What is the Kinetic Chain? The Human Machine.

To Accomplish:
- Motion
- Force Transfer
- Acceleration
- Energy Absorption

Kinetic Chain

- Avg. Foot Plant: 175% BW
- Peak Pelvis Rotation: 200 rpm
- Peak Trunk Rotation: 400 rpm
- Avg. Arm Rotation: 2300 rpm
- Avg. Ball speed: 1500 rpm = 104 MPH

Link Sequencing

- Link sequencing describes the development and transfer of forces in serial linkage (legs, trunk, scapula, and arm) to accomplish acceleration

Definitions

Open Kinetic Chain (OKC)

- Exercise or movement pattern where the distal aspect is not fixed to an object (free in space)
- Distal motion around a fixed proximal segment
- The force applied by the body is great enough to overcome the resistance

Steel, 1955

Joel Zumaya: 104 MPH
Photo by G. Newman Lowrance/Getty Images; Medi-Mation

Closed Kinetic Chain (CKC)

- Exercise or movement pattern where the distal aspect is fixed to or against an object (not free in space)
  - OR
- Proximal motion over a fixed distal segment
  - OR
- The force applied by the body is NOT great enough to overcome the resistance

Steindler, 1955

History

- 60-70’s: free weights, Schwarzenegger
- 1980’s: OKC Isokinetics; Nautilus
- 1990’s: “Functional” CKC
- Current: Appropriate isolation, integration, and combination of multiple exercise methodologies

Functional?

- CKC was considered more functional, particularly in the LE
- OKC and CKC used and needed for function, recovery and progression
  (Noyes, Barber, Tegner, Wilk, others)

Function Example

- Function-serial CKC and OKC e.g.:
  - Walking Gait: 65% CKC; 35% OKC
  - Running Gait: 65% OKC; 35% CKC
  (Wilk, Athletic Training, 1995)

Which to choose?

- CKC alone does not provide adequate stimulus to the quadriceps for functional recovery after surgery
  (Snyder-Mackler, J Sport Rehab, 1996)
- Critical assessment, biomechanical knowledge, and application required for all chain applications
  (Davies, J Sports Rehab, 1995)

KINETIC CHAIN: Comparative Analysis
**OKC vs. CKC**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Open Chain</th>
<th>Closed Chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stress Pattern</td>
<td>Rotary</td>
<td>Linear</td>
</tr>
<tr>
<td>Axes</td>
<td>1 primary</td>
<td>Multiple</td>
</tr>
<tr>
<td>Segments</td>
<td>1 fixed; 1 mobile</td>
<td>Both mobile</td>
</tr>
<tr>
<td># Joints</td>
<td>Isolated</td>
<td>Multiple</td>
</tr>
<tr>
<td>Planes of Motion</td>
<td>Single</td>
<td>Multiple</td>
</tr>
<tr>
<td>Muscle(s)</td>
<td>Isolated (Group)</td>
<td>Multiple/Co-contraction</td>
</tr>
<tr>
<td>Pattern</td>
<td>Usually non-functional LE; Functional UE</td>
<td>Function oriented LE</td>
</tr>
</tbody>
</table>

**Joint Forces**

Compression = Joint Stability = CKC
Shear/Traction = Joint Instability = OKC

**OKC vs. CKC**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Open Chain</th>
<th>Closed Chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint Surfaces</td>
<td>Traction</td>
<td>Compression</td>
</tr>
<tr>
<td>Application/Use</td>
<td>Arthritis, Meniscal, Labral, UE instability</td>
<td>LE instability</td>
</tr>
</tbody>
</table>

**CKC Testing**

- CKCUEST
- Push Up Test
- Not appropriate in early stages of most pathology

**Closed Kinetic Chain Upper Extremity Stability Test**

- Push up position
- Lines 3 ft. apart
- Move hands to lines max. times in 15 sec. 3X
- Count total & avg.
- Normalize score
- Score = Touches/height
- Power = 68%BW x avg/15

Davies, Dickoff-Hoffman. JOSPT 18, 1993
Testing

### Push Up Test (Men)

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<thead>
<tr>
<th></th>
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<td>&gt;47</td>
<td>&gt;41</td>
<td>&gt;34</td>
<td>&gt;31</td>
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<td>20-27</td>
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<td>12-19</td>
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<td>10-16</td>
<td>9-18</td>
<td>6-14</td>
<td>5-12</td>
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<td>0-1</td>
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</table>

### Push Up Test (Women)

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>&gt;35</td>
<td>&gt;36</td>
<td>&gt;37</td>
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<td>3-5</td>
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<tr>
<td>Poor</td>
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<td>0-2</td>
<td>0-2</td>
<td>0-2</td>
<td>0-2</td>
</tr>
<tr>
<td>Very Poor</td>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
</tr>
</tbody>
</table>

The Human “Chain”

- The body does not operate in isolated segments (LINKS) but rather works as a dynamic unit (CHAIN).
- Rehabilitation programs should include and emphasize:
  - Isolation when needed
  - Closed and open kinetic chain exercises
  - Core-stabilization exercises
  - Functional progressions
  - Used in all phases.

CONSIDERATIONS PRIOR TO CHAIN APPLICATIONS

- Pathology
- Core proficiency
- Scapular alterations
- GH alterations
- Distal alterations
  - Especially elbow

Segment Control:

**Chain ≠ Isolation**

- Correct early in rehab
- Core/trunk > scapula
- Scapula > rotator cuff
- No GH shoulder is motion possible
- Restore normal physiology/proprioception

Miscellaneous Mechanics

- Total Motion
- Scapular Mechanics
- Cuff Function
- GIRD
- Link System
Total Motion Concept

- 180 degrees total rotation
- Increased ER accompanied by decreased IR
- Loss of IR leads to substantially increased shoulder pain/dysfunction
- “GIRD”

Wilk et al. AJSM 2002

Glenohumeral Internal Rotation Deficit

- This lost of motion requires an enhanced deceleration mechanism in which the slowing down of a rotating shoulder occurs more quickly than in a person with normal range of motion
- CKC Impact: exercise emphasis on accurate eccentric deceleration

Andrews, Wilk et al. The Athlete’s Shoulder 2 Ed

Glenohumeral Motion

- Internal Rotation: Lift off stretch
- Internal Rotation

Shoulder Funnel Function

- Kinetic Chain
  - Legs
  - Core
  - Scapula
  - GH
  - Arm

Scapular Mechanics

- Muscular weakness, inflexibility, and neuromuscular adaptations contribute to loss of scapular control and scapular dyskinesis
- CKC Impact: Carefully monitor scapular position during exercise

Scapular Dyskinesia

- It is defined as observable alterations in the position of the scapula & the patterns of scapular motion in relation to thoracic cage
- The term does not suggest etiology or define patterns that correlate with specific shoulder injuries
- Classification of scapular dyskinesia patterns and positions can help to determine treatment
- Factors responsible
  - Bony posture or injury
  - Contractures & other flexibility problems
  - Alteration in muscle function

CKC Impact: limit exercises creating anterior GH translation e.g. “down” push ups

Wilk et al. AJSM 2002
SCAPULAR EVALUATION SHOULD INCLUDE
- Postural evaluation
- Resting Scapular Evaluation
- Dynamic Evaluation of scapular motion
- Corrective measures

STATIC EVALUATION
- SCAPULAR EVAL SHOULD BE DONE FROM POSTERIOR ASPECT
- FIRSTLY SCAPULA SHOULD BE EVALUATED IN STATIC POSITION AS IN LONG-STANDING SCAPULAR DYSKINESIS, RESTING WINGING MAY BE SEEN

DYNAMIC EVALUATION
- Should be examined in both elevating & lowering phase of motion
- Muscle weakness & mild dyskinesis is commonly seen in lowering phase of arm movement
- These commonly present as hitch or jump in otherwise smooth motion of scapula and may be more noticeable with several repetitions

KIBLER’S CLASSIFICATION OF SCAPULAR DYSKINESIS

Scapula Dyskinesis
- 3 types of scapula winging have been identified, there may be overlap between the types.

TYPE I
PRONUNENCE OF INFERIOR MEDIAL SCAPULAR BORDER
ABNORMAL ROTATION AROUND TRANSVERSE AXIS
INDICATES WEAKNESS OF LOWER TRAP, LAT, DORSI, SERR ANT OR TIGHT PECT MINOR, MAJOR
**S.I.C.K. Scapula**

- Scapular malposition
- Inferior medial-type 1 scapular winging
- Coracoid tenderness
- Scapular dysKinesis.

**Type I Movement Characteristics**

- Inferior angle loses contact with thorax
  - Excess ant. tilt
  - Glenoid: inf, med, anter
- Internal/External Impingement
  - GIRD
  - Coracoid mm tight
  - Serratus/trap failure

**Type I Treatment**

- Pec Minor Stretch
- GIRD Stretch
- Muscle Weakness
  - Serratus
  - Lower Trap
  - Teres Major

**TYPE II**

**CLASSIC WINGING**

- PROMINENCE OF ENTIRE MEDIAL SCAPULAR BORDER
- ABNORMAL ROTATION AROUND VERTICAL AXIS
- INDICATES WEAKNESS OF SERR ANT, RHOBOIDS ALL FIBERS OF TRAP

**Type 2 - Medial border prominence**

- Winging of the entire medial border
- Occurs after repetitive elevation of the upper extremity
- Fatigue of the scapula stabilizing muscles (serratus, trapezius, and rhomboids)

**Type 2 - Medial border prominence: Trapezius weakness**

- Weakness/fatigue of the scapula stabilizing muscles
- Triangle Test/Sign -unable to lift arm off bed in prone
**Type II Movement**

**Characteristics/Pathology**

- Medial border loses contact with thorax
  - Excess int. rotation
  - Glenoid: inf, med, anterior
- Labrum (SLAP)
- Long Thoracic N.
- Anterior Muscles Tight?
- Serratus/ Post. MM Failure

**Type III**

**PROMINENCE OF SUPERIOR MEDIAL SCAPULAR BORDER WITH SUPERIOR TRANSLATION OF ENTIRE SCAPULA**

Indicates overactivity of Levator Scapulae & imbalance of upper & lower trap force couple

**Type 3 - Supero-Medial Border Prominence**

- Prominence: superior medial border
- Posterior tipping of the scapula leads to functional narrowing of the subacromial space during the overhead motion
- Associated with impingement and rotator cuff injury

**TESTS PERFORMED TO INDICATE WEAKNESS OF SCAPULAR MUSCLES**

- Isometric scapular pinch test
- Wall push-ups
- Lateral scapular slide test
- Scapular assistance test
- Scapular retraction test

**ISOMETRIC SCAPULAR PINCH TEST**

- Scapula can be normally held in retraction with isometric pinch for 15 to 20 seconds without burning pain or muscle weakness
- Scapular ms weakness may manifest as burning pain in less than 15 sec.

**WALL PUSH - UPS**

- Wall push ups are effective for evaluating serratus anterior strength
- Abnormalities may be noted with 5 to 10 Wall push-ups
Lateral Scapular Slide Test (LSST)

- Measurements are taken on each side from the inferior medial tip of the scapula to the nearest spinous process.
- Three positions - arms by side, hands on hips, arms abducted to 90 degrees and maximally internally rotated.
- 1.5 cm difference significant.


LATERAL SCAPULAR SLIDE TEST

Lateral Scapular Slide Test (LSST) but......

- Sensitivity and specificity based on the criterion of greater than 1.5 cm difference were 28% and 53%, 50% and 58%, and 34% and 52%, respectively, for the 3 scapular positions.
- Scapular position was commonly asymmetrical in the asymptomatic subjects.
- "LSST has low specificity and its use is not recommended for determining shoulder dysfunction".


SCAPULAR ASSISTANCE TEST

- During abduction or forward elevation, assistance is provided by manually stabilizing the scapula and rotating inferior border of scapula as the arm moves.
- This proc simulates force couple activity of serratus ant and lower trap.
- Elimination or modification of symptoms indicate these muscles should be major focus in rehab.

SCAPULAR RETRACTION TEST

- The examiner stabilizes the medial scapular border as the arm is elevated or externally rotated.
- Relief of impingement symptoms is a positive test.

Rotator Cuff: Functional Gyroscope

- Approximates and “seats” humerus
- Supraspinatus assists deltoid in abduction
- Subscapularis, infraspinatus & teres minor depress humeral head
Rotator Cuff Exercise Without Scapular Stability Could…

- Increase the risk of glenohumeral translation
- Create pain in rehabilitation
- Increase the risk of further injury.
- Closed kinetic chain exercises promote co-contraction of rotator cuff musculature at submaximal levels.

Upper Extremity Linkage

CORE

- Hip
- Lumbo-pelvic
- Abdomen
- Thorax

Shoulder Girdle Muscles

Primary Muscles: shoulder girdle (scapula & clavicle)
- Trapezius - upper, middle, lower
- Rhomboids
- Levator scapula
- Serratus anterior
- Pectoralis
- Teres Major

Osseous Links

- Core
  - Hip/Legs
  - Lumbo-pelvic
  - Abdomen
  - Thorax
- Scapula
- Clavicle
- Humerus

Muscular Links

- Legs
- Core
  - Hip
  - Lumbo-pelvic
  - Abdomen
  - Thorax
- Scapula
- Clavicle
- Humerus
Scapulothoracic Rotation

- Inferior angle of the scapula
- Hand/forearm are supporting humerus
- Both hands move together to produce and resist rotation
- Downward, upward, and circumduction rotation of the scapula

SHOULDER MUSCULATURE

- FROM AXIAL SKELETON TO HUMERUS
  - Pectoralis major
  - Latissimus
- SCAPULA AND CLAVICLE TO or FROM HUMERUS
  - RTC
  - Deltoid
  - Arm

The Applied Chain

- Principles
- Applications
- Progressions
- Foundations
- Motor Programs
- PNF Concepts
- Plyometrics
- Exploitation
- Examples

Chain Principles

- Patterns sequentially use the leg, core, and scapular musculature to activate/facilitate shoulder musculature
- Gain active range of motion and increase strength
- Functional movement patterns and closed kinetic chain exercises could be incorporated throughout the rehabilitation process depending on pathology

Kinetic Chain Exercises Can Aid in Attaining Flexibility but...

- Stretching
- Joint mobilizations
- Massage
- Therapeutic modalities

Application

- Shoulder pathology determines treatment
- Includes rest, control of inflammation, and isolated muscle strengthening
- Additional components are scapular stabilization, proprioceptive, and core/LE exercises.
THEORETICAL FOUNDATION

- The proximal segments (legs and trunk) accelerate the entire system and sequentially transfer the momentum to the next distal segment.

- Sequential deceleration of the proximal segments conserves momentum by transferring segmental velocity distally along the kinetic chain.

Motor Programs

- Coordinated groups of muscles and joint movements (Synergies)
- Learned behaviors
- Often in a proximal-to-distal fashion
- Simplify movement tasks

- Kinetic chain shoulder exercises employ these natural motor programs
- Focuses on the neuromuscular system rather than on isolated movement and muscle activation.

Kinetic Chain Rehabilitation

- Concepts from PNF
  - Motor behavior is a sequence of total patterns
  - Goal-directed movement and posture depend on synergies to balance muscular activity

- Concepts from PNF
  - Normal motor development occurs in a proximal-to-distal direction
  - Stronger component patterns augment weaker components by the irradiation reflex
Irradiation Reflex

- As the intensity of an applied stimulus increases, the area of response increases.

- Example: Thoracic extension can stimulate scapular retraction. Resistance to thoracic extension should increase this stimulus and elicit an increase in scapular retraction.

Biofeedback

- Successful acquisition of movement patterns is feedback sensitive and requires consistent observation to avoid compensatory movements.

- Gradual removal of the feedback is a form of exercise progression.

Components of Plyometrics

Stretch-Shortening Cycle

- Eccentric Phase: muscle potentiation
- Amortization Phase: deceleration/motion reversal
- Concentric Phase: acceleration

Plyometric Rehabilitation Applications

- Quick stretch - PNF
- Step downs
- Dynamic wall push-ups
- Medicine ball
- Angle boards

Upper Extremity Plyometric Activities

- Beware weight magnification
- Plyometric push-up
- Clap push-up
- Drop-and-catch push-up
- Medicine ball push-up
- Medicine ball activities
  - catch and throws

Kinetic Chain Exploitation

- Kinetic chain rehabilitation: exaggerating the role of the hip extensors in instances of limited forward elevation
- Forcing hip extension by including an ipsilateral step-up with a shoulder-flexion exercise facilitates shoulder flexion
Kinetic Chain Exploitation

- Proximal-to-distal muscle activation in rotational patterns consistent with PNF can facilitate shoulder rotation.
- Patterns promote sequential muscle activation and coordination of proximal segment.
- Example: "Shoulder Dump"

SCAPULAR FUNCTION AND CONTROL

- Common clinical scapular compensation involves the substitution of the upper trapezius.
- The kinetic chain approach de-emphasizes the upper trapezius by concentrating on scapular depression with the retraction.

SCAPULAR FUNCTION AND CONTROL

- Adjustments in the direction and amount of trunk motion minimize muscular compensations.
- Increase trunk rotation and thoracic extension with scapular retraction to inhibit scapular elevation.

Closed Chain Exercise Prescription

- Accommodate pathology.
- "If in doubt, leave it out.”
- Paucity of research:
  - Kibler et al 1995
  - Ellenbecker and Davies 2001
- Some suggestions......

Example Exercise Modification: Anterior Pathologies

- Hand spacing less than 1.5 times the biacromial width.

Example Exercise Modification: Anterior Pathologies

- Maintaining shoulder abduction at less than 45°.
Some examples:

Wall Press
- Primary Muscles: serratus, pectorals, deltoids, cuff, triceps, core
- Indications: scap. stabilization, throwers
- Contra-indications: posterior pathology

Stabilization (Bilateral)
- Primary Muscles: serratus, pectorals, deltoids, cuff, triceps, core
- Indications: scap. stabilization, throwers
- Contra-indications: posterior pathology

Modified Push Up
- Primary Muscles: serratus, pectorals, deltoids, cuff, triceps, core
- Indications: scap. stabilization, throwers
- Contra-indications: posterior pathology

Push Up
- Primary Muscles: serratus, pectorals, deltoids, cuff, triceps, core
- Indications: scap. stabilization, throwers
- Contra-indications: posterior pathology

Pull Ups
- Primary Muscles: pectorals, biceps, rhomboids, traps, lats, serratus, core
- Indications: winging, gen. strength, rhythm stability
- Contra-indications: acute RTC, lmp., SLAP, AC, anterior instab.
Monitor Spine and Scapula

- Monitor exercise volume to avoid overloading the involved tissue when integrating multiple segments
- Continually monitor scapulo-thoracic rhythm (early indicator of a compensation)

Not too fast!

Summary

To progressively load the distal segments, the exercises advance from:
- Static closed kinetic chain to...
- Dynamic axially loaded to...
- Open kinetic chain
- OKC for "weak links"

CONCLUSIONS

- Nontraditional approach to rehabilitation that concentrates on movement patterns
- Proximal-to-distal kinetic link model
- Addresses glenohumeral motion through scapular control
  AND
- Scapular control through trunk movement
Thank You!

Time to......