Movement System Impairment
Syndromes of the Shoulder
Shirley Sahrmann, PT, PhD, FAPTA
Professor Emeritus
Program in Physical Therapy

The Body System for which Physical Therapists are Responsible.
The System of our Expertise
Our Identity – APTA 2013
THE HUMAN MOVEMENT SYSTEM

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• Movement is an essential function of life at all levels of living organisms.
  • From ions moving through membranes to moving your limbs to moving in your environment.

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Why Do Repeated Movements and Sustained Alignments Change Movement Precision?
• Alters intra & inter joint relative flexibility
• Muscle adaptations of relative length, strength, stiffness
• Neuromuscular activation and deactivation

Movement System Diagnoses

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Kinesiopathologic Model of Movement System

INDUCERS
- Repeated movements
- Sustained alignments
- Personal Characteristics - intrinsic
- Activity Demands - extrinsic

Path of Least Resistance

The Challenge: Keeping the Acute Problem From Becoming Chronic

- Step 1: alleviate the acute symptoms
  - Possible with a wide variety of interventions
- Step 2: prevent reoccurrence
  - Why is there reoccurrence?
  - Because the cause - the impaired movement - has not been identified & addressed. Tx is symptomatic not preventive
- Step 3: identify the cause & contributing factors
- Step 4: develop a treatment program that includes
  - Specific exercises
  - Correction of performance of daily activities

Movement System Impairment Syndromes – Guiding Theory

- Little things mean a lot!!!
- Underlying problem: micro-instability:
  - The Wobble – Wobble condition
  - Accessory motion (roll, spin, glide) becomes excessive in one or more directions (hypermobility/micro-instability)
  - Micro-trauma from sheer force and points of high contact pressure
  - Becomes macro-trauma

Joint Micro-Instability

- Characterized by moving
  - in range that is more than optimal (joint surfaces not optimal during movement)
  - Points of high contact stress & shear force
  - More often than optimal
  - More readily in specific directions
- Accessory motion micro-instability
- Can progressively increase
- With physiological motion that is
  - Normal
  - Excessive
  - Limited
**Movement System Impairment (MSI) Syndromes**

- Impairment level of the organism
  - Any abnormality of anatomical, physiological or psychological function.
- Syndromes
  - Collection of impairments based on observable impairments, primarily kinesiological, and their relationship to symptoms
  - Correction decreases or eliminates the symptoms
  - Named for principal impairment – the movement direction most consistently affecting the symptoms
  - Other impairments are contributing factors

**Key Concepts I**

- Path of least resistance for motion
- Relative Flexibility
  - Intra-joint; intrinsic accessory motion mobility
  - Inter-joint; physiological motion, e.g. back vs hip
- Relative Stiffness: passive tension of muscle & connective tissue
- Joint (micro-instability) hypermobility causes the pain
  - Accessory motion
  - Range & Frequency
  - What moves is what hurts

**Key Concepts II**

- The way everyday activities are performed is the critical issue
  - Repetitive movements and
  - Sustained alignments

**Key Concepts III**

- You get what you train (many strategies to create moments at a joint or within a limb)
- Presence of a muscle does not mean appropriate use
- No magic in an exercise except if the desired motion is evident

**Movement System Impairment (MSI) Syndromes**

- Named for movement direction that causes symptoms and that is impaired.
- Correction of the movement usually decreases the symptoms.
- Identify the cause of the dysfunction & contributing factors
  - tissue & neuromuscular impairments
- Organize & cluster specific tissue and movement impairments
- Provide a direction for treatment
  - do not require identification of a specific pathoanatomical structure (source)
- Based on anatomy and kinesiology

**Cause versus Source Operational Definitions**

**Cause**

- the mechanical factor (movement) that results in tissue irritation
- e.g. scapular insufficient upward rotation, humeral anterior glide

**Source**

- the tissue or pathoanatomical structure that is symptomatic
- e.g. impingement, supraspinatus tendinosis, ositis, opathy
Glenohumeral Considerations

- Superior capsular ligg - relaxed
- Inferior capsular ligg – taut
- Need inferior glide to prevent impingement
- 1 cm translation with 22 deg abd

Pain Problem – No Identifiable Pathology
- Movement impairment
- Mechanisms
  - Weakness
  - Insufficient stiffness
  - Length adaptation
  - Activation impairment

Interscapular pain for 2 years; radiological & electrophysiological studies negative: No pathoanatomical diagnosis
MSI diagnosis: scapular internal rotation with anterior tilt & abduction

Shoulder Flexion – Optimal or Impaired?

Movement System Impairment Syndromes
- Scapular
  - Internal rotation: with insufficient upward rotation, anterior tilt, abduction
  - Depression with insufficient upward rotation
  - Adduction with insufficient upward rotation
  - Elevation
  - Winging
- Humeral
  - Anterior glide, superior glide, hyps, multidirectional hyper, medial rotation,

Muscle Strain - weakness
- Excessive load
- Prolonged load
- Disruption of sarcomeres
  - Z-line
  - Overlap of actin & myosin
- Common in upper shoulder girdle muscle
Thoracic Pain for 3 months after lifting file cabinet rated at 7/10

Alleviation of Symptoms

Alleviate Strain–Support Scapula
Decrease Load on Shoulder

Shoulder Flexion with Support of Scapula

No Sxs – Able to Lift 30#

Initial 6 weeks later

Pre Post
**Muscle Condition**

- Strain – tears of Z-lines of sarcomeres
- Results in pain and weakness

**Muscle Strain**

Treatment requires
alleviation of stress
time to heal
progressive strengthening

**Length-associated Changes**

- Muscles maintained in lengthened position
  - add sarcomeres in series
  - shift length-tension curve to right
  - test weak at short length

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Williams & Goldspink 1981

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Williams & Goldspink
Tested in Shortened Length

Kendall: Muscles Testing & Function

Scapular Adductors - Long

Experienced muscle cramps when adducted

Muscle Length Impairments

• Increased length
  • Addition of sarcomeres in series
  • Decreased length
  • Decreased sarcomeres in series

Serratus anterior long
Rhomboids short
Passive stiffness of muscle and connective tissue

**RELATIVE STIFFNESS**

**Relative Muscle Stiffness**
- Hypertrophy of muscle increases the passive stiffness
- Daily activities can induce different degrees of hypertrophy of muscles on either side of a joint

**Relative Stiffness of Muscle**
- Abdominal muscles stiffer than hip flexors
- No pelvic tilt with stretch of hip flexors
- Hip flexors stiffer than abdominals
- Pelvic tilt with stretch of hip flexors

**Relative Stiffness: serratus anterior vs scapulohumeral muscles**

**Muscle Stiffness =** passive tension
- Change in tension/unit change in length
  - normal property
- Through the range
  - sarcomeres in parallel
  - Muscle size
Relative Stiffness

- In a multi-joint system, movement occurs at the joint with the least resistance.
  - Taking the path of least resistance (law of physics).

- In a system with "springs" in series, the least stiff "spring" will elongate when stretch is applied to the segments to which the "springs" (muscle attach) are attached.

Optimal Relative Stiffness

Impaired Relative Stiffness

Abdominal Muscle Overdevelopment

Line of Gravity Affects on Muscle

Kendall
Thoracic Kyphosis
Sport? Effect on Shoulder

Initial
3 months later

Scapular Internal Rotation:
Shoulder Lateral Rotators stiffer than Serratus Anterior, Rhomboids & Trapezius

Scapular Internal Rotation
What muscle lacks definition?

Tennis Professional with Jaw Pain

Short Scapulohumeral Muscles:
Serratus Anterior & Lower Trap less stiff than Glenohumeral Lateral Rotators

Scapular (Winging) Internal Rotation
Brace for Scapular Winging – Shoulder Instability

Capsular Shrinkage for Instability

Correcting Movement Pattern

Definitions of Scapular Movements

- Adduction (clavicular retraction-SC):
  - the scapula translates medially along the rib cage toward the vertebral column.
- Abduction: (clavicular protraction-SC)
  - translates laterally
- During these motions there is associated scapular internal or external rotation occurring at the AC joint.

Definitions of Scapular Movements

- Elevation: (clavicular elevation-SC)
  - a movement in which the scapula translates along the ribcage in a cranial direction.
- Depression: (clavicular depression-SC)
  - translates in a caudal direction.

- Upward rotation (lateral rotation):
  - AC joint
    - a movement of the scapula about an axis perpendicular to the plane of scapula
    - inferior angle moves laterally
    - glenoid fossa rotates to face cranially.
  - SC joint
    - posterior axial rotation of clavicle also contributes to UR.
- Downward rotation (medial rotation):
  - inferior angle moves medially
  - glenoid fossa rotates to face caudally.

Ludewig PM et al. 2009
Definitions of Scapular Movements

- **Anterior tilt/tipping:**
  - AC joint
  - A movement of the scapula about an axis parallel to the scapular spine
  - Coracoid moves anteriorly and caudally
  - Inferior angle moves posteriorly and cranially.
- **Posterior tilt/tipping:**
  - Coracoid moves posteriorly and cranially
  - Inferior angle moves anteriorly and caudally.

Ludewig PM et al. 2009

**Internal rotation:**
- AC joint
  - Rotation of the scapula about a vertical axis
  - Lateral border of the scapula moves anteromedially
  - Vertebral border moves posterolaterally such that the costal surface of the scapula faces more toward the midline of the body
- SC joint
  - Clavicular protraction also results in scapular IR

Ludewig PM et al. 2009

**External rotation:**
- Lateral border of the scapula moves posterolaterally
- Vertebral border moves anteromedially

Ludewig PM 2009

Scapular Internal Rotators

- Posterior deltoid
- Teres major
- Teres minor
- Infraspinatus
- Pectoralis Minor (Ludewig PM)

Definition of Scapular Movements

- **Winging:**
  - AC Joint
    - Abnormal movement of the scapula about a vertical axis
    - Vertebral border moves in a posterior and lateral direction away from the ribcage (Hall, CM, Brody LT.)

Ludewig PM 2009

Summary - Scapular Motions

- **Upward rotation:**
  - Primarily from the SC joint via posterior axial rotation of the clavicle on the sternum
  - Secondarily from the AC joint
  - Minimal from elevation at the SC joint
- **Posterior tilt:**
  - Primarily from the AC joint
- **External rotation:**
  - SC joint (clavicular retraction)
  - AC joint

Ludewig PM 2009

Normal Resting Standing Alignment

- 19° SC joint clavicular retraction
- 6° SC clavicular elevation
- 41° scapular internal rotation
- 5° scapular upward rotation
- 13.5° scapular anterior tilt

12 subjects; mean age 29.3

Ludewig PM 2009
Normal Movement at the AC and SC Joints (Ludewig PM. JBJS; 2009)
Bone Pin study with 12 subjects
- During arm elevation 0-120°
  - SC joint:
    - Retraction-16°
    - Elevation-6°
    - Posterior axial rotation-31°
  - AC joint:
    - UR-11°
    - IR-8°
    - Post tilt-19°

Normal Scapular Motion During Arm Elevation
- Scapula upwardly rotates and posteriorly tilts
  - Ludewig PM et. al., JOSPT 1996, 2009
  - Kibler JOSPT 2009
  - Lukasiewicz AC et. al., JOSPT 1999
  - McClure PW et. al., J Shoulder Elbow Surg 2001

Normal Scapular Motion During Arm Elevation
- Scapula externally rotates especially at the end ranges. (Ludewig PM 2009)
- Scapula internally rotates until after ~125° and then starts to externally rotate (Braman JP 2009)
- By the end of arm elevation the scapula ER so it is 10-20 degrees anterior to the frontal plane.

Normal Scapular Motion During Arm Elevation
- Scapula should elevate but only slightly (6-10°) Ludewig PM 2009
- Vertebral border of scapula should remain in contact with thorax
- Normal GH:ST rhythm:
  - 2.1:1 for abduction; 2.4:1 for flexion; 2.2:1 for scapular plane abduction (Ludewig PM 2009)

Clinical Assessment: Criteria for Normal Scapular Motion
- By the end range of arm elevation:
  - Acromion should be aligned with C6-7
  - Root of spine of scapula should be aligned with T3
  - The vertebral border of the scapula should reach 55-60° (+ or - 5°).
  - Normal scapular abduction is 7.5 cm (3") from the vertebral spine to the root of the spine of the scapula.
  - Scapula should posteriorly tilt 10° Ludewig PM 2009
  - Scapula should externally rotate so it is 10-20° anterior to the frontal plane Ludewig PM 2009

Normal Scapular Motion During Arm Lowering
- You shouldn’t see increased anterior tilting during arm lowering
- No prominence of vertebral border
  - Scapula had greater posterior tilting (2°) during arm lowering compared to arm raising Ludewig PM 2009
Normal Scapular Motion During Arm Lowering

Arm lowering
- There should be decreased scapular relative to GH movement during arm lowering compared to arm raising

Braman JP 2009

Normal Resting Standing Alignment
- 19° SC joint clavicular retraction
- 6° SC clavicular elevation
- 41° scapular internal rotation
- 5° scapular upward rotation
- 13.5° scapular anterior tilt

12 subjects; mean age 29.3
Ludewig PM 2009

Evidence for Scapular Movement Impairments - Impingement
- Decreased scapular posterior tilting
  - Lukasiewicz AC et al, JOSPT 1999
  - Ludewig PM & Cook TM, Phys Therapy 2000
  - Hebert LJ et al., Arch Phys Med Rehabil, 2002
  - Endo K et al, J Orthop Sci 2001
  - Lin JJ et al 2006
- Decreased scapular upward rotation
  - Ludewig PM & Cook TM, Phys Ther 2000
  - Endo K et al, J Orthop Sci 2001
  - Lin et al 2006
  - Lawrence RL 2014
- Increased scapular internal rotation
  - Ludewig PM & Cook TM, Phys Ther 2000

Lukasiewicz AC et al, JOSPT 1999
Ludewig PM & Cook TM, Phys Therapy 2000
Hebert LJ et al., Arch Phys Med Rehabil, 2002
Endo K et al, J Orthop Sci 2001
Lin JJ et al 2006
Lawrence RL 2014

Torque capabilities of Trapezius (Fey AJ, ....Ludewig PM JOSPT Jan 2007 Abstract)
- Used 3-D motion analysis and computer modeling of muscle moment arms
- Findings of Primary Torque Capability:
  - Upper trap = clavicular elevation
  - Middle trap = scapular external rotation
  - Lower trap = scapular external rotation and upward rotation
  - Serratus anterior = upward rotation, posterior tilt and external rotation

Scapular Internal Rotation

Anterior Tilt at Rest and Insufficient External Rotation - End range
Scapular Internal Rotation with Anterior Tilt - End range

- Secondary test:
  - Passively or actively increasing scapular external rotation and posterior tilt at end range arm elevation decreases symptoms.

Scapular Internal Rotation with Anterior Tilt - Muscle activation

- Movement Impairments when there is a muscle activation problem
  - These patients usually have a combination of IR and tilting

- Secondary test:
  - Correction by verbal and manual cues to dissociate GH from ST motion decreases symptoms

Scapular Internal Rotation with Anterior Tilt - scapulohumeral muscle control > axioscapular muscles

Axioscapular Muscle Control > Scapulohumeral
Program in Physical Therapy

Alignment Impairments

• Scapular Internal Rotation:
  - Scapula > 30 to 40 degrees anterior to frontal plane at rest
• Scapular Anterior Tilting or Tipping:
  - Prominence of inferior angle of scapula
  - Criteria: >10-15° anterior tilt at rest = abnormal Ludewig PM

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Structural Variations in Rib Cage with Scapular Internal vs. External Rotation

Structural considerations
- Heavy or long arms
- Thoracic kyphosis
- Shape of rib cage/thorax

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Scapular IR and AT - Intervention

• Increase stiffness of posterior axiscapular muscles
  - Improve activation and hypertrophy
• Stretch
  - Sh muscles while maintaining scapular position
  - Pectoralis minor
• Dissociating GH from ST motion
  - Letting go with Sh muscles

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Scapular Internal Rotation with Anterior Tilt (end range)

Intervention Exercises

• standing with back to wall – shoulder abduction with lateral rotation to work middle trap at shortened length/increase stiffness; stretch pectoralis major
• shoulder flexion with back to wall once patient able to control scapula to increase stretch on SH muscles

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Scapular Internal Rotation with Anterior Tilt - End range

Intervention:
• Facing wall shoulder flexion with arm lift (external rotation and posterior tilt at end range)
  - Increasing activation and relative stiffness of serratus anterior and lower trapezius. Serratus anterior is key!
  - Maintain correct head alignment
  - May need to limit ROM initially
  - *May contribute to scapular internal rotation by reaching toward wall.
Scapular Internal Rotation with Anterior Tilt - End range

- Intervention: Exercises
  - Shoulder flexion facing the wall with arm lift at end
  - During lifting arms off wall, focus has to be on scapular movement, not on GH movement

Scapular Internal Rotation with Anterior Tilt - Muscle activation

- Intervention: Quadruped Rocking Backward

Improve performance of serratus anterior

Elongation posterior scapulo-humeral

Scapular Internal Rotation with Anterior Tilt - Muscle activation

- Intervention: Stretch Pectoralis Minor

Intervention: Exercises cont.
- Serratus anterior activation and strengthening
  - Quadruped and standing shoulder flex
  - Lower and middle trapezius activation and strengthening:
    - sidelying, standing, prone
  - Pec. minor stretching
  - Stretch SH muscles

Scapular Internal Rotation with Anterior Tilt - Muscle activation

- Intervention: Function
  - Reaching Bend elbow to shorten lever arm

Weight lifting
  - Decrease weight until scapular muscles can maintain correct scapular alignment throughout motion.
Scapular Internal Rotation with Anterior Tilt - Muscle activation

GHJ extension contributes to scapular anterior tilt

Scapular Internal Rotation with Insufficient Upward Rotation

- The movement impairment can happen anywhere in the ROM.
- Serratus anterior is the best upward rotator

Insufficient Scapular Upward Rotation

Symptoms
- If pain is along vertebral border of scapula, the source of the pain is usually the cervical spine.
- May have pain in the area of the rhomboid muscle

Activities
- New mothers
- String instrument musicians
- Weightlifters, heavy laborers, waitresses, jobs that require arm to be sustained in flexion
- Sit with keyboard or arm rests too low

Scapular Internal Rotation with tilt and Insufficient Upward Rotation

- Right (involved) shoulder lower
- Right acromion is low
- Scapula is downwardly rotated or depressed
- Insufficient scapular upward rotation during abduction

Scapular Internal Rotation with Insufficient Upward Rotation

- Structural Variations (alter stresses on the tissues)
- Thoracic kyphosis
Scapular Internal Rotation with Abduction

Excessive scapular abduction and internal rotation during shoulder flexion

Corrected

Scapular Internal Rotation with Abduction

Alignment:
Backview:
- vertebral border >3” (7.5 cm) from spine

Normal scapular alignment
- 3” Sobush DB. 1996
- 2.5”, Neumann DA, 2002
- 2” (5 cm) Kendall FP, 1993, Hoppenfeld S, 1976

Left scapula 4” (10 cm), right 3.5” (9 cm) from spine

Scapular Internal Rotation with Abduction

Activity contributing to abduction: wrestling

Scapular Internal Rotation with Abduction

Thoracic pain:
Segment of thoracic spine is more flexible than shoulder girdle:
(Contributing factors: heavy arms, stiff pectoral muscles, scapular abduction)

Scapular Internal Rotation with Abduction

right scapular pain and popping
PhD student working a lot at bench under hood so has to reach forward
pain at end of day
right handed
large breasts

Scapular Internal Rotation with Abduction

corrected
Scapular Internal Rotation with Abduction

- Avoid excessive scapular abduction at rest & during arm motions

Scapular IR with AT and ABD

Dissociating GH from ST Motion

Scapular IR with AT and ABD

video

Depression with Insufficient Scapular Upward Rotation

Unsuccessful Correction of Alignment Using Rhomboids

Scapular Depression

- Acromion depresses in the first 90 degrees of shoulder flexion or abduction
- Acromion does not begin to elevate after about 30 degrees of arm elevation
- Acromion below C6-7 at end range
Scapular Depression

Alignment
• Increased slope of shoulders R > L
• Scapula lower than T2 - T7 Swift TR, 1984
• Scapula normally positioned between T2-T7
  Kendall FP 1993 and Hoppenfeld S 1976

Scapular Depression With Insufficient Upward Rotation

Alignment
• Horizontal clavicles Swift TR, 1984
  • normally clavicle should have slight upward slope
    • 25-29° Todd TW, 1912
    • 20° Telford S, 1948
    • 6° Ludewig PM 2009
• Right arm appears longer
• Increased slope

Scapular Depression With Insufficient Upward Rotation

Preferred
Corrected

Neck Pain with Scapular Depression and Cervical Flexion

Pilates Instructor

videos

Scapular Depression With Insufficient Upward Rotation

Arm rests need to be close to body and high enough to support shoulders at correct height.

Positioning keyboard on desktop may be better than keyboard tray for arm support.
**External Rotation/Adduction With Insufficient Upward Rotation**

**Impairments of Resting Alignment**

- Vertebral border of scapula is $< 6.25$ cm (2.5”) from vertebral spine
- Scapula is oriented less than 30° anterior to frontal plane
- Clavicle is retracted more than 20-25°
- The thoracic spinal curve is often decreased or flattened.

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**External Rotation/Adduction With Insufficient Upward Rotation**

- Scapula less visible from sideview compared to person with scapular IR
- Associated with flat thoracic spine.

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**Scapular Winging**

Strength of serratus anterior on MMT is $< 3/5$

Scapular winging - long thoracic nerve injury

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**Left Side Involved**

Onset after biking trip for several weeks with backpack on back; 20 y/o
Scapular Elevation
Movement Impairment
- Excessive scapular elevation is usually identified early in the range and continues throughout arm elevation.
- The primary problem is typically limited glenohumeral motion and not poor muscle performance.

Scapular Elevation
Primary Focus of Intervention:
- If GH hypomobility is present - increase GH mobility.
- If rotator cuff function is deficient but expected to return focus is on restoring precise GH without scapular elevation.
- If rotator cuff function is deficient and not expected to improve then scapular elevation as a compensatory technique may be necessary.