Assessment and Management of Scapular Dyskinesis




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COI Disclosure Information
Tim L. Uhl PhD PT ATC FNATA

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Objectives

- Describe and demonstrate an evaluation procedure for upper extremity that incorporates the entire system (kinetic chain) and incorporates scapular assessment as part of comprehensive shoulder examination.
- Explain theoretical rationale for an integrated kinetic chain approach for evaluation and rehabilitation.
- Demonstrate exercise interventions incorporating a kinetic chain approach that would address impairments and functional limitations in patients that presenting with shoulder pain and have associated scapular dyskinesis impairment.

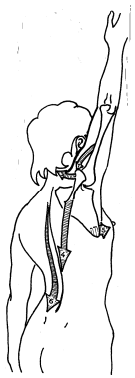
Assessment of Scapular Dysfunction

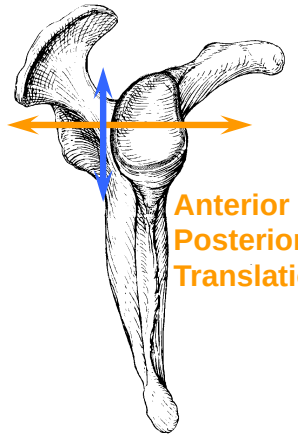
- Share an overview of assessment of scapular dysfunction developed in Lexington
  - W. Ben Kibler MD
    - Colleague since 1985
- Understanding scapular kinematics, muscle activation is critical in assessment of the shoulder

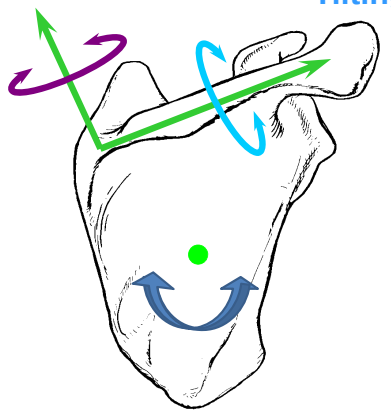



Appreciate Normal Motor Control and Kinematics

- The ability to lift arm is dependent on proximal stability
  - Joint integrity
  - Scapular motion & musculature
  - Spine motion & musculature







Shoulder Evaluation

- Focus on location of pain
- Myopic view

Shoulder Evaluation

- Focus on location of pain
- Myopic view
- Miss the rest of the potential causes of pain
- Evaluate the whole system

Clinical Assessment of Shoulder Function

- **Observation**
  - **Posture**
  - **Scapular assessment**
    - **Static position**
    - **Dynamic motion**
    - **Scapular Repositioning**
- **ROM**
- **Strength**
  - **Manual Muscle Testing**
- **Special or Provocative Tests**

Laboratory

Tests	Considerations	Findings
Static posture bilateral stance	Feet / Knee / Hips / Pelvis Thoracic Scolosis / Kyphosis – Inclinometer Scapular position Shoulder/Scapula – double square / Atrophy Forward Head	
Dynamic Posture Core Stability (note hip/knee/ankle)	Dynamic gait	
	Stand on R leg	
	Stand on L leg	
	Squat on right leg	
	Squat on left leg	

Tests	**Considerations**	**Right**	**Left**
Shoulder ARROM	Active Forward Elevation		
	Active Abduction		
	External Rotation		
	Internal Rotation up spine		
Scapular AROM	**Flexion with load when appropriate**		
	Scaption with load when appropriate		
Cervical AROM			
Trunk AROM			

Tests	**Considerations**	**Right**	**Left**
Scapular Tests (standing)	Scapular Assistance Test (+) reduction of pain with scapular support		
	Scapular Retraction Test (+) reduction of pain and/or increase strength		
		Right	**Left**
Rotator Cuff Strength (standing)	Supraspinatus – thumb up		
	Subscapularis – belly or lift off		
	Infraspinatus – internal rotated 45°		
	Serratus Anterior - 120° elevated		

Tests	Considerations	Right	Left
Special Tests (standing)	Neer		
	Hawkins-Kennedy		
	Active compression		
	Dynamic Labral Shear		
		Right	**Left**
Scapular Strength (lying)	Protraction for Serratus Anterior		
	Prone flexion at 135° abduction (Lower Trapezius)		
	Medial border retraction (Rhomboids and Middle Trap.)		
	Posterior Shoulder Endurance Test		

Tests	Considerations	Right	Left
PROM/ Glenohumeral Instability (lying)	GH. internal rotation with scapula stabilized		
	GH. External rotation active and passive		
	Horizontal Adduction with scapula stabilize		
	Elevation active and passive		
	Apprehension		
	Relocation (instability / labral)		
	Crank		
	Biceps Load		

Assessment Summary

- **Assessment of scapular motion can be performed with moderate reliability within the standard examination of the upper quarter**
- **Its presence is relatively common but it's role is unclear and at this time be considered an impairment that may be a factor contributing to pain**
  - **Much like excessive pronation in patellofemoral pain syndrome**
- **Repositioning tests to alter symptoms along with other assessments of strength and flexibility forms a complete examination**
- **Further investigation to the meaningfulness or the predictive nature of these test is needed.**

Algorithm of treatment of shoulder pain

Fig. 1 Assessment and treatment algorithm for a patient with shoulder pain. [1]Muscle performance deficits may take the form of strength, strength ratio, active or passive length or recruitment pattern deficits. [2]Examples of methods to assess symptom reduction with alterations in movement: scapular assistance test [29, 30]; scapular retraction test [30, 31]; change of posture [32]

- **Co-ordinated (smooth) scapulohumeral movement based on movement analysis research and side-side comparison with correct humeral head position in glenoid and no compensatory trunk movement**
  - **Klintberg et al., 2014**

Applying Principles of Kinetic Chain into Scapular Rehabilitation

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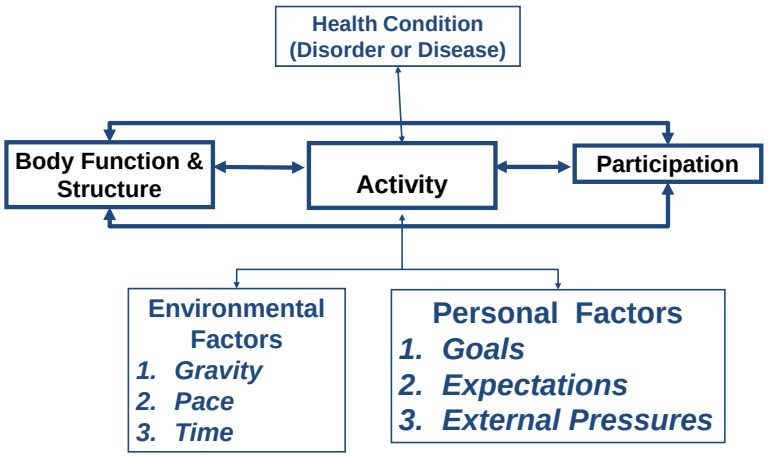
Rehabilitation Plan Considerations (ICF)

- Body Function & Structure
  - Strength
  - Flexibility
  - Tissue disruption
- Activity Limitations
  - Reaching overhead
  - Throwing
  - Weight lifting
- Participation status
  - Practice/ Game/ Work

International Classification of Function (ICF) Model

World Health Organization, 2002



Theoretical Foundations of Kinetic Chain Rehabilitation?

1. Kinetic link model
2. Motor control activation patterns
3. Proprioceptive Neuromuscular Facilitation principles
   - McMullen & Uhl JAT 2000

1. Kinetic Link Model

- A model of linked segments commonly used in biomechanics
- Acceleration of distal segment comes from the "controlled deceleration" of proximal segments

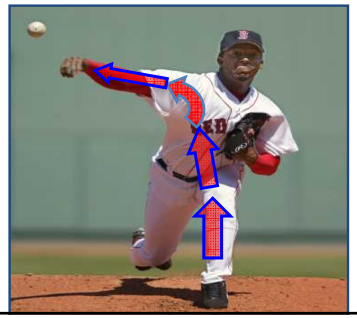
2. Motor Control Activation Patterns

Proximal Stabilization Anticipatory Postural Adjustment

- Transverse abdominal and multifidus musculature precedes distal arm motion
- This activation provides trunk stabilization and prevents postural perturbation
  - Hodges and Richardson. Exp Brain Res 1997
  - Cordo and Nashner. J Neurophysiol 1982
- Panjabi Model spine
  - Passive – Osseoligamentous structures
  - Active – Muscular system
  - Neural – Control system
    - Panjabi J Spinal Disorder 1992

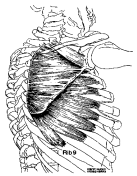
Force Transmission through the Kinetic Chain

- Diagonal orientation of muscle that produce large forces to move distal segment
- Other Functions
  - Absorb force
  - Stabilize spine



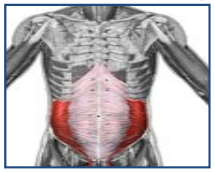
Core Anatomy: Anterior Serape Anterior Oblique Sling

Serratus Anterior



External Obliques

Internal Obliques

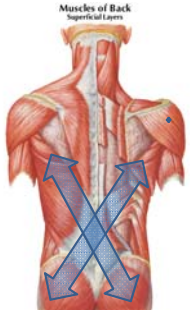


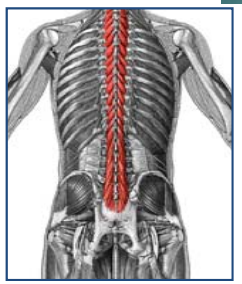
Hip Flexors

Drive off same leg

Core Anatomy: Posterior Serape Posterior Oblique Sling

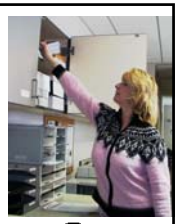
Decelerators: Posterior cuff/ Scapular / Multifidus / Thoracodorsal fascia / Gluteals/ Thigh musculature



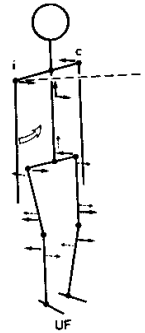


Decelerate off contralateral leg

3rd Component is Integrating PNF Principles



- Normal development proximal to distal and cervicocaudal (Head to toe)
- Reciprocal relationship between flexors and extensors for stability and normal motion
- Motor behavior is an orderly sequence of total patterns of movement and posture
- Improvement of motor ability depends on motor learning
- Frequent stimulation promotes learning
- Goal directed activities (Task)

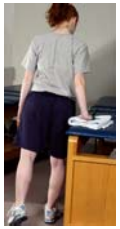


Applying PNF Principles to Kinetic Chain Rehabilitation

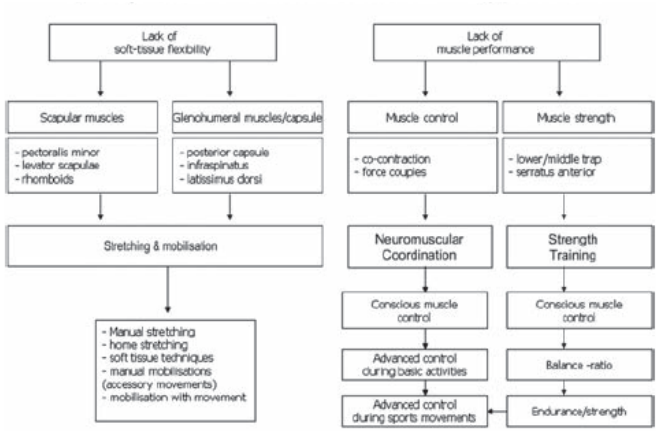
- Clinician must help the patient relearn the movement pattern
  - Selecting resistance or assistance
  - Visual, auditory, and tactile feedback
  - Increased muscular recruitment
    - Seitz et al., J Electromyog Kines 2014
- Stronger components of a movement pattern facilitate weaker (irradiation)

Isolating vs. Integrating Exercises

- Prone Extension
  - Posterior cuff (teres minor) and deltoid >60% MVIC
    - Blackburn et al., JAT 1990
    - DeMey et al., AJSM 2012
- Standing shoulder extension with forward step
  - Trunk / Scapular/ Cuff musculature
- Two different approaches neither is wrong



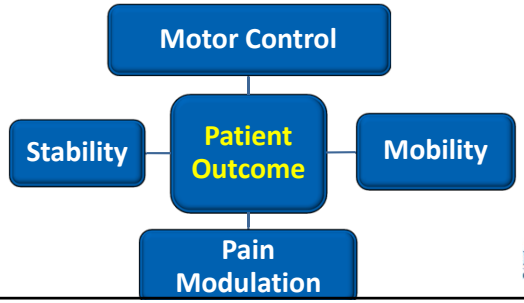
Scapular Rehabilitation Algorithm



Ellenbecker & Cools Br J Sports Med 2010

Scapular Rehabilitation Interventions

1. Post-operative Shoulder Rehabilitation
2. Scapular dyskinesis and shoulder pain in overhead athlete during season
3. Scapular dyskinesis 6 months following labral repair



1. Post-op Patient

- Status-Post 5-10 day from superior labral repair
- Physician want to follow a phased motion recovery
  - Wilk et al., JOSPT 2005
- Patient is in moderate pain and somewhat apprehensive to move

	Flexion	Internal Rotation	External Rotation
Week 0-2	75	45	0-10
Week 3-4	90	55	25
Week 5-6	145	55 @ 45 ABD	50 @ 45 ABD
Week 7-9	180	75 @ 90 ABD	90 @ 90 ABD

Post-Operative Rehabilitation
SLAP Repairs: Precautions

Immobilized for approximately ≈ 3 weeks
- Restrict external rotation to 0°
- Restrict shoulder extension
- Gradual ROM progression

- Sleep in shoulder immobilizer ~ 4wk
- Avoid isolated biceps contractions (5-6 wks)
  - Wilk et al., JOSPT 2005
- Caution with bimanual tasks (open jar) increases Biceps activity
  - Smith et al., JSES 2004
- Posterior shear forces tears bicep anchor to labrum with less force than distraction force
  - Shepard et al., AJSM 2004
- Late cocking position of throwing (Abd & ER) produce greatest labral strain on anterior and posterior portion of superior labrum
  - Pradhan et. al, AJSM 2001
- Rehabilitation Implications:
  - Limit external rotation / abduction gradually increase motion over the first 2 months

Passive & Active Assistive Exercises

- Scapula Orientation
  - Sternal lifts
  - Clock
- Arm supported motion
  - Forward Bow
  - Table slides

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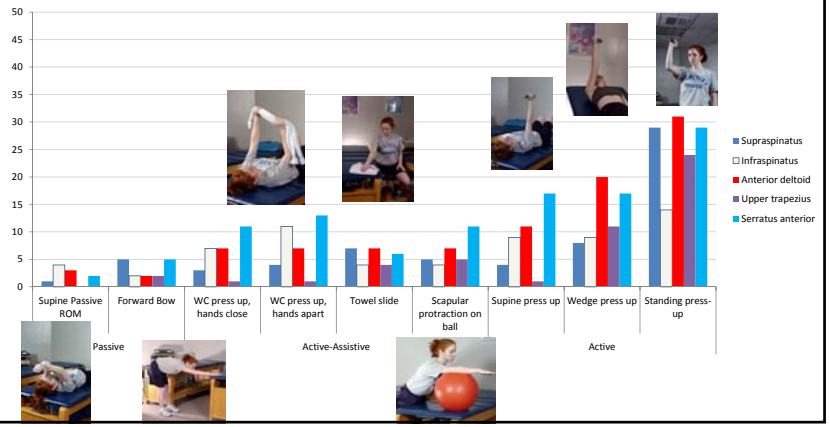
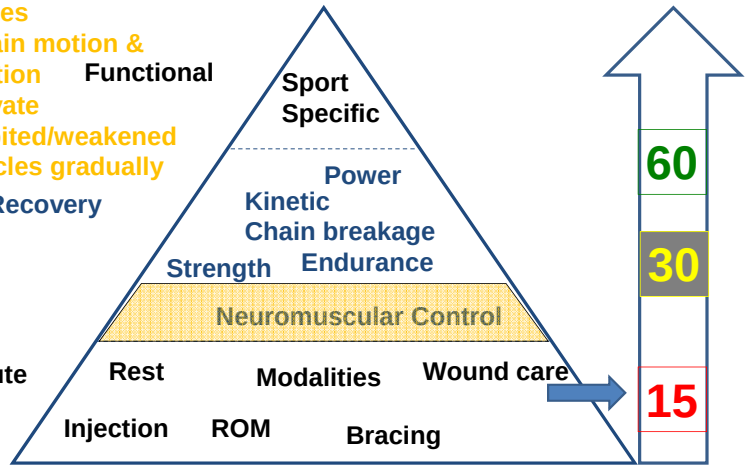
EMG Assessment of Passive, Active-Assistive, & Active Exercises

-Uhl, Phy Med Rehab 2010

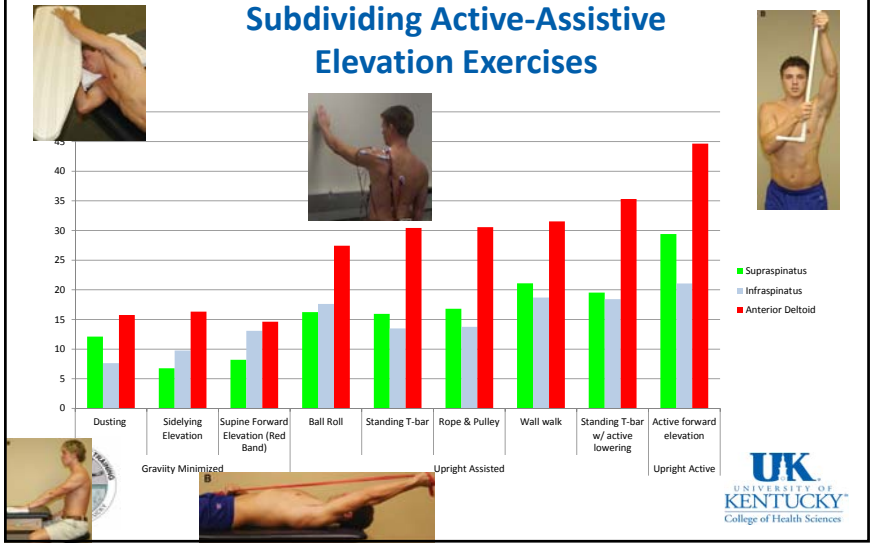


Rehabilitation Progression

- Protect weakened tissues
- Regain motion & function
- Activate inhibited/weakened muscles gradually



Subdividing Active-Assistive Elevation Exercises



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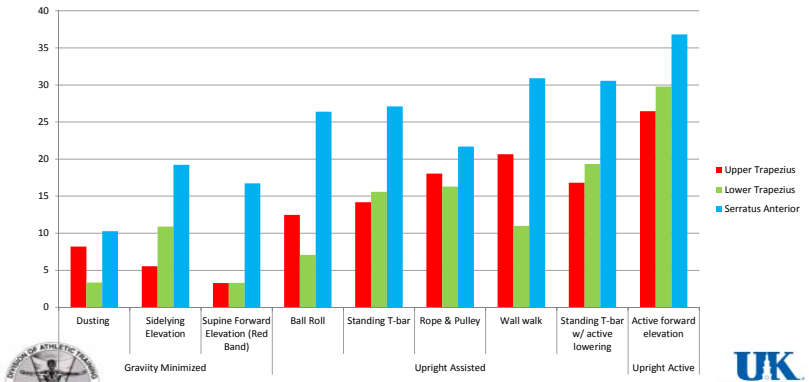
Scapular Muscle Activation Levels



UT/SA Ratio = .2 for supine forward elevation

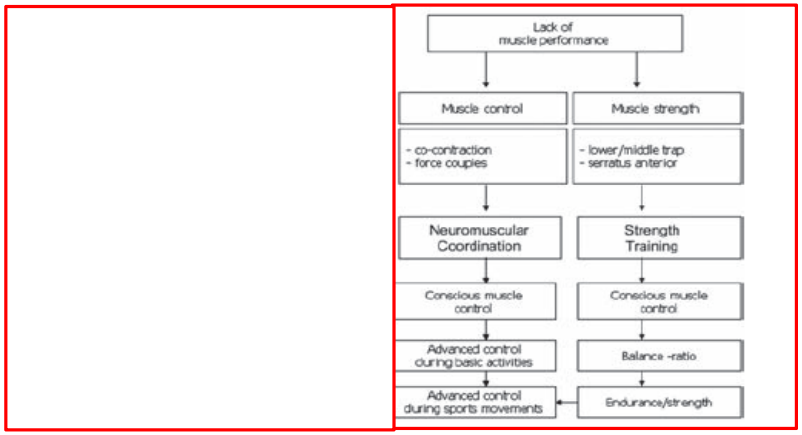
Positional Progressions

- Altering gravitational loads based on biomechanical theories is suggested in the literature
- Massive RC tears - Supine → wedge → upright
  - Levy JSES 2008
- Biceps tenodesis - Side-lying → supine → upright
  - Krupp JOSPT 2009
- Utilizes patient's hand in contact with surface to unload the weight of the arm for AAROM exercises
  - Wise, JSh Elb Surg 2004
- Clinician based exercise progression following these concepts
  - Gravity minimized
  - Upright assisted
  - Active unassisted
    - Gaunt et al., Sports Health (2010)
- Incorporates legs and trunk to initiate and facilitate arm elevation
  - Kibler , Med Sci Sport Ex 1998
  - McMullen & Uhl JAT 2000

2. Non-operative Scenario

- 17 y.o. overhead athlete
- Hx: Insidious onset of shoulder pain over 4 wks with overhead sport
- Objective:
  - Painful arc at 110° with (+) SAT
  - 4/5 Weakness with pain in
    - Elevation
    - External rotation
    - Lower trapezius
  - Rates pain with activity as 5/10
  - Forward shoulders & head
  - Scapular dyskinesis

Scapular Rehabilitation Algorithm



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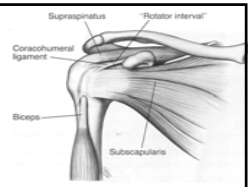
Patient Education



- Determine and set expectations
  - Exercises must be integrated into their life
- Explain to the patient what is going on and how treatment will address complaints
- Provide 2 week expectations with treatment
- Identify activities that provoke symptoms
- Identify exercises that can address deficits that don't increase symptoms
- Use Science
  - Continuum of functional rehabilitation is driven by patient's response to exercise

Finding Appropriate Intensity Level of Exercise

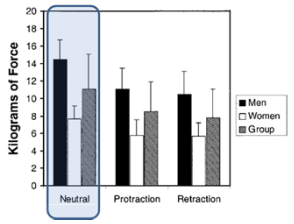
- Standing - attempt to gain scapular control with sagittal plane elevation
  - Functional
- Standing - work on transverse plane
- Static arm – exercise trunk and possibly scapula
- Unload weight of arm or shorten lever arm

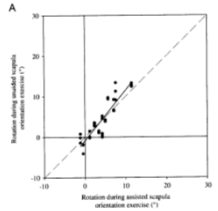
Exercise Selection based on Scapular Control & Pain Response

Exercise	Lower Trapezius	Infraspinatus
	15 ± 11%	Unknown
	20 ± 21%	27%
	65±37%	62±13%
	59±27%	39±17%

Regaining Scapular Motor Control: Science

- Scapular orientation effects strength
  - Neutral position generates more strength than either protraction or retraction
    - Smith et al., Arch Phy Med Rehab 2002
- Scapular orientation exercises indicate patients can learn to find a neutral scapular orientation position (r=.92)
  - Mid-position
    - UR/DR
    - IR/ER
    - AT/PT
    - Mottram et al., Man Ther 2009





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Conscious Control Increases Motor Activity: Science

- Visual, Auditory, & Kinesthetic cueing of scapular orientation
  - Increased Scapular Muscular Recruitment by 7-10% in Sidelying ER & Prone Extension
  - No alteration of UT/LT muscle ratios occurred
    - DeMey et al., JOSPT, 2013
- Auditory & Kinesthetic cueing of scapular of scapular retraction during PHA
  - Increased lower trapezius activation over written instructions by 10-15%
    - Seitz et al., J Electromyog Kines. 2014

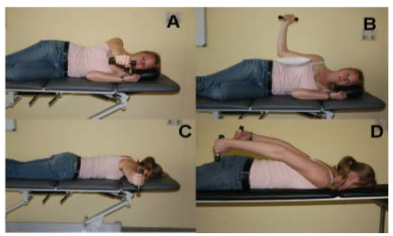
Regaining Scapular Motor Control: Art

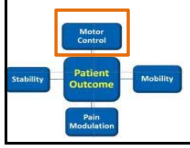
- Scapular orientation exercises using a scapular clock to learn to control scapula independent of arm
- Arm supported scapular motor control
  - Rhythmic initiation
- Biofeedback

Fundamental Program

- Side-lying
  - Elevation
  - ER
- Prone
  - Horizontal Abduction with ER
  - Extension

Effective in increasing function & reduced UT compensation during elevation





Scapular Muscle Rehabilitation Exercises in Overhead Athletes With Impingement Symptoms

Effect of a 6-Week Training Program on Muscle Recruitment and Functional Outcome

Kristof De Mey,*† PT, Lieven Danneels,† PT, PhD, Barbara Cagnie,† PT, PhD, and Ann M. Cools,† PT, PhD
Investigation performed at Ghent University Hospital, Department of Rehabilitation Sciences and Physiotherapy, Ghent, Belgium

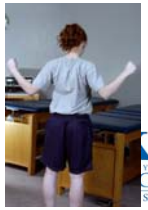
Low Demand Exercises to Facilitate External Rotation Progression

- Low to Moderate activity 20-40%MVIC

Kinetic Chain to Facilitate Scapular Position

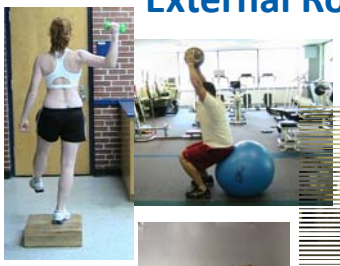
- Active trunk extension (sternal lift) with scapular retraction
- Facilitate <u>proper posture</u> with re-education techniques



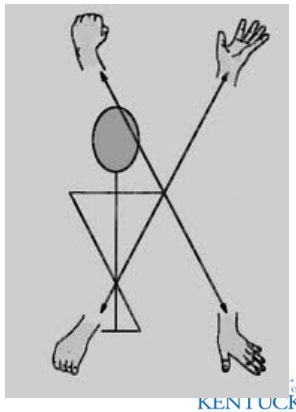
High Demand Exercises to Facilitate External Rotation Progression

High activity
>60%MVIC




Fundamental Movements

- PNF Diagonals
- Reaching / Lowering
- Push / Punch / Throw
- Pull
- Functional

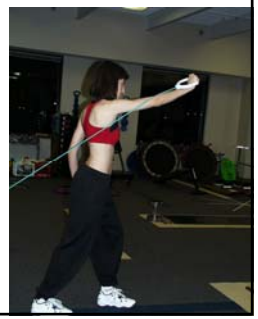



Fundamental Patterns

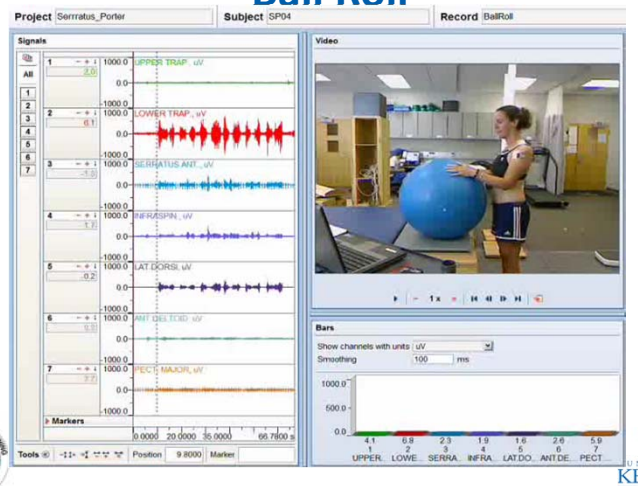
- Punch or Pull
- Reverse Throw


Integrating Entire Body with Elevation

- Step forward punch
- Activate legs→ trunk → scapula & rotator cuff muscle in normal pattern
  - Zattara & Bouisset. J Neurol 1988
  - ~10% increase in scapular recruitment
    - Uhl et al., PMR 2010, Smith et al., APMR 2006
- Support arm to reduce substitution
  - Wise et al., JSES 2002
- PNF concept of irradiation (strong muscles facilitate inhibited muscles)



Ball Roll



Wall Slide

Scapular Dyskinesis 6 months following Superior Labral Repair

- Penn Shoulder Score
- Pain was 21/30
- Satisfaction was 4/10
- Function 42/60
- What else do you need to examine?
  - Algorithm

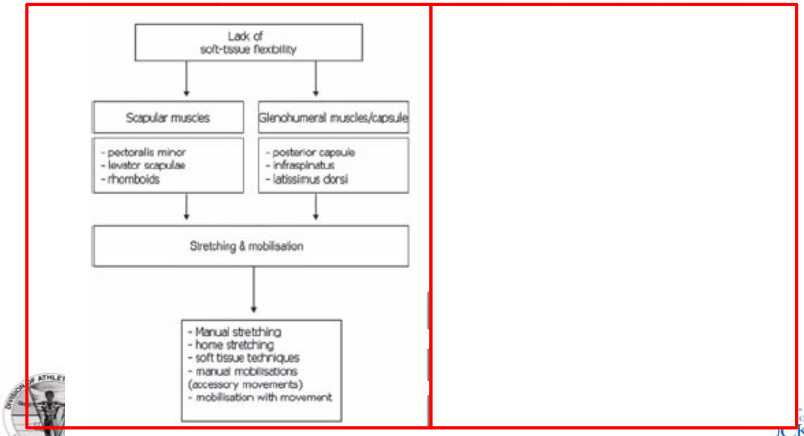
ROM & End Feel

	Right	Left
Active Flexion	182	162
Active Abduction	164	154
Active ER	96	66
Pass ER	80	55
Pass IR	58	54

- Inferior glide was significantly less mobile but not reactive to overpressure
- Pain in superior shoulder during abduction and external rotation
  - Relieved by humeral head posterior glide

Scapular Rehabilitation Algorithm

Ellenbecker & Cools Br J Sports Med 2010



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Stretching Matrix: Hold 30 Seconds for 4 repetitions

Anterior			
Home	Towel Roll	1 arm doorway	2 arm doorway
Clinic	Massage/ Manual	Contract/Relax	Manual w/ trunk
Posterior			
Home	Cross body	Cross body stabilized	Sleeper stretch
Clinic	Massage/ Manual	Contract/Relax	Active stretch
Cervical/Thoracic			
Home	Supine AROM	Sitting AROM	Manual overpressure
Clinic	Massage/ Manual	Contract Relax	
Inferior			
Home	Towel slides	Doorway slides	
Clinic	Massage/ Manual	Contract/Relax	Active stretch

Addressing Posterior Shoulder Tightness and Scapular Stability

- Stabilizing scapula with overpressure
- Integrate massage to teres/lats
  - Trigger point release

Blocked Scapula Stretching

- Pure glenohumeral motion
- Pain free
- Patient controls stretch
- Therapist stabilizes scapula
- Need to have at least 120° unblocked passive flexion

Take Home Points

- Find appropriate intensity level
- Use the scientific foundations to create your art of rehabilitation
- From a scientific foundation & patient's response
  - Individualize patients intervention
- Mobility to Stability
- Think motor control not just strengthening

Evaluation and Treatment of Scapular Dyskinesis

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Description: The body functions as an integrated system, in sport and in work, and is in part driven by specific activities. Understanding how the entire system works together as a functional unit within its environment is indispensable for appropriate evaluation and intervention to restore patients' to their full functional level. An individual patient develops movement patterns and resting postures dependent on their physical characteristics (strength, flexibility, endurance) to meet the demands of the activities (throwing, lifting packages into a truck, inserting rivets) and the environment the task is performed (athletic field, in the water, at a desk). In the common micro-traumatic presentation of an injury our job is to determine which component(s) are creating the pathology, impairments, and functional limitations that are affecting the individual participation in sport or work. The focus of this presentation will address the biomechanical, anatomical, and the physiological considerations needed to create interventions to ultimately resolve the functional limitations to allow the patient to return to full function.

Rehabilitation just as evaluation needs to incorporate the entire functional unit. The first step in rehabilitation is a complete and thorough assessment.[1] During rehabilitation our focus needs to shift from isolating the problem to creating interventions that address the impairments and functional limitations. The approach described in this presentation takes an integrated approach incorporating the kinetic chain model, motor control pattern of proximal to distal activation, and incorporating many principles of proprioceptive neuromuscular facilitation to achieve the goals of restoring function. Consideration for the individual impairments and the environment that the individual lives must be integral to the intervention as the patient is often attempting to return to the same activity that may have precipitated the initial injury.

Objectives:

1. Review normal function of scapular dynamic motion.
2. Explain theoretical rationale for an integrated kinetic chain approach
3. Describe and demonstrate an evaluation procedure for upper extremity that incorporates the entire system (kinetic chain) and incorporates scapular assessment as part of comprehensive shoulder examination.
4. Demonstrate exercise interventions incorporating a kinetic chain approach that would address impairments and functional limitations in patients that present with shoulder pain and have scapular dyskinesis impairment.

Why do We Care about Scapular Dysfunction[2]

- Scapular motion is critical for normal motion and function of upper extremity[3]
- Critical link between trunk and upper extremity
  - Site of multiple muscular attachments
- Provide mobile base for the humerus to maintain glenohumeral stability[2]

Incidence of Problem

- Scapular dyskinesis is intimately involved with glenohumeral derangement
  - 64% Instability
  - 100% Impingement[4]
- Dyskinesis is not associated with the presence of mild pain in athletes[5]

- Recent 3-D kinematic analysis suggests that asymmetry is very common. The dominant side scapula appears to be more internally rotated and anteriorly tilted in healthy college athletes.[6]
- 76% of the participants out of 56 had at least one plane of scapular asymmetry[7]
- Observation of dyskinesis does not indicate injury but in the presence of symptoms should be a trigger to further investigate causes

Potential Scapular Dysfunction Factors

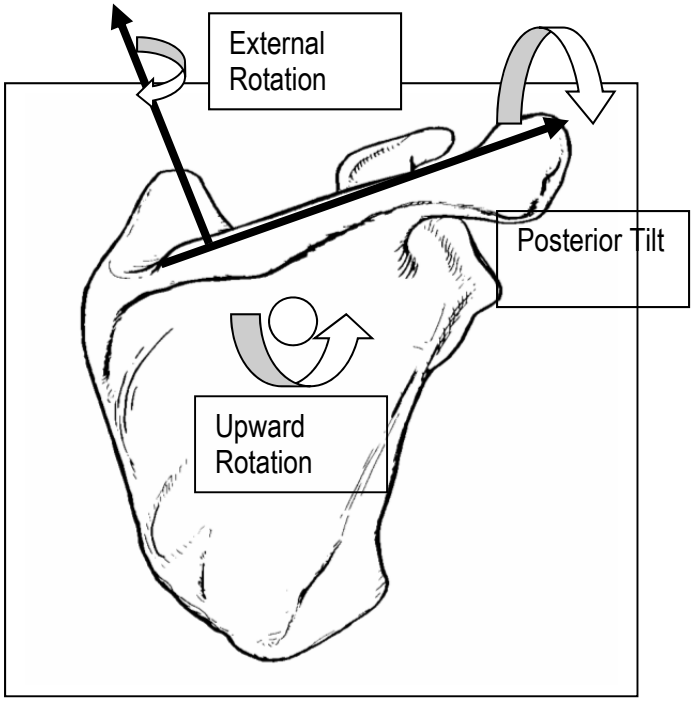
- Glenohumeral pathology[8-10]
- Glenohumeral stiffness
- Neuropathy[11,12]
- Muscle weakness[13]
- Muscle tightness[14]
- Muscle fatigue [15]
- Pain[16]
- Loss of neuromuscular control [17,18]
- Dyskinesis - Impairment of the power of voluntary movement resulting in fragmentary movements.[19]

Appreciate Normal Motor Control and Kinematics

- The ability to lift arm is dependent on proximal stability
- Glenohumeral joint stability
- Scapular musculature
- Spine stability
- Dynamic stability of proximal segments arises due to anticipatory postural adjustments[20,21]

Scapular Kinematics[22,23]
3-D Kinematics
Recent advances in technology and the continued integration of research with clinical assessment has facilitate a better understanding of scapular motion[24,25]

- 3 Rotations
  - Upward/ Downward (50 ± 5°)
  - Internal/External (24 ± 13°)
  - Anterior/Posterior (30 ± 13°)
- 2 Translations
  - Superior/Inferior
  - Anterior/Posterior
  - Medial/Lateral constrained by clavicle



Clinical Assessment of Shoulder
1. Observation
Static Postural Assessment[26-29]
-Cited as a potential cause of shoulder and neck pain [30]
Slouched thoracic posture reduces humeral and scapular motion along with reducing strength[28]
-Hyperkyphosis should be taken into consideration when evaluating patient's with shoulder pain due to potential effect on subacromial space[29]

-Recent report on short pectoralis minor has demonstrated reduced scapular motion [14]
-Double square ($15.00 x 2) alternative approach to measure forward posture.[31,32]
-Length of pectoralis major can be assessed with tape measure[33]

Single leg balance and control

- Single leg balance indicates the leg, pelvic, and trunk strength and dynamic balance without a stable platform it is difficult to generate distal force or maintain appropriate trunk posture.[34,35]
- Screening process for more specific impairments with motion or strength issues.[36-39]

2. ROM

Scapular observational analysis during AROM assessment

Static observation of scapular position[40]
-Downward Rotation
-Depression
-Abduction
-Winging and tilting syndrome

Dynamic[41]
-Normal
-Superior border pattern
-Medial border pattern
-Inferior angle pattern

Follow up study of observational assessment method is better with 2 category system [7]

- Presence of scapular dyskinesia
- Absence of scapular dyskinesia

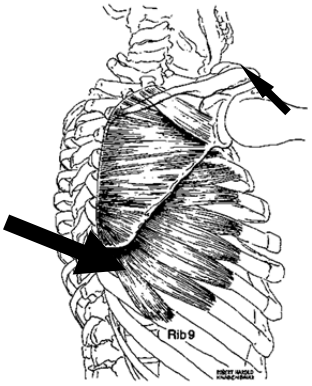
Scapular Dyskinesis Test

Individually evaluates scapular utilizes a loading system to bring out the dyskinetic pattern more clearly and basically uses the same idea of present or absent.[5,42]

-Dysrhythmia: Premature or excessive scapular elevation or protraction, nonsmooth or stuttering motion during arm elevation or lowering, or rapid downward rotation during arm lowering.
-Winging: Any portion of the scapular medial border is posteriorly displaced away from the thorax.

Scapular Assessment Special Tests (Reposition tests)

Repositioning the scapula to facilitate better scapular functional position and potentially open subacromial space
Many impingement tests drive the humerus into the scapula where these tests consider moving the scapula out of the way of the humerus



Scapular Assistance Test[43]

- Assist the scapula retract and upwardly rotate as the arm is elevated
- (+) Pain diminished and range of motion increased
- Indicates improving scapular motion may diminish symptoms
- Moderate to good reliability =.-5-.9[44]

Scapular Retraction Test

- Perform provocative test
- Assess strength of deltoid and rotator cuff
- Have patient retract scapula and manually provide scapular stability then retest strength

- Improved symptoms (strength~20%) indicates scapular muscular control is compromised not truly a rotator cuff problem. A small cohort with similar characteristic were found in water polo athletes.[45,46]
- Alters scapular kinematics[47]

Range of Motion

- Standard directions, ASES recommends 5
- Loss of IR important to asses[48]
- Loss of IR and Total Range of Motion (TROM) is predictive of future injury in baseball and softball players[49,50]
- Posterior shoulder tightness of internal rotation and horizontal adduction require specific consideration especially for athletic and overhead population
  - Expect overhead athlete to have internal rotation deficit
  -In measuring glenohumeral internal rotation it is important to stabilize the scapula.[51]
  -Horizontal adduction should be evaluated as it goes as symptoms go in pathological shoulders.[52,53]

3. Strength

Assessment of Rotator Cuff Muscle Function[54]

- Supraspinatus – elevated to 90° and thumb up
- Infraspinatus – elbow at side with arm internal rotated 45°
- Subscapularis – lift off or belly press

Assessment of Scapular Muscle Function [55]

- Lower Trapezius-Prone arm is abducted to 135° shoulder is flexed and scapula retracted, apply pressure in line with fibers of lower trapezius and anteriorly to move scapula anteriorly
- Middle Trapezius and Rhomboids - Prone humerus is extended and scapula retracted (medial border near spine), apply pressure
- Serratus Anterior - Supine arm is flexed to 90° with arm protracting so that scapular moves laterally along thoracic wall, apply pressure to resist protraction
- Upper Trapezius - cervical spine side bent and rotated away with scapula shrugged, apply pressure to resist elevation and posterior occiput

	Mean (Kg)	*SD (Kg)*	*ICC*	*MDC_{90} (Kg)*
Lower Trapezius	9.2	3.4	,89	2.6
Medial Trapezius / Rhomboids	11.1	3.2	.94	1.8
Upper Trapezius	16.1	7.1	.96	3.3
Serratus Anterior	15.3	6.3	.94	3.6

Scapular Muscle Endurance

- As fatigue increases scapulohumeral relationship approaches a 1:1 ratio especially above 90°. Increased scapular rotation may be compensating for rotator cuff fatigue or improve length tension relationship [15]
- Muscular latency decreases ~ 20% after fatigue of max abduction effort [56]
- Many studies have investigated the effects of fatigue[57-59] on scapular motion but not really a test of scapular endurance
- Two clinical endurance tests: Dynamic and Static Posterior Shoulder Endurance Test. Pilot testing in the laboratory suggest that recruits and fatigues all of the trapezius, posterior deltoid and to a limited extent the infraspinatus. These test recruit entire posterior shoulder musculature so not isolating scapular muscular endurance but shows promise as is moderately reliable, responds to training, and is clinically feasible. Reliability testing is moderate to good with MDC for the static test is 30 seconds[60] and the dynamic test is 5 repetitions.[61]

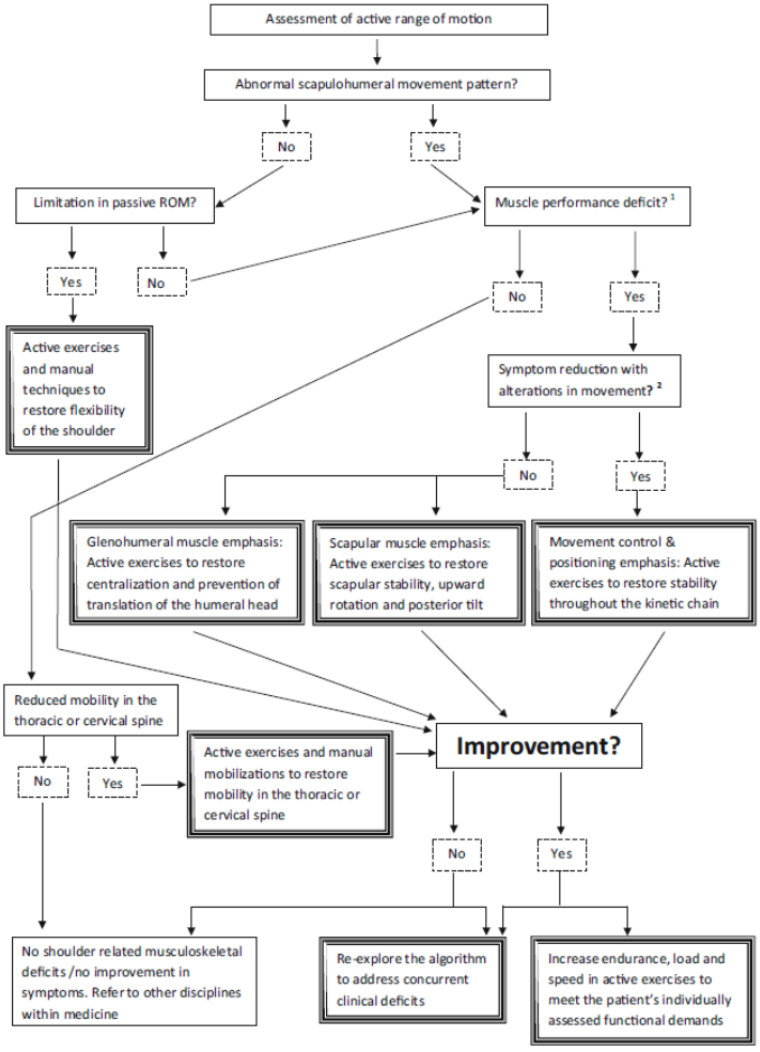
4. Special Test – Provocative testing[62]
   a. Rotator Cuff[63,64]
   b. Instability[65]
   c. Labral[66]

Summary:
A complete assessment of a patient with an upper extremity injury should include assessment and consideration of scapular, spine, and lower extremity dysfunction as part of a thorough evaluation. Continued research and evolution of this approach will hopefully lead to a better clinical assessment of scapular dysfunction.

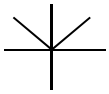
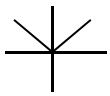
Supplies for Shoulder Evaluation: Tape Measure, Goniometer or Inclinometer, Towel, Dumbbells, Double Level, Video recorder, Hand Held Dynamometer

International Consensus for physiotherapy for Shoulder Pain[67]

Fig. 1 Assessment and treatment algorithm for a patient with shoulder pain. [1]Muscle performance deficits may take the form of strength, strength ratio, active or passive length or recruitment pattern deficits. [2]Examples of methods to assess symptom reduction with alterations in movement: scapular assistance test [29, 30]; scapular retraction test [30, 31]; change of posture [32]



Clinical Evaluation of Shoulder and Kinetic Chain

	Considerations	Findings	
Static posture bilateral stance	Feet / Knee / Hips / Pelvis Thoracic Scolosis / Kyphosis – Inclinometer Scapular position (Lateral Scapular Slide) Shoulder/Scapula – double square / Atrophy Forward Head		
Dynamic Posture Core Stability (note hip/knee/ankle)			
	Dynamic gait		
	Stand on R leg		
	Stand on L leg		
	Squat on right leg		
	Squat on left leg		
Trunk AROM	Cervical/Trunk motion (6 directions) with over pressure		
		Trunk	*Neck*
Shoulder AROM		Right	Left
	Active Forward Elevation		
	Active Abduction		
	External Rotation		
	Internal Rotation up spine (functional)		
Scapula AROM	Add load for appropriate patients	Dysfunction	
	3-5 reps forward flexion	Yes	No
	3-5 reps scaption	Yes	No
Scapular Tests (standing)		Positive	Negative
	Scapular Assistance Test (+) reduction of pain with scapular support		
	Scapular Retraction Test (+) reduction of pain and/or increase strength		
Rotator Cuff Strength (standing)		Right	Left
	Supraspinatus – thumb up		
	Subscapularis – belly or lift off		
	Infraspinatus – internal rotated 45°		
	Serratus Anterior - 120° elevated		
Special Tests (standing)		Right	Left
	Neer		
	Hawkins-Kennedy		
	Active compression		
	Dynamic Labral Shear		
Scapular Strength (lying)		Right	Left
	Protraction for Serratus Anterior		
	Prone flexion at 135° abduction (Lower Trapezius)		
	Medial border retraction (Rhomboids and Middle Trap.)		
	Posterior Shoulder Endurance Test		
PROM/ Glenohumeral Instability (lying)	GH. internal rotation with scapula stabilized		
	GH. External rotation active and passive		
	Elevation active and passive		
	Apprehension		
	Relocation (instability / labral)		
	Crank		
	Biceps Load		
	Horizontal Adduction		

Treatment of Scapular Dyskinesis

The Basis for using the Trunk in Upper Extremity Rehabilitation[68]

1.The Kinetic Chain Model[69]

- A model of linked segments commonly used in biomechanics
- The human body can be characterized as a kinetic chain
- Sport activities attempt to strike or throw at high velocities[69,70]
- Kinetic chain and Leading Joint Hypothesis theory supports that distal force production is due to summation of forces in the proximal segments throughout the entire kinetic chain[71]
- Ability to decelerate proximal segment allows transfer of momentum to next distal segment

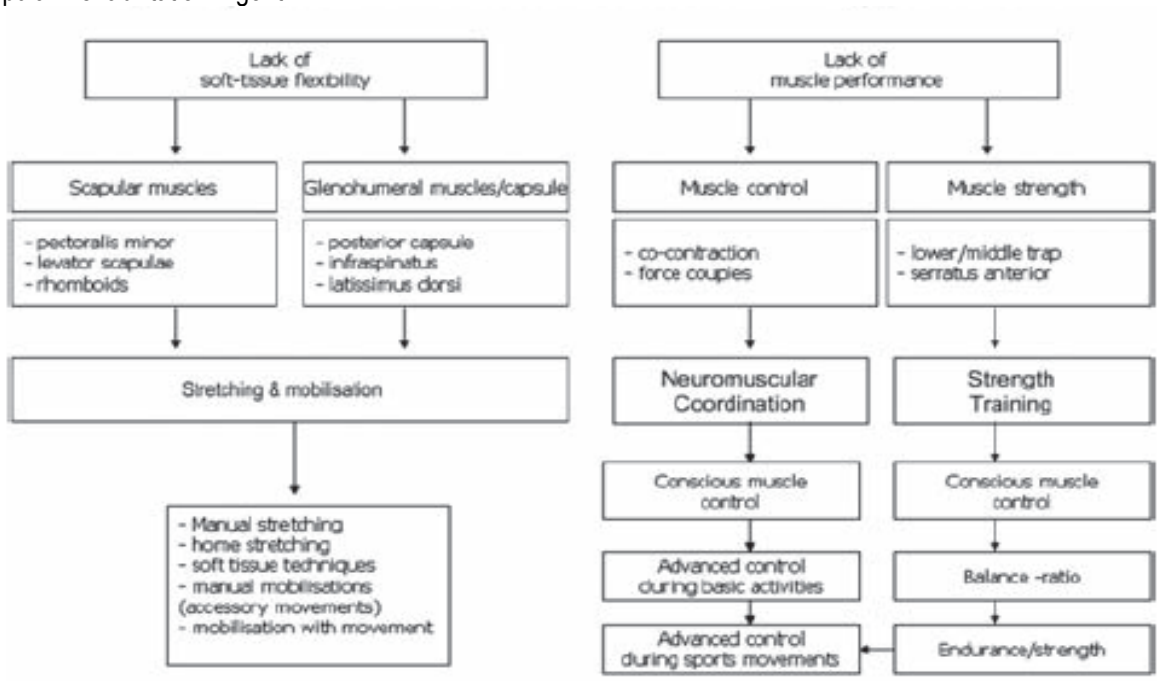
2. Typical motor control pattern activates in a proximal – distal manner in Shoulder Elevation [20,72]

- Transverse abdominal and multifidus musculature precedes distal arm motion
- This activation provides trunk stabilization and prevents postural perturbation
- This pattern facilitates force production in everyday life and in high demand sports
- Proximal stability before distal mobility
- Core critical to shoulder function
  - Trunk function – stabilize, generate and absorb force
  - Spine Model [73]
    - Passive Structures
    - Active Structures
    - Neural Control System
- Breakdown anywhere along the chain can lead to increased demand and added biomechanical stresses ultimately leading to decreased performance and symptoms
- Serape effect is described as the function of trunk muscles generating forces and transferring it to the extremities[74]

3. Applying PNF Principles to Kinetic Chain Rehabilitation[75,76]

- Motor behavior is a sequence including head, trunk, and extremities
- Goal directed movements are dependent on synergies
- Normal motor development occurs in a proximal to distal manner
- Stronger components of a movement pattern facilitate weaker (irradiation)
- Clinician must help the patient relearn the movement pattern
  - Selecting resistance or assistance
  - Verbal cueing
  - Manual contact
  - Visual, auditory, and tactile feedback[77]
- Combining all three planes of motion is functional and is a fundamental principle for many power motions[78]

Scapular Rehabilitation Algorithm[79]



Case 1. Status-Post 5-10 day from superior labral repair

- Physician want to follow a phased motion recovery[80]
- Patient is in moderate pain and somewhat apprehensive to move

	Flexion	*Internal Rotation*	*External Rotation*
Week 0-2	75	45	0-10
Week 3-4	90	55	25
Week 5-6	145	55 @ 45 ABD	50 @ 45 ABD
Week 7-9	180	75 @ 90 ABD	90 @ 90 ABD

Rehabilitation Implications

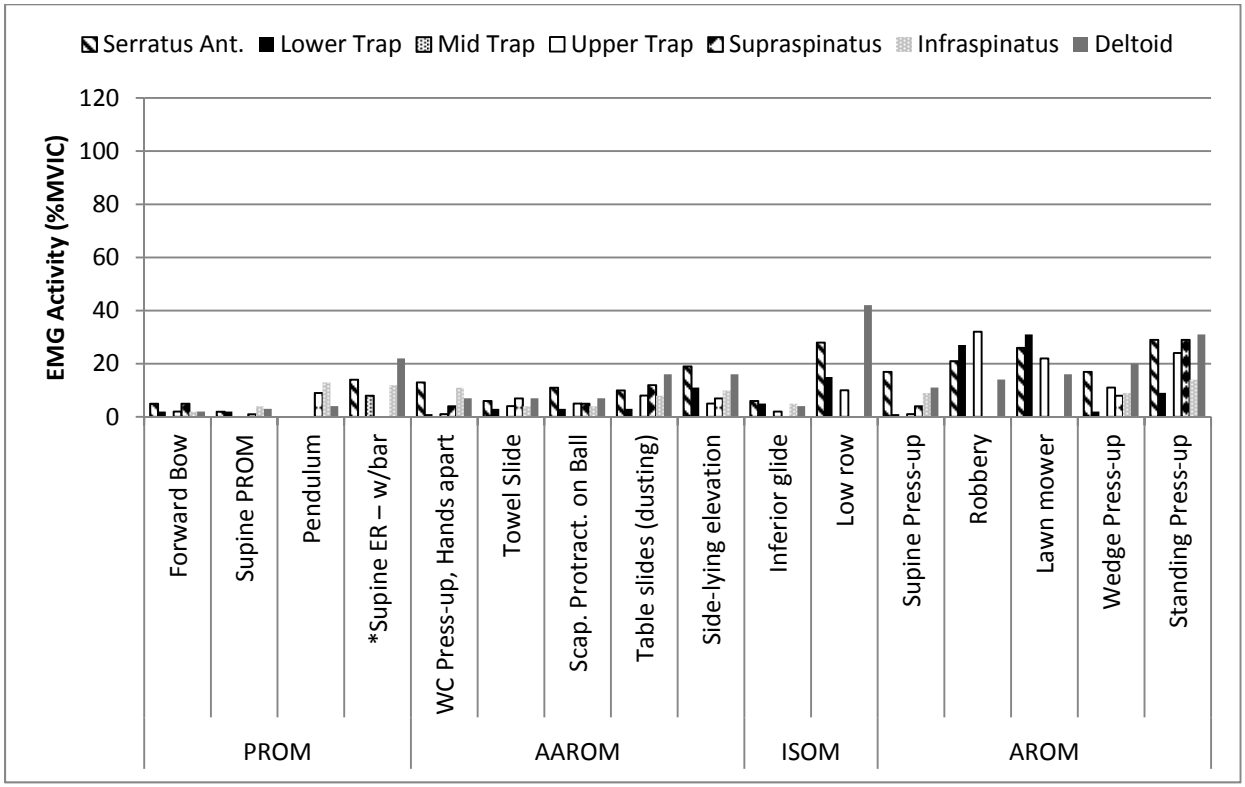
- Gradually increase stress to the arm while staying within restrictions
- Progressively increase motion and muscular activation levels
- Exercise progression should be modified up or down based on patient's pain and response to exercise

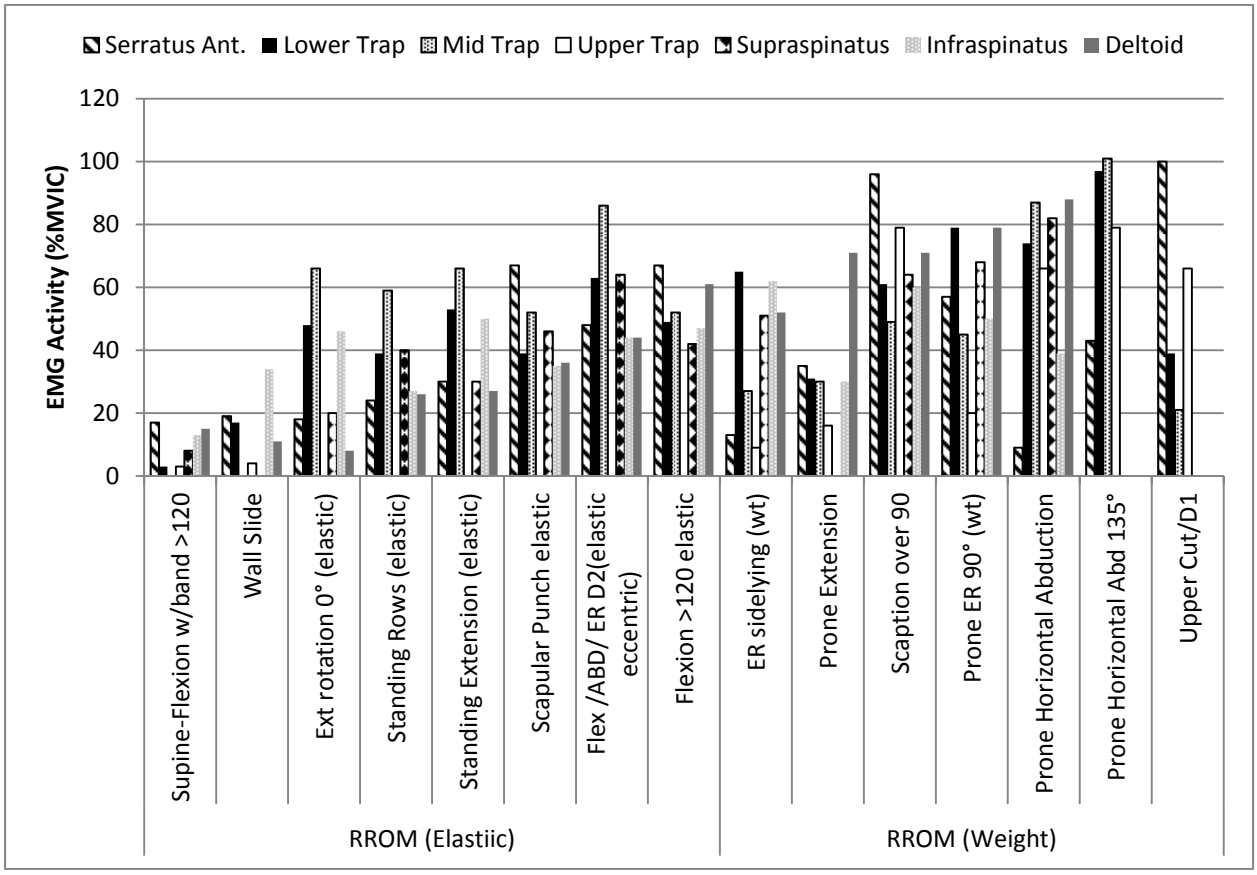
Case 2. 17 year old overhead athlete presents with complaints of shoulder pain due to insidious onset

- Objective Findings:
  - Painful arc at 110 with (+) SAT
  - 4/5 Weakness with pain in Elevation, External Rotation, and Prone Flexion with External Rotation (Lower Trapezius)
  - Single leg squat reaches only 50%
- Forward shoulders & head
- Scapular dyskinesis
- Rates pain with activity as 5/10 at worse, resting pain 0-2 seems to be getting worse

Rehabilitation Implications

- Identify patient expectations and discus realistic goals in 2 weeks
- Identify exercises that address deficits without aggravating symptoms
- Fundamental program is good starting point but may need to address kinetic chain deficits and improper movement patterns





Exercise Continuum based on EMG literature [81-90]

Case 3.Scapular Dyskinesis 6 months post SLAP Repair

- 27 year old rock climber underwent SLAP repair
- Reports mild to moderate shoulder pain
- Not satisfied with shoulder function (Penn Score 67/100)
- Scapular Dyskinesis is apparent
- Humeral motion restricted

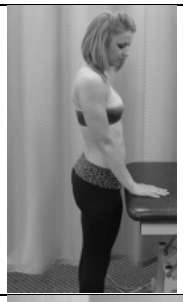
Rehabilitation Implications

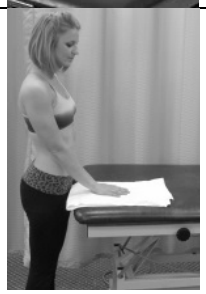
- Address soft-tissue restrictions
- Joint mobilization
- Blocked scapular stretching – with clinical and home assistance

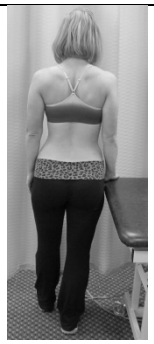
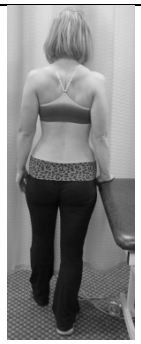
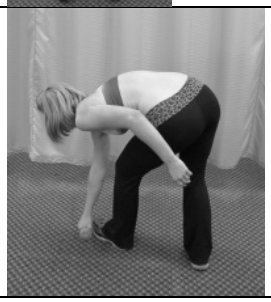
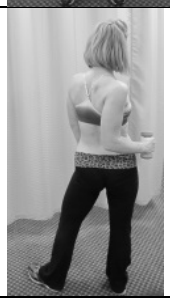
Shoulder stretching matrix

Tight Anterior structures (Pectoralis major/minor)			
Home	Supine lying ½ foam roll or towel roll	1 arm doorway stretch with humerus at 45 to 90°	2 arm doorway stretch
Clinic	Manual stretching in supine / Massage	Contract/Relax techniques	Manual stretching incorporating trunk rotation or functional position
Tight Posterior glenohumeral structures			
Home	Cross body stretch	Cross body with stable scapula	Sleeper stretch
Clinic	Manual horizontal adduction or internal rotation/ Massage	Contract/Relax techniques	Active internal rotation with scapula stable
Cervical/ Thoracic			
Home	Supine AROM	Sitting AROM	Manual overpressure
Clinic	PROM and Massage	Contract Relax	Mobilization
Inferior Structures (Lats, Teres Major			
Home	Table top stretch sitting	Doorway Slides	Kneeling flexion w/trunk rotation

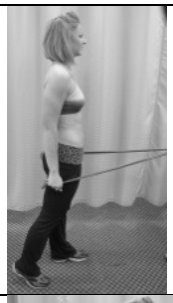
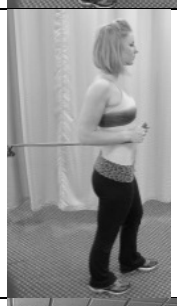
Exercises Illustrated

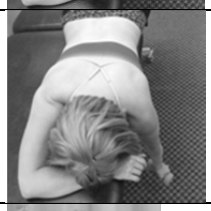
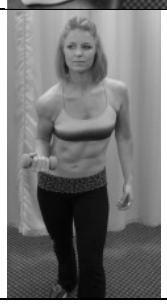
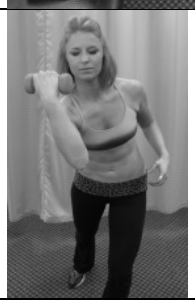
PROM	Forward Bow		
	Supine PROM		

	*Supine ER – w/bar		
AAROM	WC Press-up, Hands apart		
	Towel Slide		
	Scap. Protract. on Ball		
	Table slides (dusting)		
	Side-lying elevation		

ISOM	Inferior glide		
	Low row		
AROM	Supine Press-up		
	Robbery		
	Lawn mower		

	Wedge Press-up		
	Standing Press-up		
RROM (Elastiic)	Supine-Flexion w/band >120		
	Wall Slide		
	Ext rotation 0° (elastic)		
	Standing Rows (elastic)		

	Standing Extension (elastic)		
	Scapular Punch elastic		
	Flex /ABD/ ER D2(elastic eccentric)		
	Flexion >120 elastic		
RROM (Weight)	ER sidelying (wt)		
	Prone Extension		

	Scaption over 90		
	Prone ER 90° (wt)		
	Prone Horizontal Abduction		
	Prone Horizontal Abd 135°		
	Upper Cut/D1		

References:

1. Kibler WB, Livingston B, Bruce R. Current concepts in shoulder rehabilitation. *Advances in Operative Orthopaedics.* 1995;3:249-299.
2. Kibler WB. The role of the scapula in athletic shoulder function. *American Journal of Sports Medicine.* 1998;26((2)):325-337.
3. Inman VT, Saunders M, Abbot LC. Observations on the function of the shoulder joint. *Journal of Bone and Joint Surgery, American Volume.* 1944;26(1):1-30.
4. Warner JJP, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome. *Clinical Orthopaedics and Related Research.* 1992;285(191):199.
5. Tate AR, McClure PW, Kareha S, Irwin D, Barbe MF. A clinical method for identifying scapular dyskinesis, part 2: validity. *J Athl Train.* 2009;44:165-173.

6. Oyama S, Myers JB, Wassinger CA, Daniel Ricci R, Lephart SM. Asymmetric resting scapular posture in healthy overhead athletes. *J Athl Train.* 2008;43(6):565-570.
7. Uhl TL, Kibler WB, Gecewich B, Tripp BL. Evaluation of clinical assessment methods for scapular dyskinesis. *Arthroscopy.* 2009;25(11):1240-1248.
8. Glousman R, Jobe FW, Tibone JE, Moynes D, Antonelli D, Perry J. Dynamic electromyorgrapic analysis of the throwing shoulder with glenohumeral instability. *Journal of Bone and Joint Surgery, American Volume.* 1988;70-A(2):220-226.
9. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys.Ther.* 2000;80(3):276-291.
10. Lukasiewicz AC, McClure P, Michener L, Pratt N, Sennett B. Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. *Journal of Orthopaedic and Sports Physical Therapy.* 1999;29(10):574-586.
11. Schultz JS, Leonard JA, Jr. Long thoracic neuropathy from athletic activity [see comments]. *Archives of physical medicine and rehabilitation.* 1992;73(1):87-90.
12. Warner JJ, Navarro RA. Serratus anterior dysfunction. Recognition and treatment. *Clinical Orthopaedics And Related Research.* 1998(349):139-148.
13. Cools AM, Witvrouw E, Declercq GA, Vanderstraeten GG, Cambier DC. Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms. *British Journal of Sports Medicine.* 2004;38:64-68.
14. Borstad JD, Ludewig PM. The effect of pectoralis minor length on scapular kinematics in subjects without shoulder pathology. *Journal of Orthopaedic and Sports Physical Therapy.* 2004;34(1):A16.
15. McQuade KJ, Dawson JD, Smidt GL. Scapulothoracic muscle fatique associated with alterations in scapulohumeral rhythm kinematics during maximum resistive shoulder elevation. *Journal of Orthopaedic and Sports Physical Therapy.* 1998;28(2):74-80.
16. Brox JI, RÃ¸e C, Saugen E, VÃ¸llestad NK. Isometric abduction muscle activation in patients with rotator tendinosis of the shoulder. *Arch Phys Med Rehabil.* 1997;78(11):1260-1267.
17. Scovazzo ML, Browne A, Pink M, Jobe FW, Kerrigan J. The painful shoulder during freestyle swimming, an electromyographic cinematographic analysis of twelve muscles. *American Journal of Sports Medicine.* 1991;19((6)):577-582.
18. Wadsworth DJ, Bullock-Saxton JE. Recruitment patterns of the scapular rotator muscles in freestyle swimmers with subacromial impingement. *International journal of sports medicine.* 1997;18(8):618-624.
19. Friel JP. *Dorland's Illustrated Medical Dictionary.* Philadelphia: WB Saunders; 1974.
20. Cordo PJ, Nashner LM. Properties of postural adjustments associated with rapid arm movements. *Journal of Neurophysiology.* 1982;47(2):287-308.
21. Zattara M, Bouisset S. Posturo-kinetic organisation during the early phase of voluntary upper limb movement. 1 Normal subjects. *Journal of Neurology, Neurosurgery, and Psychiatry.* 1988;51:956-965.
22. McClure PW, Michener LA, Sennett BJ, Karduna AR. Direct 3-dimensional measurement of scapular kinematics during dynamic movements in vivo. *J.Shoulder.Elbow.Surg.* 2001;10(3):269-277.
23. Ludewig PM, Phadke V, Braman JP, Hassett DR, Cieminski CJ, LaPrade RF. Motion of the shoulder complex during multiplanar humeral elevation. *J Bone Joint Surg Am.* 2009;91(2):378-389.
24. van-der-Helm FC. Analysis of the kinematic and dynamic behavior of the shoulder mechanism. *Journal of Biomechanics.* 1994;27(5):527-550.
25. van der Helm FCT, Pronk GM. Three-dimensional recording and description of motions of the shoulder mechanism. *Journal of Biomechanical Engineering.* 1997;117:27-40.
26. Greenfield B, Catlin PA, Coats PW, Green E, McDonald JJ, North C. Posture in patients with shoulder overuse injuries and healthy individuals. *Journal of Orthopaedic and Sports Physical Therapy.* 1995;21(5):287-295.
27. Lewis JS, Wright C, Green A. Subacromial impingement syndrome: the effect of changing posture on shoulder range of movement. *Journal of Orthopaedic and Sports Physical Therapy.* 2005;35(2):72-87.
28. Kebaetse M, McClure P, Pratt N. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinetics. *Archives of physical medicine and rehabilitation.* 1999;80:945-950.
29. Gumina S, Di Giorgio G, Postacchini F, Postacchini R. Subacromial space in adult patients with thoracic hyperkyphosis and in healthy volunteers. *Chir Organi Mov.* 2008;91(2):93-96.

30. Kamkar A, Irrgang JJ, Whitney SL. Nonoperative management of secondary shoulder impingement syndrome. *Journal of Orthopaedic and Sports Physical Therapy.* 1993;17(5):212-224.
31. Peterson DE, Blankenship KR, Robb JB, et al. Investigation of the validity and reliability of four objective techniques for measuring forward shoulder posture. *Journal of Orthopaedic & Sports Physical Therapy.* 1997;25(1):34-42.
32. Kluemper M, Uhl TL, Hazelrigg H. Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. *Journal of Sport Rehabilitation.* 2006;15(1):58-70.
33. Borstad JD. Measurement of pectoralis minor muscle length: validation and clinical application. *J Orthop Sports Phys Ther.* 2008;38(4):169-174.
34. Hertel J, Miller J, Denegar CR. Intratester and intertester reliability during the star excursion balance test. *Journal of Sport Rehabilitation.* 2000;9:104-116.
35. Trojian TH, McKeag DB. Single leg balance test to identify risk of ankle sprains. *British Journal Of Sports Medicine.* 2006;40(7):610.
36. Livengood AL, DiMattia MA, Uhl TL. "Dynamic Trendelenburg": Single-Leg-Squat Test for Gluteus Medius Strength. *Athletic Therapy Today.* 2004;9(1):24-25.
37. DiMattia MA, Livengood AL, Uhl TL, Mattacola CG, Malone TR. What Are the Validity of the Single-Leg-Squat Test and Its Relationship to Hip-Abduction Strength? *Journal of Sport Rehabilitation.* 2005;14(2):108.
38. McCann RS, Kosik KB, Beard MQ, Terada M, Pietrosimone BG, Gribble PA. Variations in Star Excursion Balance Test Performance between High School and Collegiate Football Players. *Journal of strength and conditioning research / National Strength & Conditioning Association.* 2015.
39. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *J Athl Train.* 2012;47(3):339-357.
40. Sahrmann SA. *Diagnosis and Treatment of Movement Impairment Syndromes.* St. Louis: Mosby; 2002.
41. Kibler WB, Uhl TL, Maddux JQ, McMullen J, Brooks PV, Zeller B. Qualitative clinical evaluation of scapular dysfunction. A reliability study. *Journal of Shoulder and Elbow Surgery.* 2002;11(6):550-556.
42. McClure PW, Tate AR, Kareha S, Irwin D, Zlupko E. A clinical method for identifying scapular dyskinesis, part 1: reliability. *J Athl Train.* 2009;44:160-164.
43. Kibler WB, McMullen J. Scapular dyskinesis and its relation to shoulder pain. *Journal of American Academy of Orthopaedic Surgeons.* 2003;11:142-151.
44. Rabin A, Irrgang JJ, Fitzgerald GK, Eubanks A. The intertester reliability of the Scapular Assistance Test. *J Orthop Sports Phys Ther.* 2006;36(9):653-660.
45. Kibler WB, Sciascia A, Dome D. Evaluation of apparent and absolute supraspinatus strength in patients with shoulder injury using the scapular retraction test. *Am J Sports Med.* 2006;34(10):1643-1647.
46. Tate AR, McClure PW, Kareha S, Irwin D. Effect of the Scapula Reposition Test on shoulder impingement symptoms and elevation strength in overhead athletes. *J Orthop Sports Phys Ther.* 2008;38(1):4-11.
47. Kibler WB, Ludewig PM, McClure PW, Uhl TL, Sciascia A. Scapular summit 2009. *J Orthop Sports Phys Ther.* 2009;39(11):A1-A13.
48. Kibler WB, McQueen C, Uhl T. Fitness evaluations and fitness findings in competitive junior tennis players. *Clin.Sports.Med.* 1988;7(2):403-416.
49. Shanley E, Rauh MJ, Michener LA, Ellenbecker TS, Garrison JC, Thigpen CA. Shoulder Range of Motion Measures as Risk Factors for Shoulder and Elbow Injuries in High School Softball and Baseball Players. *Am J Sports Med.* 2011;39(9):1997-2006.
50. Wilk KE, Macrina LC, Fleisig GS, et al. Correlation of glenohumeral internal rotation deficit and total rotational motion to shoulder injuries in professional baseball pitchers. *The American Journal Of Sports Medicine.* 2011;39(2):329-335.
51. Awan R, Smith J, Boon AJ. Measuring shoulder internal rotation range of motion: a comparison of 3 techniques. *Arch Phys Med Rehabil.* 2002;83:1229-1234.
52. Myers JB, Laudner KG, Pasquale MR, Bradley JP, Lephart SM. Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathologic internal impingement. *Am J Sports Med.* 2006;34(3):385-391.

53. Tyler TF, Nicholas SJ, Lee SJ, Mullaney M, McHugh MP. Correction of posterior shoulder tightness is associated with symptom resolution in patients with internal impingement. *Am J Sports Med.* 2010;38(1):114-119.
54. Kelly BT, Kadrmas WR, Speer KP. The manual muscle examination for rotator cuff strength. An electromyographic investigation. *The American Journal Of Sports Medicine.* 1996;24(5):581-588.
55. Michener LA, Boardman ND, Pidcoe PE, Frith AM. Scapular muscle tests in subjects with shoulder pain and functional loss: reliability and construct validity. *Physical Therapy.* 2005;85(11):1128-1138.
56. Cools AM, Witvrouw EE, De Clercq GA, et al. Scapular muscle recruitment pattern: electromyographic response of the trapezius muscle to sudden shoulder movement before and after a fatiguing exercise. *Journal of Orthopaedic & Sports Physical Therapy.* 2002;32(5):221-229.
57. Tsai N, McClure PW, Karduna AR. Effects of muscle fatigue on 3-dimensional scapular kinematics. *Archives of Physical Medicine & Rehabilitation.* 2003;84(7):1000-1005.
58. Ebaugh DD, McClure PW, Karduna AR. Scapulothoracic and glenohumeral kinematics following an external rotation fatigue protocol. *J Orthop Sports Phys Ther.* 2006;36(8):557-571.
59. Ebaugh DD, McClure PW, Karduna AR. Effects of shoulder muscle fatigue caused by repetitive overhead activities on scapulothoracic and glenohumeral kinematics. *J Electromyogr Kinesiol.* 2006;16(3):224-235.
60. Day JM, Bush H, Nitz AJ, Uhl TL. Scapular muscle performance in individuals with lateral epicondylalgia. *J Orthop Sports Phys Ther.* 2015;45(5):414-424.
61. Moore SD, Uhl TL, Kibler WB. Improvements in Shoulder Endurance following a Baseball-Specific Strengthening Program in High School Baseball Players. *Sports Health: A Multidisciplinary Approach.* 2013;5(3):233-238.
62. Hegedus EJ, Cook C, Lewis J, Wright A, Park JY. Combining orthopedic special tests to improve diagnosis of shoulder pathology. *Phys Ther Sport.* 2015;16(2):87-92.
63. Park HB, Yokota A, Gill HS, El Rassi G, McFarland EG. Diagnostic accuracy of clinical tests for the different degrees of subacromial impingement syndrome. *J Bone Joint Surg Am.* 2005;87(7):1446-1455.
64. Litaker D, Pioro M, El Bilbeisi H, Brems J. Returning to the bedside: using the history and physical examination to identify rotator cuff tears. *J.Am.Geriatr.Soc.* 2000;48(12):1633-1637.
65. Farber AJ, Castillo R, Clough M, Bahk M, McFarland EG. Clinical assessment of three common tests for traumatic anterior shoulder instability. *J Bone Joint Surg Am.* 2006;88(7):1467-1474.
66. Michener LA, Doukas WC, Murphy KP, Walsworth MK. Diagnostic accuracy of history and physical examination of superior labrum anterior- posterior lesions. *J Athl Train.* 2011;46(4):343-348.
67. Klintberg IH, Cools AM, Holmgren TM, et al. Consensus for physiotherapy for shoulder pain. *Int Orthop.* 2014.
68. McMullen J, Uhl TL. A kinetic chain approach for shoulder rehabilitation. *Journal of Athletic Training.* 2000;35(3):329-337.
69. Putnam CA. Sequential motions of body segments in striking and throwing skills: Description and explanations. *Journal of Biomechanics.* 1993;26:125-135.
70. Hirashima M, Yamane K, Nakamura Y, Ohtsuki T. Kinetic chain of overarm throwing in terms of joint rotations revealed by induced acceleration analysis. *J Biomech.* 2008;41(13):2874-2883.
71. Dounskaia N. Control of human limb movements: The leading joint hypothesis and its practical applications. *Exerc Sport Sci Rev.* 2010;38(4):201-208.
72. Hodges PW, Richardson CA. Feedforward contraction of transversus abdominus is not influenced by the direction of arm movement. *Experimental Brain Research.* 1997;114:362-370.
73. Panjabi MM. The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. *J Spinal Disord.* 1992;5(4):383-389; discussion 397.
74. Konin JG, Beil N, Werner G. Facilitating the serape effect to enhance extremity force production. *Athletic Therapy Today.* 2003;8(2):54-56.
75. Knott M, Voss DE. *Proprioceptive Neuromuscular Facilitation Patterns and Techniques.* Philadelphia: Harper & Row; 1968.
76. Voss DE, Knott M, Kabat H. The application of neuromuscular facilitation in the treatment of shoulder disabilities. *Physical Therapy Review.* 1953;33(10):536-541.
77. Seitz AL, Kocher JH, Uhl TL. Immediate effects and short-term retention of multi-modal instruction compared to written only on muscle activity during the prone horizontal abduction exercise in individuals with shoulder pain. *J Electromyogr Kinesiol.* 2014;24(5):666-674.

78. Verstegen M, Williams P. *Core Performance: the revolutionary workout program to transform your body and your life.* Rodale; 2004.
79. Ellenbecker TS, Cools A. Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: an evidence-based review. *Br J Sports Med.* 2010;44(5):319-327.
80. Wilk KE, Reinold MM, Dugas JR, Arrigo CA, Moser MW, Andrews JR. Current concepts in the recognition and treatment of superior labral (SLAP) lesions. *J Orthop Sports Phys Ther.* 2005;35(5):273-291.
81. Uhl TL, Muir TA, Lawson L. Electromyographical assessment of passive, active assistive, and active shoulder rehabilitation exercises. *PM R.* 2010;2(2):132-141.
82. Long JL, Ruberte Thiele RA, Skendzel JG, et al. Activation of the shoulder musculature during pendulum exercises and light activities. *J Orthop Sports Phys Ther.* 2010;40(4):230-237.
83. McCann PD, Wootten ME, Kadaba MP, Bigliani LU. A kinematic and electromyographic study of shoulder rehabilitation exercises. *Clinical Orthopaedics And Related Research.* 1993(288):179-188.
84. Gaunt BW, McCluskey GM, Uhl TL. An Electromyographic Evaluation of Subdividing Active-Assistive Shoulder Elevation Exercises. *Sports Health.* 2010;2(6):424-432.
85. Kibler WB, Sciascia AD, Uhl TL, Tambay N, Cunningham T. Electromyographic analysis of specific exercises for scapular control in early phases of shoulder rehabilitation. *Am J Sports Med.* 2008;36(9):1789-1798.
86. Myers JB, Pasquale MR, Laudner KG, Sell TC, Bradley JP, Lephart SM. On-the-field resistance-tubing exercises for throwers: an electromyographic analysis. *Journal of Athletic Training.* 2005;40(1):15-22.
87. Reinold MM, Wilk KE, Fleisig GS, et al. Electromyographic analysis of the rotator cuff and deltoid musculature during common shoulder external rotation exercises. *J.Orthop.Sports Phys.Ther.* 2004;34(7):385-394.
88. Cools AM, Dewitte V, Lanszweert F, et al. Rehabilitation of scapular muscle balance: which exercises to prescribe? *Am J Sports Med.* 2007;35(10):1744-1751.
89. Ekstrom RA, Donatelli RA, Soderberg GL. Surface electromyographic analysis of exercises for the trapezius and serratus anterior muscles. *Journal of Orthopaedic and Sports Physical Therapy.* 2003;33(5):247-258.
90. Townsend H, Jobe FW, Pink M, Perry J. Electromyographic analysis of the glenohumeral muscles during a baseball rehabilitation program. *American Journal of Sports Medicine.* 1991;19:264-272.