BIOMECHANICS OF THROWING- PART 2

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PHASES OF THROWING

1. Preparation/Wind Up
2. Stride
3. Cocking
4. Acceleration
5. Deceleration
6. Follow-through

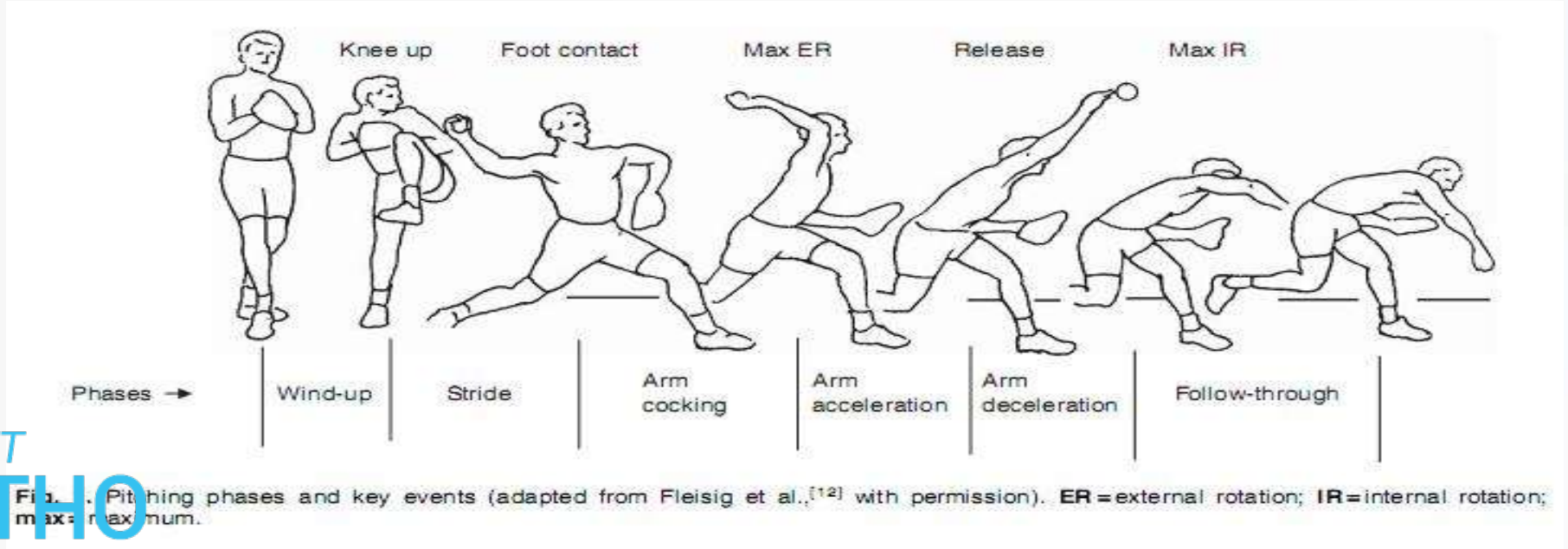


Fig. . Pitching phases and key events (adapted from Fleisig et al.,[12] with permission). **ER** = external rotation; **IR** = internal rotation; max = maximum.

Phases of Throwing

1. Biomechanics

   Entire throwing motion takes upto 2 seconds.

- Wind Up & Acceleration phase take app 75% time.(1.5s)

Wind-UP

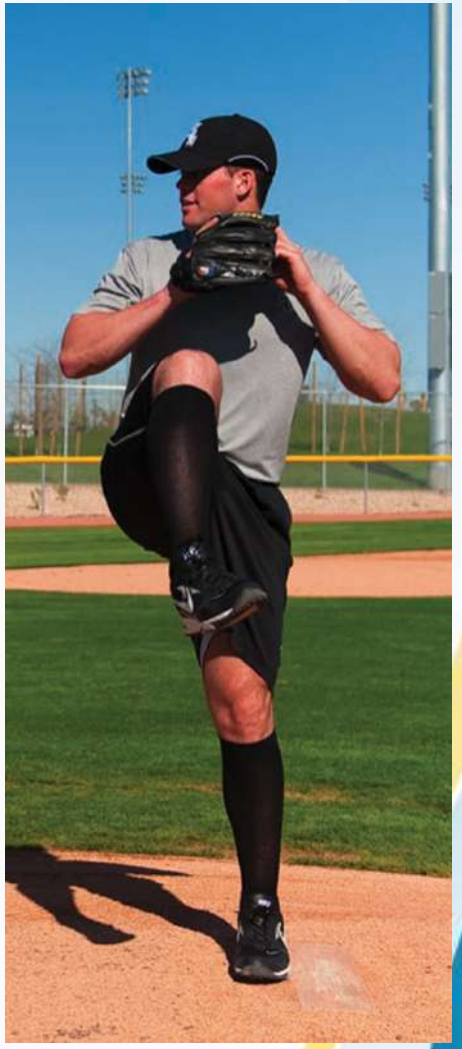
- Wind up phase is defined as initial movement to maximum knee lift of stride leg.
- During the initial movements, the pitcher brings his or her hands overheads to chest level.
- During this phase muscle of shoulder are relatively inactive...reason risk of injury is low as well.
- The wind up phase lasts 500-1000 milliseconds.

Wind-UP

The purpose of wind-up is threefold:

1. To establish a rhythm to achieve correct timing for subsequent movements
2. To conceal the ball and distract the hitter
3. To place the body in a position that may contribute to the propulsion of the ball

During windup and stride, the pitcher keeps his center of gravity back (over stance leg) for as long as possible to allow maximum generation and transfer of momentum and force to the upper extremity and ball.



Muscle Activation

- Minimum Muscle Activity & Muscle Fire at Low Intensity
- As the stride leg is flexed, the weight is transferred from the stride leg to pivot legand
- HIP ABDUCTORS,ADDUCTORS & EXTENSORS of pivot leg acts as weight absorber.
- Anterior Deltoid & Pec Major work concentrically at GHJ.
- Upper Traps, Serratus Anterior & Lower Traps work to produce upward rotation of scapula
- The ABDOMINAL muscle work to rotate & stabilize the trunk

STRIDE PHASE

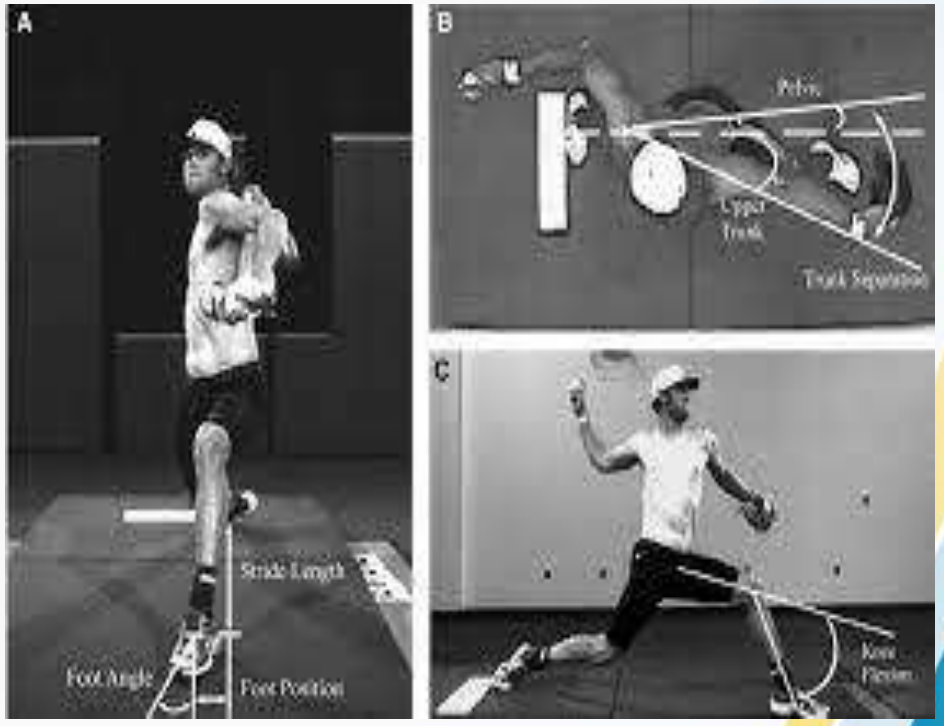
- 15 Degree Angle of Foot away from the centre of mound.
- The Stride Ankle also typically lands approximately 10cm away from the same midline.
- 3.0 N increase in anterior Force for every extra cm and a 2.1 N increase in anterior Force at shoulder with every degree increase of foot angle.

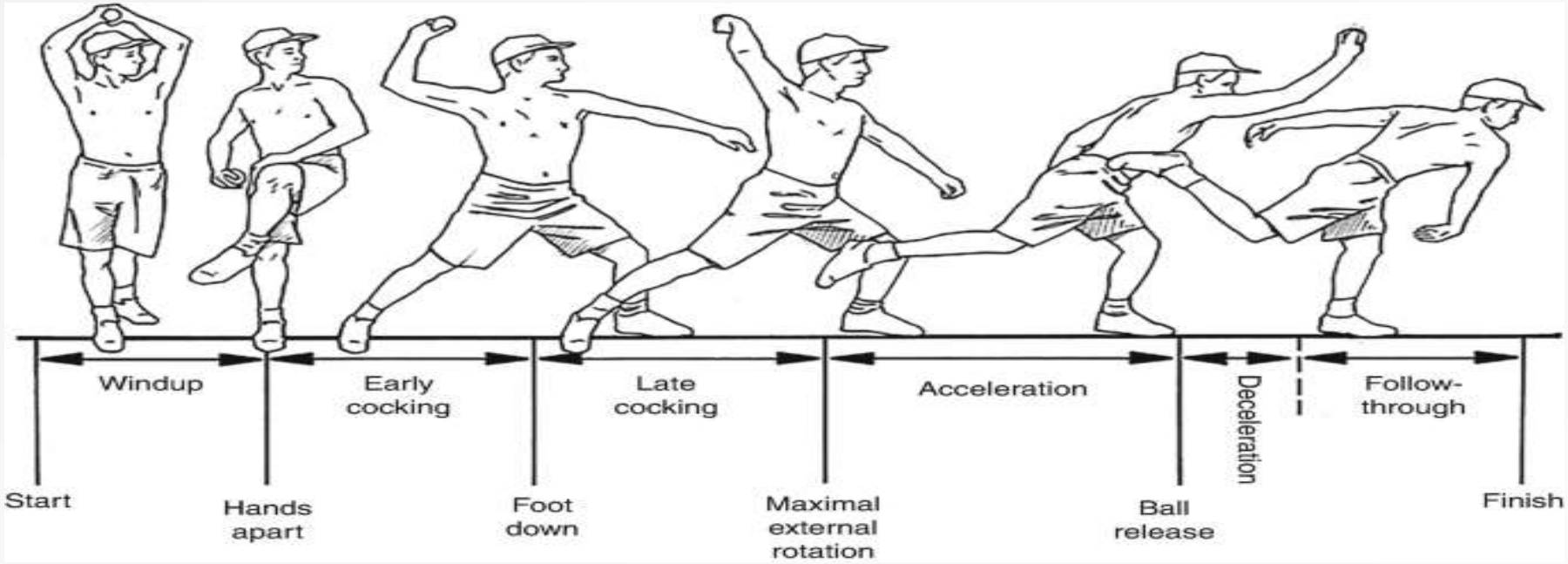
ARM COCKING PHASE

- Beginning of Lead Foot contact and ends at Maximum shoulder External Rotation. (MER)
- Kinetic Energy is transmitted to the shoulder, approximately 80% Body Weight from the Lower Extremities and Trunk Rotation.
- Scapula & Shoulder Muscles are highly activated to promote & sustain movements of the shoulder, especially External Rotations.

Early Cocking Phase

- It begins with the end of WIND-UP phase or when the stride leg reached it's maximum height and it end when the stride leg contacts the mound/ground.
- At this point the throwing arm in "semicocked" position.
- With the arm approximately 90 deg Abduction, 50 deg External Rotation.





- As the ball is removed from the Glove, COG is lowered by flexing the knee of the pivot leg and stride leg gradually extends and moves towards the batter.
- It's main function is to allow a linear & angular motion of the trunk, which lands directly in the front of the pivot leg with toes pointing slightly in.
- The knee and Hip of the PIVOT leg extend & initiate pelvic rotation & forward tilting followed by upper torso rotations.

- The supraspinatus, infraspinatus, and teres minor externally rotate the shoulder and position of the humeral head on the glenoid.
- The serratus anterior and the scapular retractors (middle trapezius, rhomboid, and levator scapulae) position the glenoid in upward rotation and retraction, providing a stable base on which the humerus can rotate.
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Early cocking/stride phase of pitching motion

1)Begins as Lead leg reaches max height.

2)Stride increases the distance over which angular/linear acceleration occurs.

3)Pelvic tilt and rotation begin.

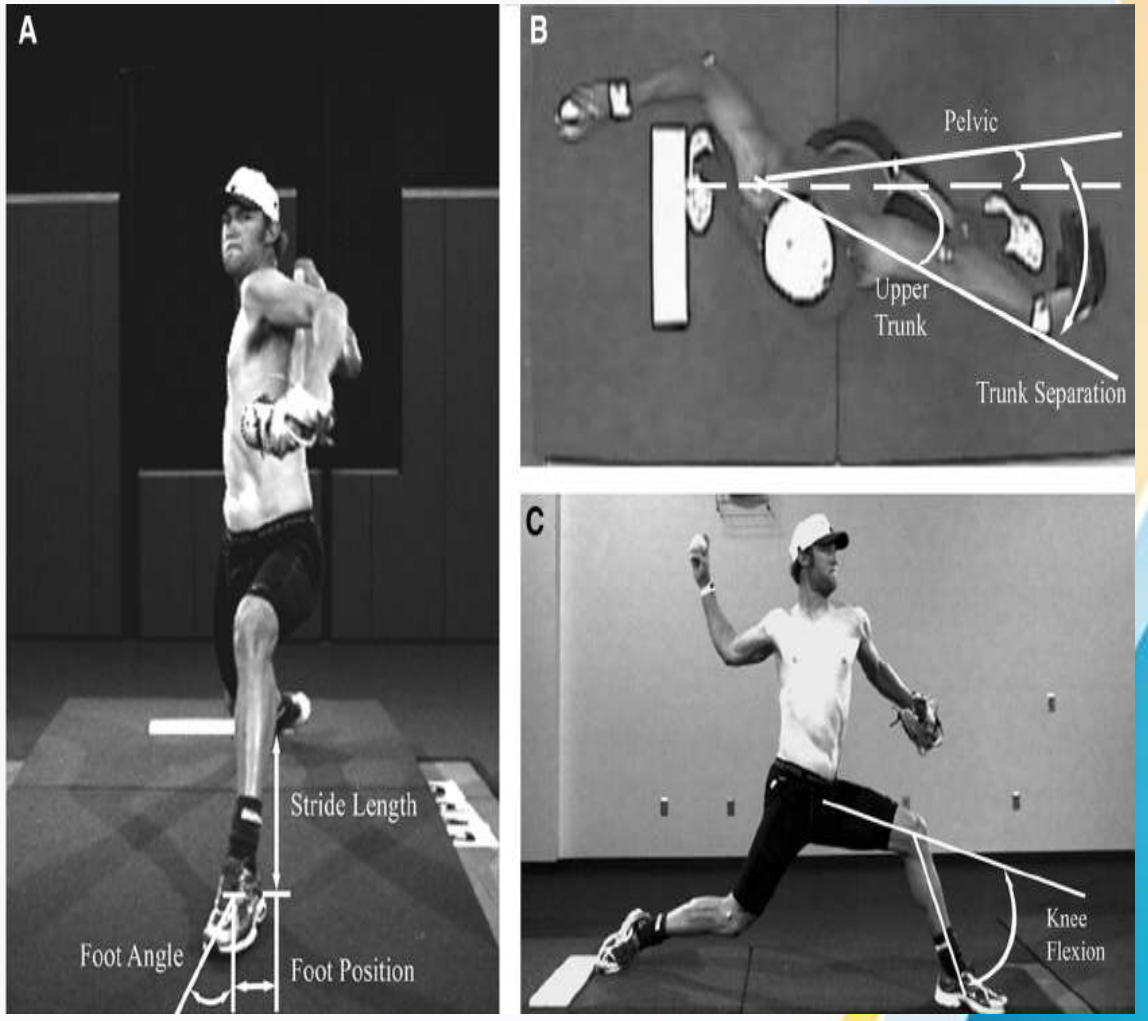
4)Deltoid is active early in phase to aid in abduction of shoulder.

5)Suprasinatus, infraspinatus, and teres minor are active late, to initiate shoulder external rotation.

6)Ends at stride (lead) foot contact.

Early cocking/Stride phase

1. The early cocking/stride phase begins once the lead leg reaches its maximum height and the ball is removed from the glove , and it ends when the lead foot contacts the pitching mound.
2. The stride functions to increase the distance over which linear and angular trunk motions occur, allowing for increased energy production for transfer to the upper extremity.
3. The stance knee and hip extend and lead to the initiation of pelvic rotation and forward tilt, followed by upper torso rotation.
4. The pelvis achieves maximum rotational velocities of 400 to 700 degrees per second during this phase.
5. The abdominal obliques eccentrically contract to prevent excess lumbar hyperextension during upper torso rotation and flexion.
6. The stance leg gluteus maximus fires to maintain slight dominant-sided extension and provide pelvis and trunk stabilization during coiling



Muscle activation in Early cocking

- Hip extensors and abductors, knee flexors and ankle plantar flexors of the pivot leg work to propel the weight forward as the stride leg is moving forward.
- And hip extensors and abductors, knee extensors and ankle plantar flexors of stride leg work eccentrically to control the lowering of body's centre of gravity.
- Abdominal obliques work eccentrically to control excess lumbar hyperextension.
- In the early cocking phase, the supraspinatus and deltoid work together to abduct the arm with a peak activity .
- And later during the late cocking phase the activity of deltoid decreases.
- The other muscles which produce peak activity during early cocking phase are right extensor carpi radialis longus and brevis, extensor digitorum communis, right gluteus maximus and left oblique for right-handed pitcher.
- And the muscle which produces a strong contraction is left erector spinae and left gluteus maximus for a right-handed pitcher.
- Whereas trapezius, serratus anterior and pectoralis are moderately active to position the scapula.

Late Cocking Phase of the Pitching Motion.

1. Occurs between foot contact and max external rotation.
2. Scapula retracts and tilts upward via actions of the rhomboids, levator, trapezius.
3. Humeral abduction and external rotation—mainly owing to infraspinatus/teres minor.
4. Supraspinatus functions primarily in glenohumeral compression, humeral head depression.
5. Pelvis reaches max rotation.
6. Increased torso rotational and angular velocities.
7. Phase ends as subscapularis, pectoralis major, and latissimus dorsi eccentrically contract to terminate external rotation.

Muscle activation in Late cocking:

- During the late cocking phase, the pivot leg hip extensor, knee flexor and calf muscles work concentrically to transfer the force up the kinetic chain and aide in force generation at the arm.
- Serratus anterior and pectoralis major produce their greatest activity during the late cocking phase just before maximum external rotation[8].
- Infraspinatus and teres minor have their peak activity to externally rotate the arm concentrically and later on their activity is decreased to moderate levels during the acceleration phase.
- Subscapularis produces significant eccentric contraction as the humerus passes neutral rotation to control the lateral rotation of the arm.
- Biceps brachii presents with peak activity during flexion of the elbow in the late cocking phase as it limits anterior translation and compression forces of the humeral head. As the wrist extension reaches a maximum, the wrist extensor is at its greatest activity[5].

END OF COCKING PHASE

ARM COCKING

EARLY

- PEAK muscle activation
- DELTOID
- I/L ECRL & ECRB(Extensor Carpi Radialis Longus & Brevis), Extensor Digitorum Communis, Gluteus Maximus & C/l Oblique
- Erector Spinae & Gluteus Maximus

LATE

- High Torque Phase with maximum Shoulder ER
- Peak Muscle Activation
- Muscles of Rotator Cuff

ELBOW IN ARM COCKING

- Near the end of arm cocking (64% of time from foot contact until ball release), maximum valgus torque is experienced at the elbow.
- The flexor and pronator muscles of the forearm generate a counter varus torque (64 Nm)
- Maximum elbow flexion is limited by eccentric contraction of the triceps, followed by concentric contraction as the elbow extends at the termination of late cocking and throughout acceleration.

ELBOW IN ARM COCKING

- A low to moderate flexion torque of 0-32 Nm is produced at the elbow throughout the phase.
- A large Valgus Torque- is produced at the elbow by
  - Pelvis & Upper torso rotations & rapid shoulder External Rotations
- To resist the valgus force... A Max Varus torque of 52-76 Nm is generated (by Flexor and Pronators of forearm) at the elbow shortly before Maximum External Rotation.

Valgus torque placed on Arm

↓

Large tensile forces on medial aspect of elbow

↓

Repetitive VALGUS LOADING torque can cause compression between radial head & capitellum

↓

Injury to UCL/Medial Epicondylitis or Flexor Pronator Tendontis

Reason for Elbow Injury

1. Maximum Medial Force 240-360N (++ Varus Torque) is applied by Upper arm, to the forearm to resist lateral translation.
2. A maximum Anterior Force 80-240 N is applied by upper arm onto the forearm to resist posterior translation of forearm at the elbow.
3. A maximum Compressive Force of 150-390 N is applied by the upper arm to the forearm to resist Elbow distraction.

Role of TRICEPS

- The elbow achieves a maximum flexion of 85-105 approx 30 milliseconds before MER.

- If the triceps muscle is paralyzed by a radial nerve block , the elbow collapses & continues flexing near its limit(approx 145 deg elbow flexion).

- Collapse is caused by Centripetal flexion torque at the elbow created by the rapidly rotating upper torso and arm.

- TRICEPS muscle contracts eccentrically and then Isometrically in resisting the centripetal flexion torque that occurs during late arm cocking.

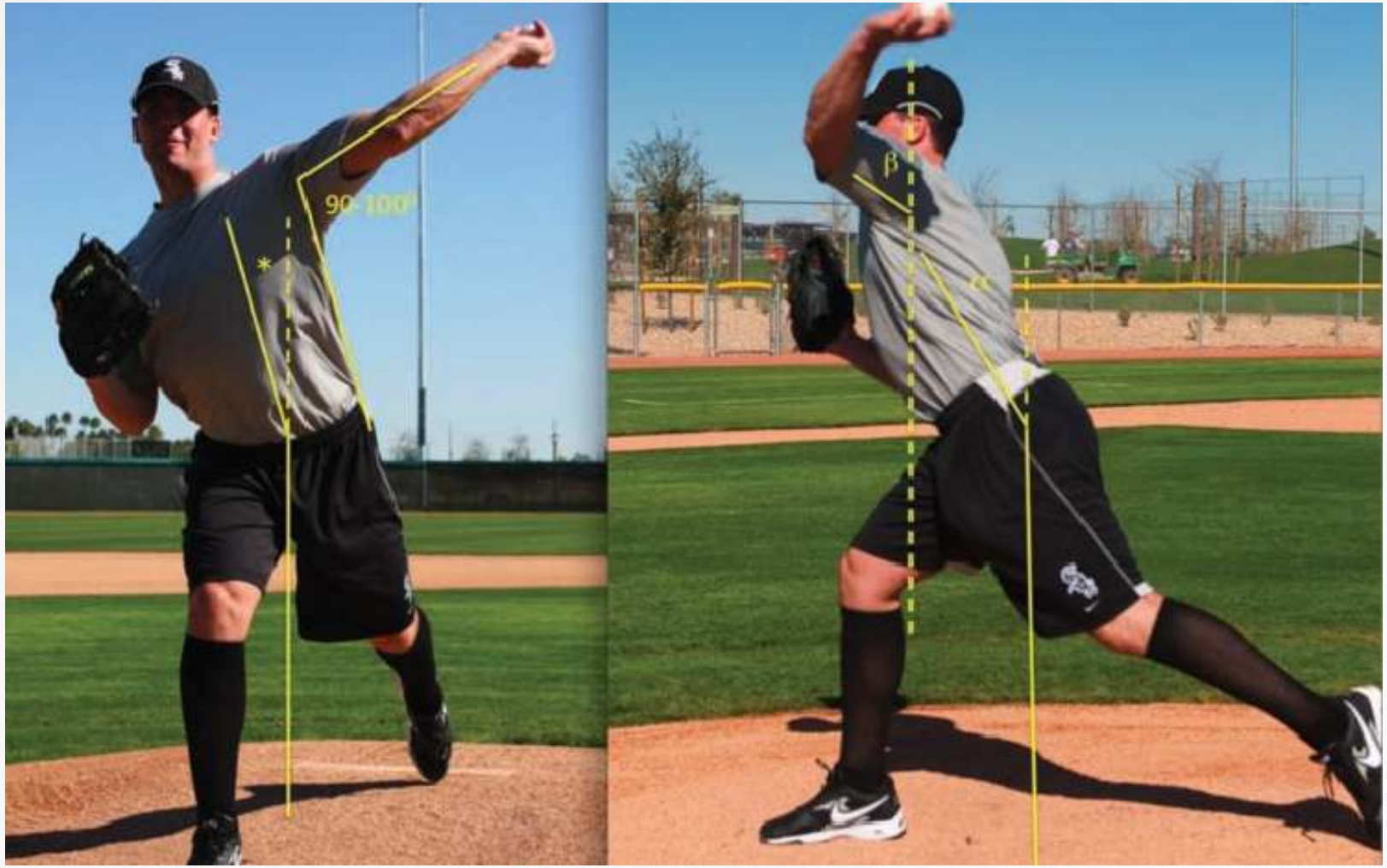
Acceleration

- The acceleration phase is defined as the time between maximum external rotation (MER) of the shoulder and ball release.
- The trunk continues to rotate and tilt, initiating the transfer of potential energy through the upper extremity.
- The scapula protracts to maintain a stable base as the humerus undergoes horizontal adduction and violent internal rotation.
- This rapid motion delivers the arm from as much as 175° of external rotation to 100° of internal rotation (at ball release) in only 42 to 58 milliseconds.

- Ball release takes place between 40 and 60 of humeral external rotation.
- The elbow first moves to about 120 deg of flexion and then rapidly extends to about 25 deg of flexion at ball release.
- At ball release elbow extension velocity peaks at approximately 2500o/sec.
- Ball release is aided by wrist flexion to neutral in the 20 milliseconds preceding release and radioulnar pronation to 90° in the 10 milliseconds prior to release. while the forearm is in about 90 deg pronation at release.
- After ball release,the elbow is flexed 25, and the arm is abducted an average of 93 and set in 6 deg of horizontal adduction.

1. The Subscapularis reaches maximum activity during this phase along with the pectoralis major and latissimus dorsi, producing the violent internal rotation of the humerus reaching forces as high as 185% of its maximum muscle test strength.
2. Internal rotation velocities as high as 7000 to 9000 degrees per second.
3. The Serratus Anterior reaches maximum activity during acceleration as it promotes scapular protraction, providing a stable glenoid for humeral rotation.
4. During acceleration, the elbow initially flexes from 90° to 120° then rapidly extends to near 25° just before ball release.
5. Elbow extension results from a combination of the centrifugal force generated by the rotating torso and the concentric contraction of the triceps; it is immediately followed by shoulder internal rotation.

1. The nondominant rectus abdominus, abdominal obliques, and lumbar paraspinous muscles all show significant activity over their dominant-side counterparts during acceleration to accentuate pelvic and trunk rotation and tilt.
2. Concentric rectus femoris contraction contributes to lead leg hip flexion and knee extension, providing a stable front side to help create increased angular momentum of the trunk.
3. Increased forward trunk tilt allows the pitching extremity to accelerate through a greater distance, allowing more force to be transferred to the ball.
4. Forward trunk tilt reaches a mean of 32-55 degrees and a Maximum angular velocity of 300 -450 degrees per second at ball release.



Acceleration phase of the pitching motion.

1. Occurs from max external rotation until ball release.
2. Scapula protracts and anterior tilts—increased activity of serratus anterior
3. Shoulder muscle forces shift from eccentric (during LC) to concentric anteriorly.
4. Shoulder muscle forces shift from concentric (LC) to eccentric posteriorly.
5. Subscapularis reaches it maximum activity, generating humeral internal rotation.
6. Max shoulder internal location velocity occurs at or milliseconds after ball release.
7. Max elbow extension angular velocity occurs at ball release.

ELBOW DURING ARM ACCELERATION

- Short time MER to ball release.
- Entire phase lasts for few 100th of seconds.

✓ Max Elbow Flexor Torque of 40-60 Nm is generated from low to moderate activity of Elbow Flexors.

✓ As Maximum Elbow Angular Velocity of 2100-2700 deg/sec occurs at approximately halfway through the phase.

Role of TRICEPS

- Elbow Extension in the phase brought by----- TRICEPS + CENTRIFUAGL FORCE(major)

- TRICEPS & ANCONEUS function more as stabilizers than accelerator...helps in inititiation angular velocity.

“VALGUS HYPEREXTENSION OVERLOAD”

- During arm acceleration, the need to resist valgus stress at the elbow can result in wedging of the olecranon against medial aspect of the trochlear groove and the olecranon fossa.

- This impingement leads to the osteophyte production at the posterior and posteromedial aspect of the olecranon tip and can causes chondromalacia and loose body formation.

- Substantial varus torque is generated throughout the arm cocking and arm acclereation phases to resist valgus torque.

- During these phases, the elbow extends through a range of approximately 65 deg (approximately 85 deg to approximately 20 deg)

Deceleration

- The deceleration phase occurs between ball release and maximum humeral internal rotation and elbow extension.
- The phase ends with completion of humeral rotation to 0°, shoulder abduction to 100°, and an increase in horizontal arm adduction to 35.
- Excessive posterior (400 N) and inferior shear forces (300 N) occur, as do elevated compressive forces (> 1000 N) and adduction torques.
- The posterior shoulder soft tissue structures (teres minor, infraspinatus, and posterior deltoid) dissipate these enormous forces during the acceleration phase as the arm continues to adduct and internally rotate.

MUSCLE ACTIVATED

- This is the most active phase for the muscles of the shoulder girdle as they work eccentrically to decelerate the arm.
- Trapezius, serratus anterior and rhomboids produce high MVIC to assist in deceleration of shoulder girdle.
- Teres minor presents with its peak activity during this phase as it resists anterior humeral head translation, horizontal adduction and internal rotation.

- In addition to teres minor, Infraspinatus, Supraspinatus and Deltoid also present high MVIC to decelerate the arm in space as it moves forward.

- Biceps brachii and brachialis produces marked eccentric contraction to decelerate the elbow extension and forearm pronation.

Follow-through

- As follow-through proceeds, the body continues to move forward with the arm until motion has ceased.
- Horizontal adduction increases to 60°, and muscle firing decreases in general.
- The follow-through phase culminates with the pitcher in a fielding position.
- The decreased joint loading and minimal forces during this phase render it an unlikely culprit for injury.

Muscle Activation

- During the follow-up phase, the Trunk Extensors work concentrically to bring the trunk in an upright position.
- And as the rest of the body catches up with the arm, the Pivot leg Hip Flexors move the leg forward and the pitcher assumes a fielding position.

Thank you.

FOR ANY QUERIES-

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