attributed to its ***stabilizer role*** potentially against posterior deltoid in the abducted position.

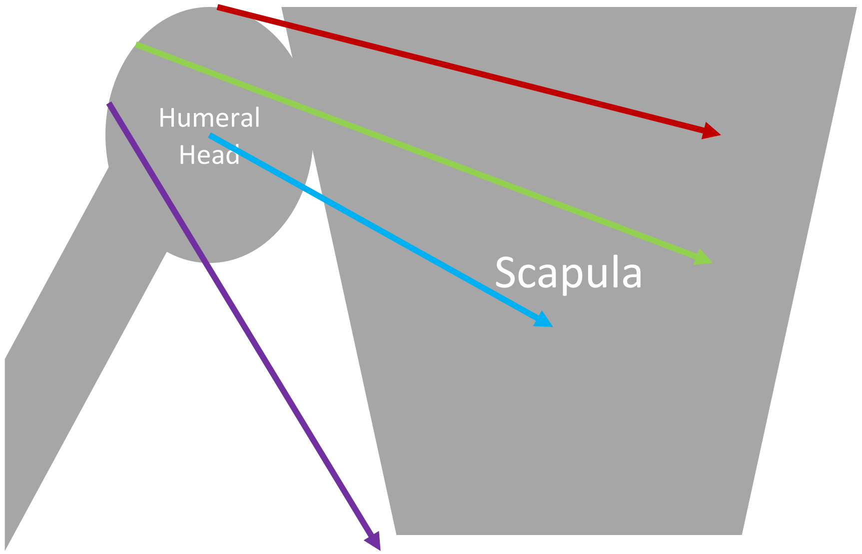
To restore normal function, should add ER and ABD exercises to focus on LSUB and IR strengthening exercises for USUB.

Rathi et al, J Biomechanics, 2017

Rotator Cuff Importance

Rotator cuff muscle provide dynamic compressive forces to keep the humeral head seated in the concave glenoid fossa.

- Supraspinatus
- Infraspinatus
- Subscapularis
- Teres Minor



Cricchio et al, J Hand Ther, 2011

Rotator Cuff Muscles: *Infraspinatus*, *Supraspinatus* and *Teres Minor*

- IM fine-wire EMG
- 10 physically active healthy males

Electromyographic Analysis of the Rotator Cuff and Deltoid Musculature During Common Shoulder External Rotation Exercises

- AUTHORS

Michael M. Reinold, DPT, ATC[1], Kevin E. Wilk, PT[2], Glenn S. Fleisig, PhD[3], Nigel Zheng, PhD[4], Steven W. Barrentine, MS[5], Terri Chmielewski, PT, PhD[6], Rayden C. Cody, MD[7], Gene G. Jameson, MA[5], James R. Andrews, MD[8]

Reinhold et al, J Ortho and Sport Phys Ther, 2004

Rotator Cuff Muscles: *Infraspinatus*, *Supraspinatus* and *Teres Minor*

- 7 Shoulder Exercises:
  - Prone horizontal abduction at 100° of abduction and full external rotation (ER)
  - prone ER at 90° of abduction
  - standing ER at 90° of abduction
  - standing ER in the scapular plane (45° abduction, 30° horizontal adduction)
  - standing ER at 0° of abduction
  - standing ER at 0° of abduction with a towel roll
  - sidelying ER at 0° of abduction

Electromyographic Analysis of the Rotator Cuff and Deltoid Musculature During Common Shoulder External Rotation Exercises

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Reinhold et al, J Ortho and Sport Phys Ther, 2004

Rotator Cuff Muscles: *Supraspinatus*

TABLE 3. Mean (±SD) electromyographic (EMG) activation of the supraspinatus expressed as a percentage of maximum voluntary isometric contraction (MVIC) for 7 shoulder exercises. Intraclass correlation coefficients ($ICC_{3,1}$) are also provided.

	Exercise*	% MVIC	ICC
1.	Prone horizontal abduction at 100° with full external rotation	82 ± 37[†]	0.97
2.	Prone external rotation at 90° of abduction	68 ± 33[‡]	0.97
3.	Standing external rotation at 90° of abduction	57 ± 32	0.94
4.	Sidelying external rotation at 0° of abduction	51 ± 47	0.89
5.	Standing external rotation at 0° abduction with a towel roll	41 ± 37	0.71
6.	Standing external rotation at 0° abduction without a towel roll	41 ± 38	0.94
7.	Standing external rotation in the scapular plane (45° abduction, 30° horizontal adduction)	32 ± 24	0.93

* The 1-way repeated-measures ANOVA indicated a significant main effect across exercises (F = 8.802, $P<.001$).

† Exercise 1 is significantly different than exercises 4 ($P = .008$), 5, 6, and 7 ($P<.001$).

‡ Exercise 2 is significantly different than exercises 5, 6 ($P = .005$), and 7 ($P = .002$).

FIGURE 1. Prone horizontal abduction at 100° with full external rotation.

" Very High" Category

Reinhold et al, J Ortho and Sport Phys Ther, 2004

Rotator Cuff Muscles: *Infraspinatus*

TABLE 1. Mean (±SD) electromyographic (EMG) activation of the infraspinatus expressed as a percentage of maximum voluntary isometric contraction (MVIC) for 7 shoulder exercises. Intraclass correlation coefficients ($ICC_{3,1}$) are also provided.

Exercise*	% MVIC	ICC
1. Sidelying external rotation at 0° of abduction	62 ± 13[†]	0.81
2. Standing external rotation in the scapular plane (45° abduction, 30° horizontal adduction)	53 ± 25	0.87
3. Prone external rotation at 90° of abduction	50 ± 23	0.92
4. Standing external rotation at 90° of abduction	50 ± 25	0.97
5. Standing external rotation at 0° abduction with a towel roll	50 ± 14	0.76
6. Standing external rotation at 0° abduction without a towel roll	40 ± 14	0.86
7. Prone horizontal abduction at 100° with full external rotation	39 ± 17	0.73

* The 1-way repeated-measures ANOVA indicated a significant main effect across exercises (F = 3.288, *P* = .008).
[†] Exercise 1 is significantly different than exercise 6 (*P* = .011) and exercise 7 (*P* = .008).

" Very High" Category

"High" Category

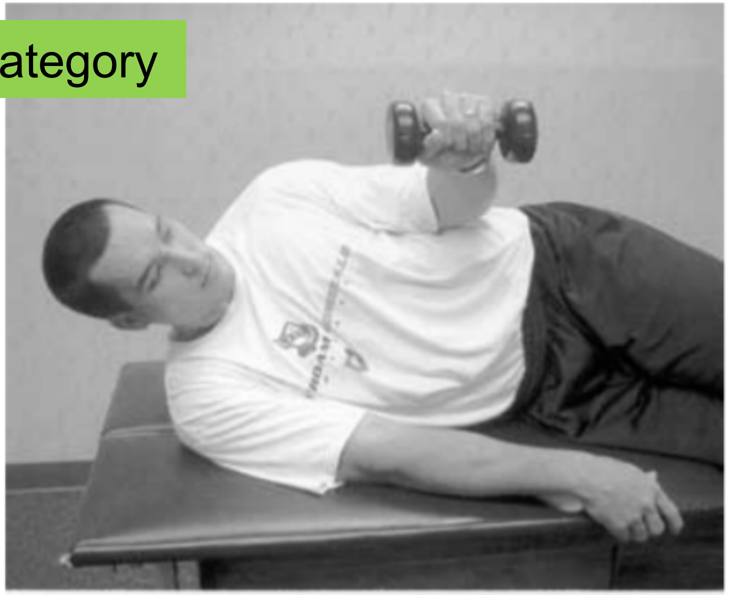


FIGURE 7. Sidelying external rotation.

Reinhold et al, J Ortho and Sport Phys Ther, 2004

Rotator Cuff Muscles: *Teres Minor*

TABLE 2. Mean (±SD) electromyographic (EMG) activation of the teres minor expressed as a percentage of maximum voluntary isometric contraction (MVIC) for 7 shoulder exercises. Intraclass correlation coefficients ($ICC_{3,1}$) are also provided.

	Exercise*	% MVIC	ICC
1.	Sidelying external rotation at 0° of abduction	67 ± 34†	0.87
2.	Standing external rotation in the scapular plane (45° abduction, 30° horizontal adduction)	55 ± 30	0.79
3.	Prone external rotation at 90° of abduction	48 ± 27	0.97
4.	Standing external rotation at 0° abduction with a towel roll	46 ± 21	0.90
5.	Prone horizontal abduction at 100° with full external rotation	44 ± 25	0.97
6.	Standing external rotation at 90° of abduction	39 ± 13	0.97
7.	Standing external rotation at 0° abduction without a towel roll	34 ± 13	0.90

* The 1-way repeated-measures ANOVA indicated a significant main effect across exercises ($F = 3.726$, $P = .004$).

† Exercise 1 is significantly different than exercise 6 ($P = .014$) and exercise 7 ($P = .003$).

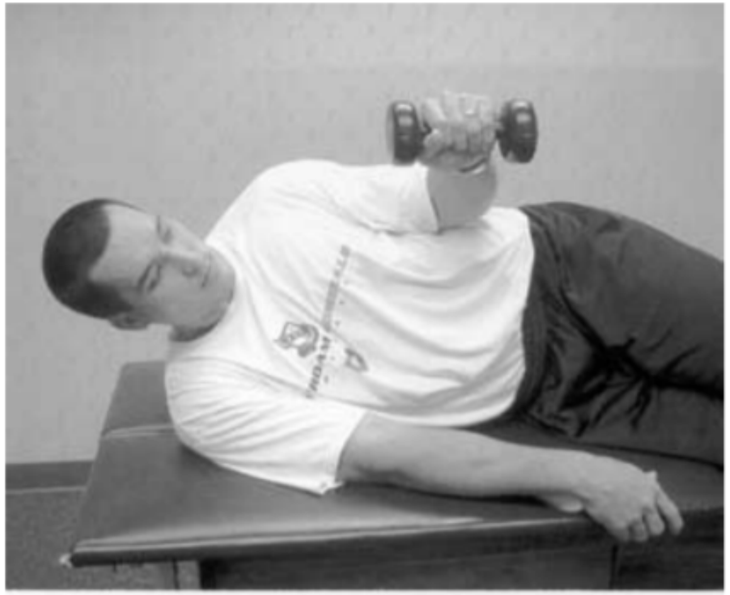


FIGURE 7. Sidelying external rotation.

" Very High" Category

Reinhold et al, J Ortho and Sport Phys Ther, 2004

Rotator Cuff Muscles: *Infraspinatus*, *Supraspinatus* and *Teres Minor*

- <u>Take Home:</u>

  - The highlighted exercises not only have the highest MVIC for the rotator cuff they are also exercises that recruit each specific muscle while quieting the deltoid muscle
    - The ensures less chance for subacromial impingement

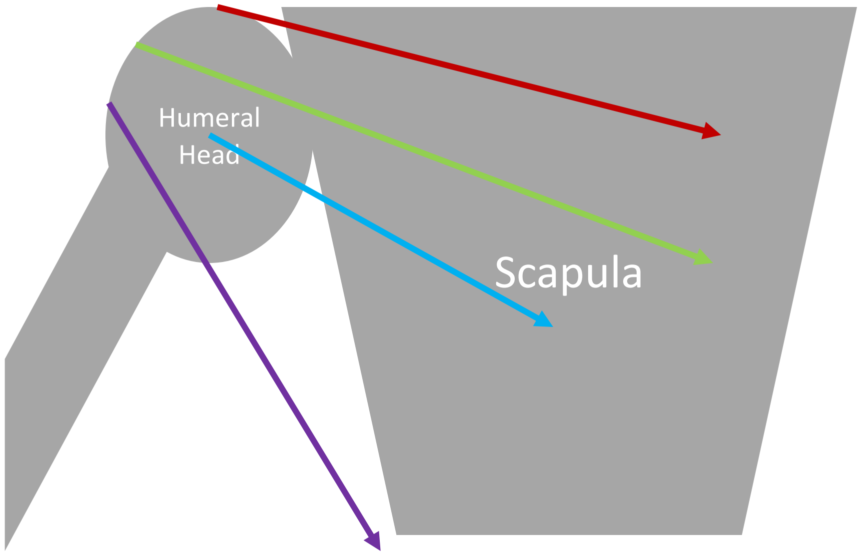
  - There could also be suggestion that if an exercise recruits deltoid muscle while also recruiting rotator cuff muscles it could be due to the assistive compressive force on the humerus
    - Considerations when selecting external rotation exercises may be made based on the amount of infraspinatus and teres minor activity as well as the amount of desired concomitant activity of the supraspinatus and deltoid musculature

Reinhold et al, J Ortho and Sport Phys Ther, 2004

Rotator Cuff Importance

Rotator cuff muscle provide dynamic compressive forces to keep the humeral head seated in the concave glenoid fossa.

- Supraspinatus
- Infraspinatus
- Subscapularis
- Teres Minor



Cricchio et al, J Hand Ther, 2011

Rotator Cuff Muscles: *Systematic Review*

- Summary of glenohumeral and scapular muscle activity (normalized by a maximum voluntary isometric contraction [MVIC]) during numerous open and closed chain shoulder exercises commonly used in rehabilitation.

Sports Medicine
August 2009, Volume 39, Issue 8, pp 663–685 | Cite as

Shoulder Muscle Activity and Function in Common Shoulder Rehabilitation Exercises

Authors | Authors and affiliations

Rafael F. Escamilla, Kyle Yamashiro, Lonnie Paulos, James R. Andrews

Escamilla et al, Sports Med, 2009

Rotator Cuff Muscles: *Systematic Review*

Exercise	Tubing force (N)*	Upper subscapularis EMG (%MVIC)†	Lower subscapularis EMG (%MVIC)†	Supraspinatus EMG (%MVIC)†	Infraspinatus EMG (%MVIC)†	Pectoralis major EMG (%MVIC)†	Teres major EMG (%MVIC)†	Latissimus dorsi EMG (%MVIC)†
Standing forward scapular punch	260±50	33±28[a]	<20[a,b,c,d]	***46±24***[a]	28±12[a]	25±12[a,b,c,d]	<20[a]	<20[a,d]
Standing IR at 90° abduction	270±30	***58±38***[a]	<20[a,b,c,d]	40±23[a]	<20[a]	<20[a,b,c,d]	<20[a]	<20[a,d]
Standing IR at 45° abduction	260±40	***53±40***[a]	26±19	33±25[a,b]	<20[a]	39±22[a,d]	<20[a]	<20[a,d]
Standing IR at 0° abduction	270±40	***50±23***[a]	40±27	<20[a,b,d,e]	<20[a]	***51±24***[a,d]	<20[a]	<20[a,d]
Standing scapular dynamic hug	260±50	***58±32***[a]	38±20	***62±31***[a]	<20[a]	***46±24***[a,d]	<20[a]	<20[a,d]
D2 diagonal pattern extension, horizontal adduction, IR (throwing acceleration)	270±30	***60±34***[a]	39±26	***54±35***[a]	<20[a]	***76±32***	<20[a]	21±12[a]
Push-up plus	300±90	***122±22***	***46±29***	***99±36***	***104±54***	***94±27***	***47±26***	***49±25***

a Significantly less EMG amplitude compared with push-up plus ($p<0.002$).

b Significantly less EMG amplitude compared with standing scapular dynamic hug ($p<0.002$).

c Significantly less EMG amplitude compared with standing internal rotation at 0° abduction ($p<0.002$).

d Significantly less EMG amplitude compared with D2 diagonal pattern extension, horizontal abduction, internal rotation ($p<0.002$).

e Significantly less EMG amplitude compared with standing forward scapular punch ($p<0.002$).

IR = internal rotation. * There were no significant differences ($p=0.122$) in tubing force among exercises; † there were significant differences ($p<0.001$) in EMG amplitude among exercises.

“ Very High” Category

Table I

Mean (± SD) tubing force and glenohumeral electromyograph (EMG), normalized by a maximum voluntary isometric contraction (MVIC), during shoulder exercises using elastic tubing and bodyweight resistance, with intensity for each exercise normalized by a ten-repetition maximum. Data for muscles with EMG amplitude >45% of a MVIC are set in bold italic type, and these exercises are considered to be an effective challenge for that muscle (adapted from Decker et al.,[10] with permission)

Escamilla et al, Sports Med, 2009

Rotator Cuff Muscles: *Systematic Review*

Exercise	Infraspinatus EMG (%MVIC)*	Teres minor EMG (%MVIC)*	Supraspinatus EMG (%MVIC)*	Middle deltoid EMG (%MVIC)*	Posterior deltoid EMG (%MVIC)*
Side-lying external rotation at 0° abduction	***62±13***	***67±34***	***51±47***^{e}	36±23^{e}	***52±42***^{e}
Standing ER in scapular plane at 45° abduction and 30° horizontal adduction	***53±25***	***55±30***	32±24^{c,e}	38±19^{e}	43±30^{e}
Prone ER at 90° abduction	***50±23***	***48±27***	***68±33***	***49±15***^{e}	***79±31***
Standing ER at 90° abduction	***50±25***	39±13^{a}	***57±32***	***55±23***^{e}	***59±33***^{e}
Standing ER at approximately 15° abduction with towel roll	***50±14***	***46±41***	41±37^{c,e}	11±6^{c,d,e}	31±27^{a,c,d,e}
Standing ER at 0° abduction without towel roll	40±14^{a}	34±13^{a}	41±38^{c,e}	11±7^{c,d,e}	27±27^{a,c,d,e}
Prone horizontal abduction at 100° abduction with ER (thumb up)	39±17^{a}	44±25	***82±37***	***82±32***	***88±33***

a Significantly less EMG amplitude compared with side-lying external rotation at 0° abduction ($p < 0.05$).

b Significantly less EMG amplitude compared with standing external rotation in scapular plane at 45° abduction and 30° horizontal adduction ($p < 0.05$).

c Significantly less EMG amplitude compared with prone external rotation at 90° abduction ($p < 0.05$).

d Significantly less EMG amplitude compared with standing external rotation at 90° abduction ($p < 0.05$).

e Significantly less EMG amplitude compared with prone horizontal abduction at 100° abduction with external rotation (thumb up; $p < 0.05$).

ER – external rotation. * There were significant differences ($p < 0.01$) in EMG amplitude among exercises.

Table II

Mean (± SD) rotator cuff and deltoid electromyograph (EMG), normalized by a maximum voluntary isometric contraction (MVIC), during shoulder external rotation exercises using dumbbell resistance with intensity for each exercise normalized by a ten-repetition maximum. Data for muscles with EMG amplitude >45% of an MVIC are set in bold italic type, and these exercises are considered to be an effective challenge for that muscle (adapted from Reinold et al.,[12] with permission)

" Very High" Category

Escamilla et al, Sports Med, 2009

Rotator Cuff Muscles: *Systematic Review*

Exercise	Tubing force (N)	Anterior deltoid EMG (%MVIC)	Middle deltoid EMG (%MVIC)	Subscapularis EMG (%MVIC)	Supraspinatus EMG (%MVIC)	Teres minor EMG (%MVIC)	Infraspinatus EMG (%MVIC)
D2 diagonal pattern extension, horizontal adduction, IR (throwing acceleration)	30±11	27±20	22±12	***94±51***	36±32	***89±57***	33±22
Eccentric arm control portion of D2 diagonal pattern flexion, abduction, ER (throwing deceleration)	13±8	30±17	44±16	***69±48***	***64±33***	***90±50***	***45±21***
Standing ER at 0° abduction	13±7	6±6	8±7	***72±55***	20±13	***84±39***	***46±20***
Standing ER at 90° abduction	12±8	22±12	***50±22***	***57±50***	***50±21***	***89±47***	***51±30***
Standing IR at 0° abduction	16±8	6±6	4±3	***74±47***	10±6	***93±41***	32±51
Standing IR at 90° abduction	16±11	28±18	41±21	***71±43***	41±30	***63±38***	24±21
Standing extension from 90–0°	21±11	19±15	27±16	***97±55***	30±21	***96±50***	***50±57***
Flexion above 120° with ER (thumb up)	26±12	***61±41***	32±14	***99±38***	42±22	***112±62***	***47±34***
Standing high scapular rows at 135° flexion	15±11	31±25	34±17	***74±53***	42±28	***101±47***	31±15
Standing mid scapular rows at 90° flexion	15±11	18±10	26±16	***81±65***	40±26	***98±74***	27±17
Standing low scapular rows at 45° flexion	12±8	19±13	34±23	***69±50***	***46±38***	***109±58***	29±16
Standing forward scapular punch	19±11	***45±36***	36±24	***69±47***	***46±31***	***69±40***	35±17

ER = external rotation; IR = internal rotation.

Table VII

Mean (± SD) tubing force and rotator cuff and deltoid electromyograph (EMG), normalized by a maximum voluntary isometric contraction (MVIC), during shoulder exercises using elastic tubing. Data for muscles with EMG amplitude >45% of an MVIC are set in bold italic type, and these exercises are considered to be an effective challenge for that muscle (adapted from Meyers et al.,[14] with permission)

" Very High" Category

Escamilla et al, Sports Med, 2009

Rotator Cuff Muscles: *In Conclusion*

- There are far more studies looking at the muscle activation of the infraspinatus and the supraspinatus compared to the teres minor and subscapularis.

- Infraspinatus, Supraspinatus and Subscapularis could all be part of the “muscle with in a muscle” theory. Things to keep in mind when picking exercises.

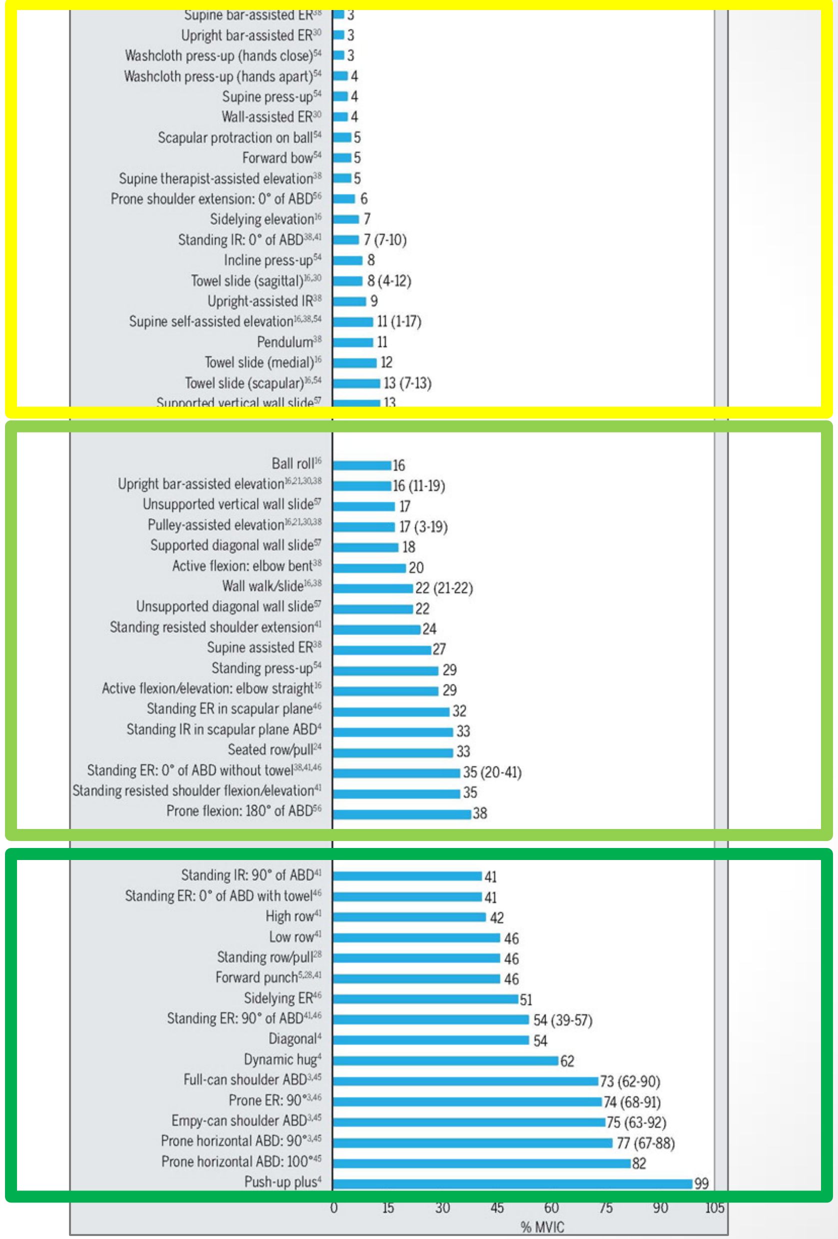
- The follow slides are a summary of some of the exercises best fit to get the most muscle activity during rehab…

Rotator Cuff Muscles: *Supraspinatus*

"Low-Moderate" Category

"High" Category

" Very High" Category



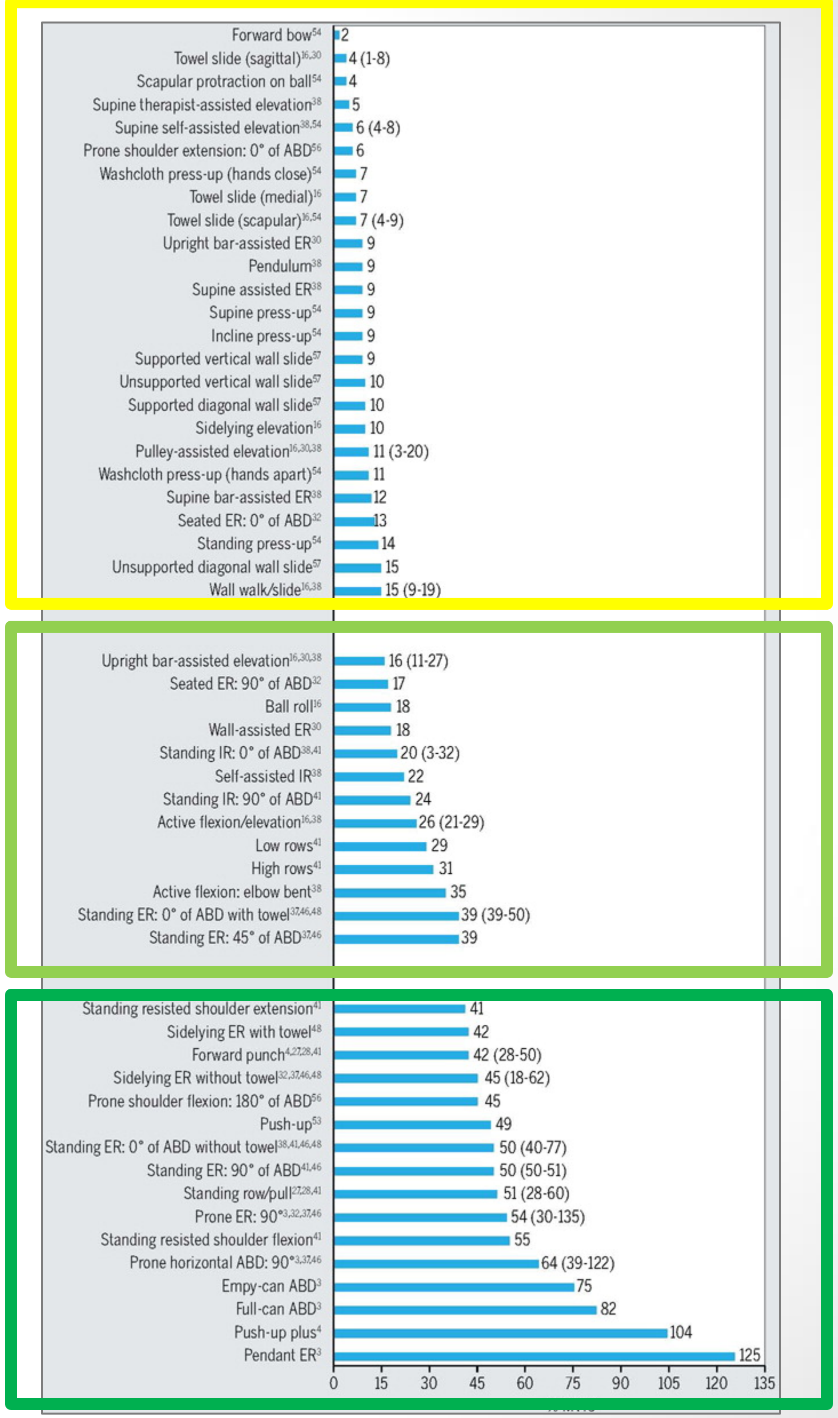
Edwards et al, J Ortho S Phys Ther, 2017

Rotator Cuff Muscles: *Infraspinatus*

“Low-Moderate” Category

“High” Category

“ Very High” Category



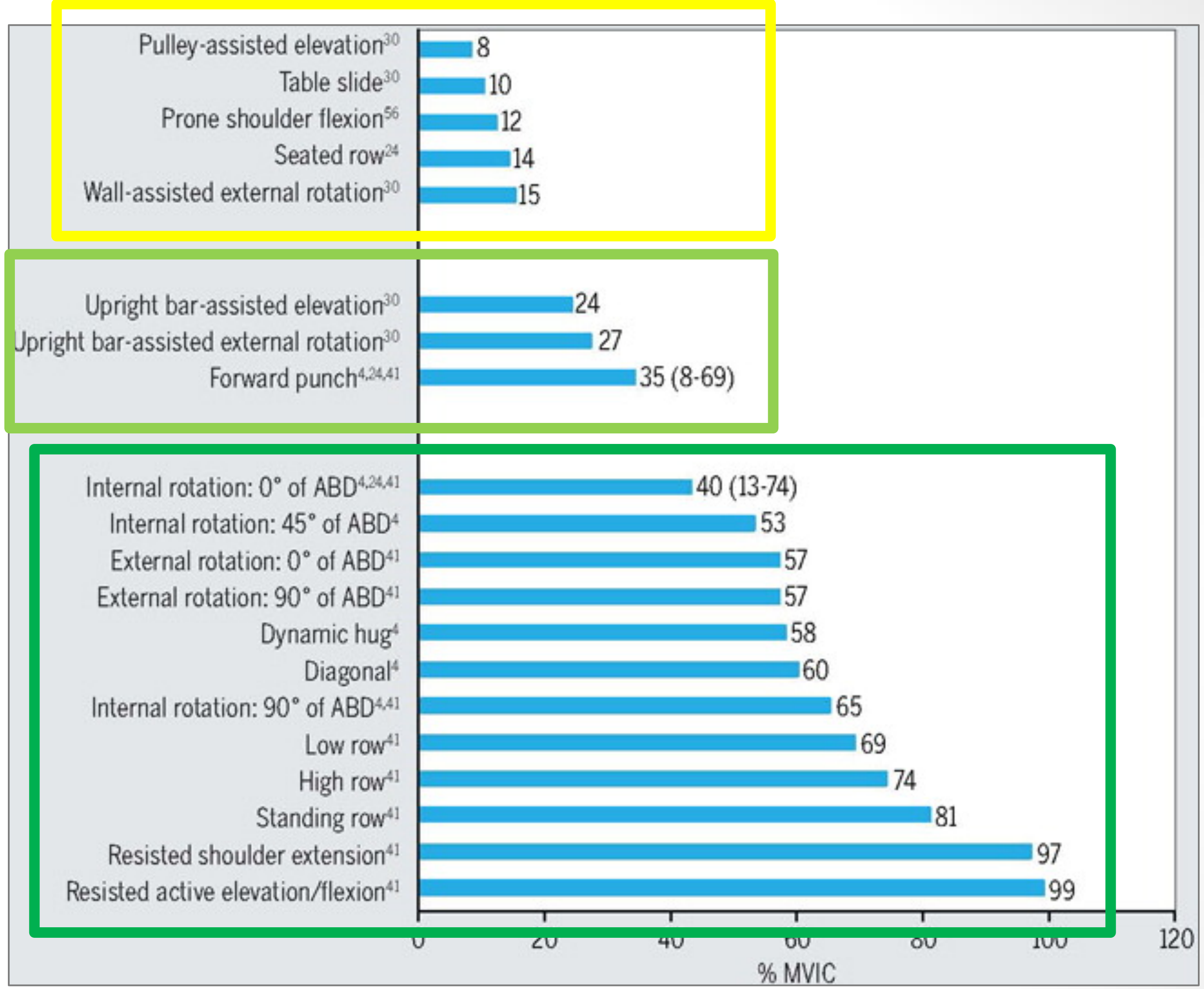
Edwards et al, J Ortho S Phys Ther, 2017

Rotator Cuff Muscles: *Subscapularis*

“Low-Moderate” Category

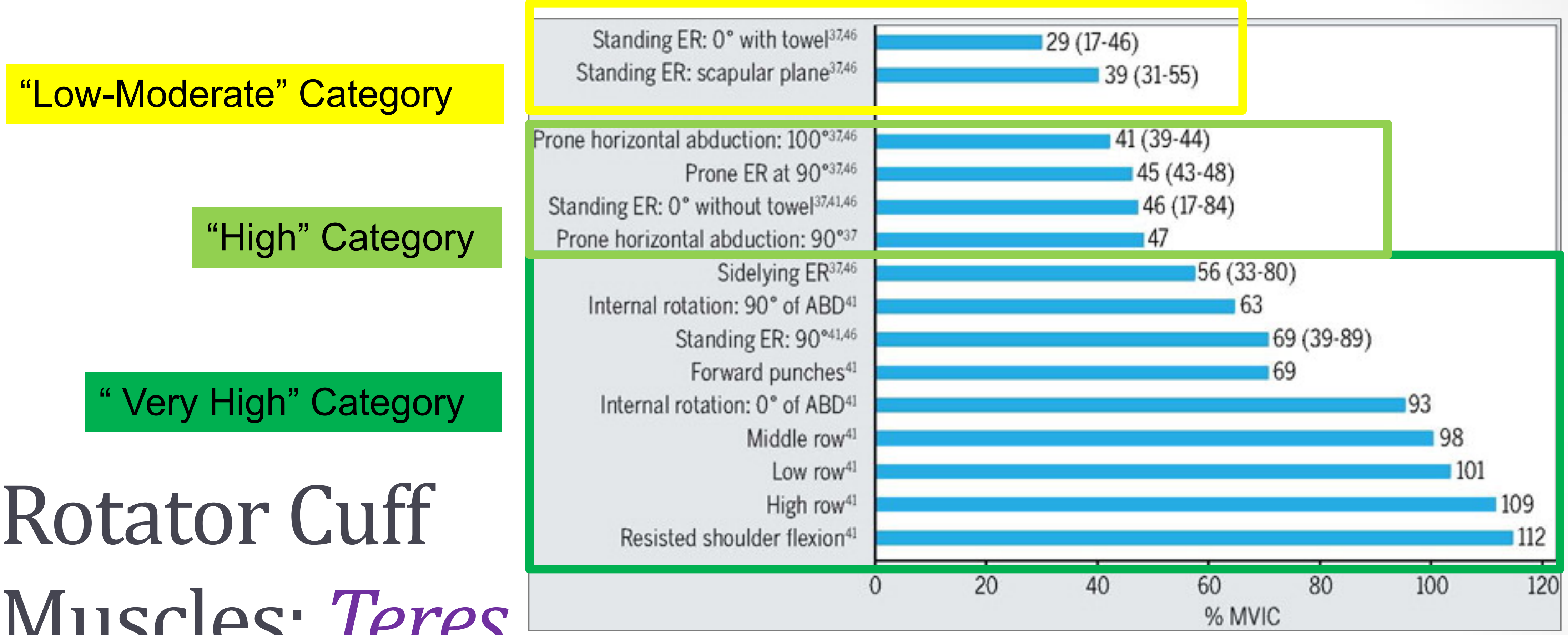
“High” Category

“ Very High” Category



Edwards et al, J Ortho S Phys Ther, 2017

Rotator Cuff Muscles: *Teres Minor*



Edwards et al, J Ortho S Phys Ther, 2017

Questions? Ideas?

Thank you!