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ISSEM

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KINETIC CHAIN ANALYSIS IN OVERHEAD ATHLETE

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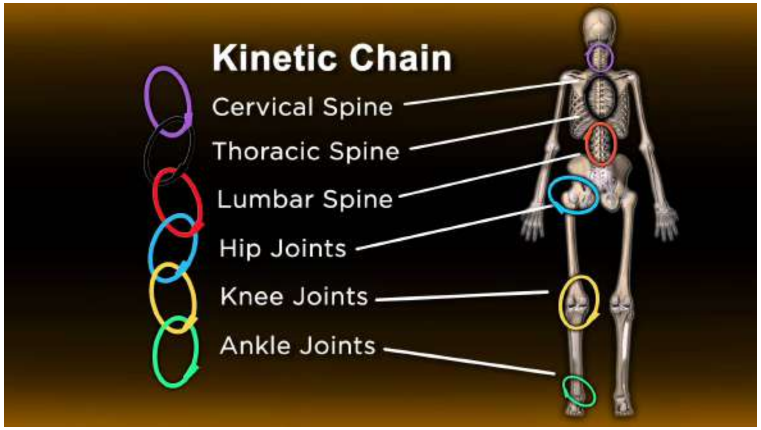
KINETIC CHAIN

- A functional kinetic chain consists of 3 components:



a) Optimized anatomy

b) Sequential generation of forces

c) Efficient Motor Patterns.

Optimized anatomy is strength, flexibility, and power of the many independent functional segments of the body, or kinetic links.

Kinetic links for throwing include the feet, lower extremities, hip and pelvis, trunk, scapulothoracic articulation, shoulder and elbow, and distal extremity.

During a throw, forces are Sequentially generated by the various segments of the kinetic chain and coordinated to accelerate the ball in the desired direction.

Efficient task-specific Motor patterns allow for minimal energy loss during transfer between independent segments of the kinetic chain

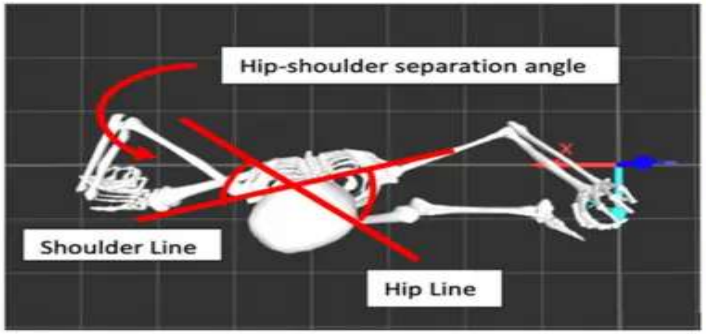
Kinetic Chain Concept in the Overhead Athlete

- Upper extremity can be viewed as a series of links include the trunk, scapulothoracic articulation, scapulohumeral or glenohumeral joints, and distal arm regions.
- Each of these links can be considered independent anatomically and biomechanically, but with reference to human function must be considered a unit.

Dysfunction of the kinetic chain

1) Disruption of anatomy (e.g., loss of shoulder range of motion, lack of hip internal rotation),
2) Inappropriate distribution of forces between segments (relying too much on arm strength without lower-extremity activation)
3) Inefficient motor patterns (scapular dyskinesis).

HIP SHOULDER SEPERATION



- Angle a pitcher creates by separating their hips and their torso through rotation.
- This movement acts like a rubber band being pulled back in a slingshot, storing energy in the trunk as the separation is increased and the rubber band is stretched further.
- This energy will then be released and used to accelerate the torso open towards the hips creating a whip affect and continuing the transfer of energy up the kinetic chain to the arm.
- This slingshot effect of the torso accelerating towards the hips going into release is what we refer to as “closing the gap”.

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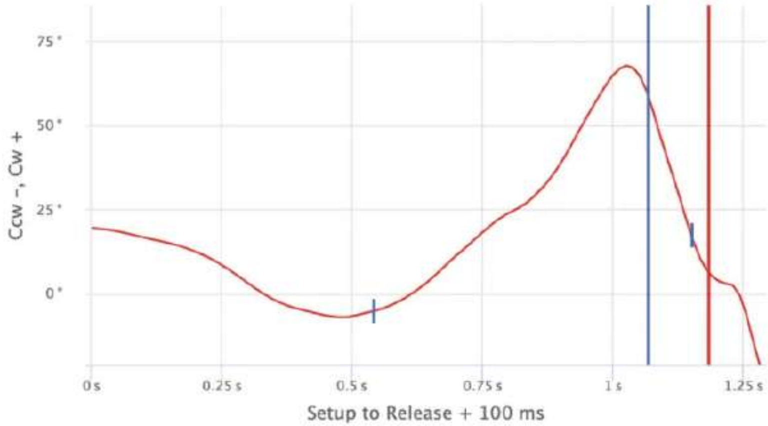
- By efficiently closing the gap, it will allow for proper anatomical positioning and sequencing, while maximizing energy transfer and efficiency up the chain.

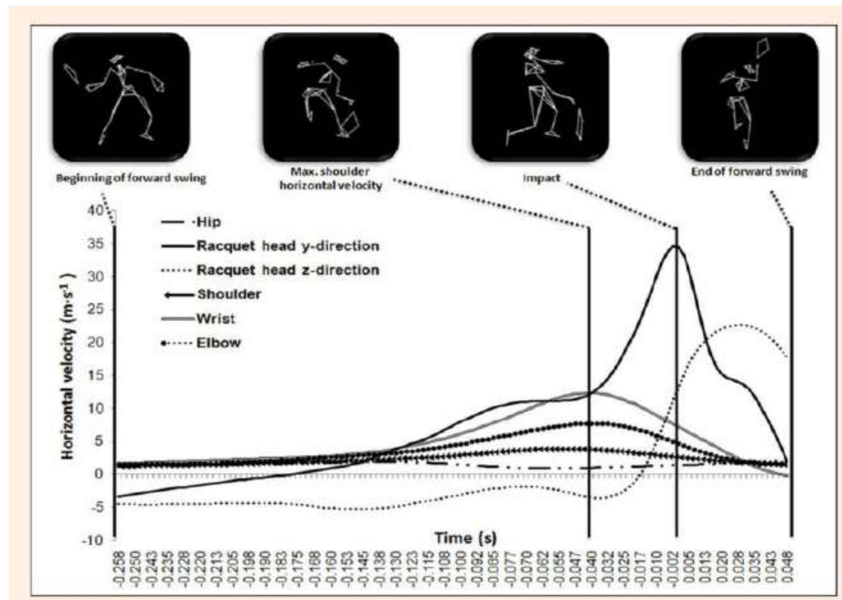
- Inability to efficiently close the gap is more a result of inefficient timing / sequencing (usually poor hip deceleration) rather than any physical or mobility limitations.

- Range: (30-55°) degrees of hip-shoulder separation.
- peak hip-shoulder separation (67°)



Proximal-to-Distal Sequencing

- Motion should be initiated with the more proximal segments, and proceeds to the more distal segments, with the more distal segment initiating its motion at the time of the maximum speed of the proximal segment.
- Each succeeding segment would generate larger endpoint speeds than the proximal segment.
- This proximal-to-distal sequencing demonstrated by examining the linear speeds of segment endpoints, joint angular velocities, and resultant joint moments.



Modification of the Proximal-to-Distal pattern.

- Throwing or striking sports shows a modification of the proximal-to-distal pattern.

- This modification occurs when the human body exploits the benefits of long-axis rotation of the humerus (internal rotation) and forearm (forearm pronation) to maximize endpoint speed.

Biomechanics of the Kinetic Chain in the Throwing Motion

- kinetic chain is influenced by multiple factors including

i. Core strength,
ii. Hip strength and
iii. Range of motion (ROM),
iv. Scapular kinematics,
v. Shoulder strength and ROM,
vi. Knee, and Ankle mobility, and

- Efficient kinetic chains

I. Decreased joint loads
II. Maximum velocity
III. Maximal force production during throwing

- The hip/trunk area contributes approximately 50% of the kinetic energy and force to the entire throwing motion.
- Decreased hip ROM in the dominant side hip compared with non-dominant side is highly correlated with shoulder injury and poor throwing mechanics.
- Inadequate hip ROM and poor balance affect an athlete’s ability to transfer energy along the kinetic chain, resulting in dysfunctional movement and increased stresses on the shoulder and elbow, and a correlation between poor lower extremity balance and overhead injuries including UCL tear.

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Kinetic Chain Evaluation of the Overhead Athlete

- One-leg stability test to assess hip and core stabilization

Y BALANCE TEST

- It can be used for both the upper quarter and lower quarter.
- The YBT for the lower quarter (LQYBT)
- patient stand on one leg while reaching out in 3 different directions with the other lower extremity.
- They are anterior, posteromedial and posterolateral.

Hip rotation range of motion.

- Prone hip internal rotation range of motion measurement

KINETIC CHAIN INVOLVEMENT IN THROWING

Windup

- The windup phase begins with the pitcher's first movement from the static position of facing the batter with both feet on the mound and is completed when the Lead leg reaches maximum knee height .
- The final moment during the windup when the knee is at maximum height is referred to as the "balance point".
- The primary contributors to successfully completing the windup phase arise from strength and proprioception in the lower extremity.

STRIDE LEG

- Lead leg reaches maximum knee height .
- Muscular activations will be seen in the iliopsoas, rectus femoris, pectineus, and sartorius to elevate the stride leg .

STANCE LEG

- Ankle joint contributes to forming a stable foundation for the stance leg.

ANKLE JOINT

- Athletes with chronic ankle instability demonstrate increased postural sway, which can result in loss of control during the windup phase

i. Anterior joint laxity
ii. Reduced posterior Talar glide
iii. Reduced range of motion,...dorsiflexion ....in turn can affect their COG within the windup phase.

HIP & PELVIS

- Tensor fascia latae, Gluteus medius, and Gluteus minimus must isometrically contract to maintain a stable pelvis...also to prevent postural sway.
- If the COG(CENTRE OF GRAVITY) is positioned too far posteriorly or anteriorly, torque will transfer to the upper extremity, thus predisposing the shoulder and elbow to injury

- Factors that can contribute to faulty windup mechanics include

I. poor balance at maximum knee height secondary to reduced lower extremity strength,

II. poor trunk control, and

LUMBOPELVIC

- As the hips develop power throughout the windup phase, it is transferred through the lumbopelvic region and finally to the throwing arm.
- Poor lumbopelvic control has been associated with increased shoulder horizontal abduction torque and elbow valgus torque, both of which may result in increased injury risk and decreased performance.
- Increased compressive force in the glenohumeral joint with increased pelvic tilt toward the throwing side, increased pelvic axial rotation velocity, and a decreased stride length

MANAGEMENT

- Banded side-walks ("lateral monster walks") for Gluteus medius strength and activation and
- Bird dogs for Core stability and strength
- Forward lunges and lateral lunges are also excellent exercises to activate and strengthen the gluteus medius

Lateral Monster Walk 	**Exercise Description:** Use a looped rubber band. Secure the band just above your knee. Squat to approximately 45 degrees. While staying in this squat position step one leg out to the side, widening the space between your feet. Then step the other leg in, narrowing the space between your feet. Be sure to maintain a constant tension in the band and not bring your feet too close together. **Duration:** Perform 2 sets of 30 steps in each direction. Maintain a good squat position throughout the exercise. **Goal:** Gluteus Medius muscle activation **Phase:** Wind-up
Forward Lunge 	**Exercise Description:** Stand with your feet shoulder width apart. Take a long step forward and slowly lower the back knee toward the ground. The front knee should ben to approximately 90 degrees and the patella should track with the second toe. Push off the front leg to return to stranding position. Alternate legs. **Duration:** Perform 2 sets of 10 repetitions on each leg **Goal:** Gluteus Medius muscle activation **Phase:** Wind-up
Lateral Lunge 	**Exercise Description:** Stand with your feet shoulder width apart. Take a big step to one side, push your hips back while bending your stride knee. Lower your body until your stride knee is bent 90 degrees. Push back to the starting position. Alternate legs. **Duration:** Perform 2 sets of 10 repetitions on each leg. **Goal:** Gluteus Medius muscle activation **Phase:** Wind-up
Bird Dog 	**Exercise Description:** Begin on all fours in your Table Top Position. Brace your core and then slowly lift and extend your right arm and left leg until they are parallel to the floor. You should squeeze your shoulder blade down and back on the right arm and flex your foot and press your heel rearward to engage your glutes on the left leg. Hold this position for 10 seconds. Return to table top position without touching the ground and repeat. Do all the reps on one side and then switch. **Duration:** Hold position for 10 seconds. Perform 10 repetitions on each side. **Goal:** Core muscle activation **Phase:** Wind-up

Stride

The stride phase begins with the throwing shoulder horizontally abducting to approximately 90° and ends with the front foot striking the ground.

From the ground up, the athlete will be engaging their ankles, legs, pelvis, core, thoracic spine, and shoulder.

Core strength, lumbar extension, and thoracic spine rotation

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DEFICIENCY

↓

"catch-up phenomenon"

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Low back pain (LBP)

- Repetitive, high-velocity spinal movement, and loading...

i. Stress reactions

ii. Stress fractures

iii. Vertebral disc degeneration

iv. Mechanical surrounding musculature

NOTE: *Maintaining a neutral spine by avoiding excessive lumbar extension and rotation during the stride and early cocking phases.*

Neutral Spine

- Lumbar stability + CORE STABILITY
- Thoracic mobility

Cocking

- The cocking phase begins with the front foot striking the ground and ends with maximum shoulder external rotation (MER) at 150 to 180° .
- This stage of throwing can be further divided into early and late cocking phases.
- Potential energy is accumulated in the early cocking phase and transferred to the throwing arm in the late cocking phase to prepare for acceleration and ball release

Early Cocking

- Begins with lead foot contact. The Quadriceps of the lead leg contracts to stabilize a fulcrum point.
- Trunk rotation and extension lag behind pelvic rotation, transferring energy from the pelvis to the upper torso .
- During rotation, the abdominal and oblique musculature is activated to stabilize the trunk through the delay between pelvic and upper torso rotation

SHOULDER IN COCKING

- Deltoid muscle activates to maintain 90° abduction of the throwing arm with the elbow flexed at 90 to 100°.
- Rotator cuff muscles achieve high activity to resist the compressive force generated by the trunk .
- The shoulder girdle muscles (levator scapulae, serratus anterior, trapezius, rhomboids, and pectoralis minor) are activated to stabilize the scapula and glenoid for subsequent humeral head external rotation.
- Scapula must protract and rotate upwards to ensure that the humeral head is positioned in the “safe zone” on the glenoid as rotation of the throwing arm lags behind the torso.

SCAPULAR DYSKINESIA

- Scapular dyskinesis... disruption of normal scapular kinematics is a major cause of injury during the early cocking phase.
- Scapular stabilization and glenoid positioning exercises needs to perform.

Late Cocking

- The late cocking phase prepares the arm for forward acceleration and subsequent ball release.
- During the late cocking phase, potential energy from the trunk is transferred to the throwing arm as it externally rotates and horizontally adducts.

- The infraspinatus and teres minor muscles contract concentrically to externally rotate the shoulder.
- As the arm externally rotates, the shoulder internal rotators (subscapularis, teres major, pectoralis major) contract eccentrically to control the speed of rotation.
- The posterior rotator cuff muscles (infraspinatus and teres minor) and latissimus dorsi contract to generate a posterior force which resists anterior humeral head translation and supports the anterior capsule .
- The pectoralis major and anterior deltoid muscles also contract concentrically to horizontally adduct the throwing arm with peak angular velocity of 600° per second

Thrower's Paradox

- Loose enough to allow excessive ER BUT stable enough to prevent recurrent subluxation.

- For throwers with excessive laxity, strategy to combat this paradox is

i. Increasing ROM elsewhere in the chain.
ii. Increasing Thoracic spine mobility in extension and
iii. Rotation toward the pitching side may eliminate the need for excessive glenohumeral external rotation range of motion and help avoid resultant anterior capsule laxity and additional stress on the long head of the biceps tendon

Acceleration

- The acceleration phase takes place from maximal external rotation to the moment of ball release.
- The trunk flexes forward (rectus abdominis, obliques)to neutral position as the throwing arm rotates internally and the elbow extends.
- Arm rotation lags behind elbow extension, with maximal elbow velocity occurring halfway through the acceleration phase and (MIRV)maximal internal rotation(latissimus dorsi, pectoralis) velocity occurring at ball release.

- This delay reduces the inertia of the shoulder to increase the torque and angular velocity of the throwing arm .
- The mean angular velocity of the arm at ball release is approximately 7,000° per second, making this one of the fastest human movements...and more prone to the injuiry.

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- Extension of the elbow during ball acceleration is achieved via the centrifugal force generated by the trunk and concentric activation of elbow extensors.

- Deceleration of elbow extension at ball release is achieved via eccentric activation of elbow flexors (biceps brachii, brachialis, and brachioradialis) .

- Wrist flexor muscles (flexor carpi radialis, flexor carpi ulnaris, and flexor digitorum) shift the wrist from hyperextension to neutral position at ball release.

Kinetics involved

- The quadriceps of the lead leg contracts concentrically to extend the leg.
- The trunk flexors (rectus abdominis, obliques) tilt the trunk forward to allow the throwing arm to accelerate through a greater distance.
- Internal rotation of the shoulder to 90 or 100° is achieved via concentric activation of the internal rotators latissimus dorsi, pectoralis.
- The rotator cuff muscles, trapezius, serratus anterior, and levator scapulae remain active to stabilize the scapula and glenohumeral joint.

Deceleration

- The deceleration phase takes place between the time of ball release and maximal humeral head internal rotation with elbow extension .
- During this last point of contact prior to completing the pitch, there are 0° of glenohumeral rotation, 100° of shoulder abduction, and 35° of horizontal adduction .
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- Teres minor, infraspinatus, and posterior deltoid are responsible for slowing the shoulder down and dissipating compressive forces across the joint.
- The biceps brachii and brachialis are also active during deceleration by contracting eccentrically to slow down elbow extension and forearm pronation.
- Trapezius, rhomboids, and serratus anterior, all assist in the deceleration phase and help the thrower stabilize their scapula throughout movement.

Follow-through

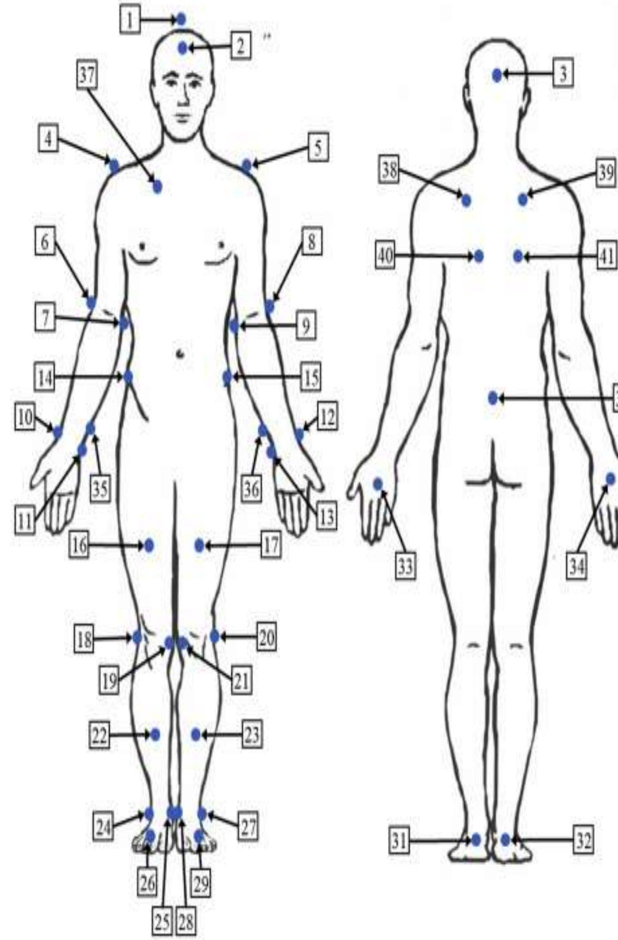
- The follow-through phase is the culmination of the kinetic chain:

i. Linking together
ii. Generating forces
iii. Delivering the pitch.

Due to decreased joint loading during this phase, the risk of injury is reduced relative to other phases.

Modern Throwing Analysis

- Marker locations for video motion capture throwing analysis



1. Top of head
2. Anterior head
3. Posterior head
4. Right acromion
5. Left acromion
6. Right lateral epicondyle of the humerus
7. Right medial epicondyle of the humerus
8. Left lateral epicondyle of the humerus
9. Left medial epicondyle of the humerus
10. Right radial styloid
11. Right ulnar styloid
12. Left radial styloid
13. Left ulnar styloid
14. Right anterior superior iliac spine (ASIS)
15. Left ASIS
16. Right anterior thigh
17. Left anterior thigh
18. Right lateral femoral epicondyle
19. Right medial femoral epicondyle
20. Left lateral femoral epicondyle
21. Left medial femoral epicondyle
22. Right anterior shank
23. Left anterior shank
24. Right lateral malleolus
25. Right medial malleolus
26. Right toe – between second and third metatarsals
27. Left lateral malleolus
28. Left medial malleolus
29. Left toe – between second and third metatarsals
30. Sacrum
31. Left heel – superior-posterior calcaneal tuberosity
32. Right heel – superior-posterior calcaneal tuberosity
33. Left dorsal hand
34. Right dorsal hand
35. Right medial forearm
36. Left medial forearm
37. Right clavicle
38. Left scapula medial supraspinous fossa
39. Right scapula medial supraspinous fossa
40. Left scapula posteriomedial border
41. Right scapula posteriomedial border

Key performance indicators (KPIs)

- Ball Speed
- Stride length
- Lead leg GRF max
- Back leg GRF max
- Shoulder Abduction/horizontal
- Abduction at Foot Strike
- Shoulder abduction at release
- Maximum shoulder external rotation (MER)
- Elbow angle at MER
- Pelvis rotation at MER
- Elbow angle at release
- Hip-shoulder separation at foot strike
- Elbow angle at foot strike
- Trunk forward flexion at foot strike
- Thorax angular velocity max
- Knee flexion angle at release
- Humerus angular velocity max
- Trunk forward flexion at release
- Elbow extension velocity max
- Trunk lateral tilt at release
- Pelvis angular velocity max
- Trunk rotation at release
- Lead knee angular velocity max
- Time between max pelvis rotation velocity and max trunk rotation velocity
- Trunk lateral tilt at foot strike Max elbow varus torque

Return to Sport

- ❑ Criteria based approach:

(1) No pain or swelling in the affected joint

(2) Restore baseline range of motion

(3)Restore baseline strength

(4) Assess for normal scapular position

(5) Asymptomatic plyometric strength progression

(6) interval throwing and workload monitoring

(7) Mechanics assessment

(8) Return to full competition

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