THE ROLE OF THE LOWER EXTREMITIES & TRUNK IN PITCHING

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OBJECTIVES

• Understand the typical phases of pitching and the goals of each phase
• Identify the common faults in each phase that influence the outcome of that phase
• Understand the lower body/trunk biomechanics and LE muscle activity that influence each phase
• Recognize that deficits in lower extremity ROM, muscle strength, and balance impact proper pitching biomechanics
BIOMECHANICAL ANALYSIS
PHASES OF PITCHING

Six phases:

- Windup
- Stride
- Arm cocking
- Arm acceleration
- Arm deceleration
- Follow-through
EMG ACTIVITY OF PITCHING

• Pitching motion was divided into 4 distinct phases:
  • Phase 1: initiation of pitch to maximum knee kick height
  • Phase 2: maximum stride leg knee height to stride foot contact
  • Phase 3: stride foot contact to ball release
  • Phase 4: follow-through

• Vastus Medialis (VM), Biceps Femoris (BF), Rectus Femoris (RF), Gluteus Maximus (GM), and Gastrocnemius (GAST)

Campbell et al. JSCR 2010
WINDUP PHASE

- The objective of the windup phase is to put the pitcher in a good starting position.
- Begins when the pitcher initiates the first motion and ends when the front knee reaches its maximum height.
- The body winds up so that all segments of the body from the legs to the arms are able to contribute to the ball’s propulsion.
- Concentric contraction of the hip flexors promotes hip flexion of the stride leg, while the hip extensors, knee extensors, and knee flexors dynamically stabilize the trail leg to promote the balance point.
- Stride foot should move behind the stance leg to generate momentum and the stride leg should come into at least 90° of knee and hip flexion.
WINDUP PHASE

• Length of time for this phase is variable

• Common faults:
  • Moving too quickly through the phase
    • Prevents 1\textsuperscript{st} balance position
  • Over-rotating the pelvis backwards
    • Requires more angular velocity
  • Decreased hip flexion of the leading leg and a more flexed trailing leg
    • Decreased ability to store gravitational potential energy to be used later
WINDUP PHASE – LE EMG

**Trail Leg**

**Stride Leg**

**Figure 2.** Percentages of MVC mean electromyography (EMG) value (± SD) for the gastrocnemius (GAST), vastus medialis (VM), rectus femoris (RF), gluteus maximus (GM), and biceps femoris (BF) muscles of the trail leg during each of the phases of the pitch.

**Figure 3.** Percentages of MVC mean electromyography (EMG) value (± SD) for the gastrocnemius (GAST), vastus medialis (VM), rectus femoris (RF), gluteus maximus (GM), and biceps femoris (BF) muscles of the stride leg during each of the phases of the pitch.

Campbell et al. JSCR 2010
STRIDE PHASE

• Production of initial linear momentum of the body and is the initial factor in the generation and transfer of momentum up through the kinetic chain.
• Begins as the stride leg begins its descent and ends with stride foot contact.
• Pitcher strides his front leg towards the target. At the time of front foot contact:
  • the stride length should be 83 +/- 4% of body height
  • the lead knee should be flexed 45 +/- 9 degrees.
  • the pelvis should be 33 +/- 10 degrees open to the target
  • the shoulder line should be about 15 degrees closed.
STRIDE PHASE

- Generally lasts between 0.5 and 0.75 seconds.
- Common faults:
  - Opening hips too early/too late
  - Altered positioning and timing of the rotation of the pelvis may affect the kinetics at the shoulder and elbow
  - Pushing off rubber vs. “controlled fall”
  - Can lead to higher humeral IR torque and elbow valgus stress
  - Missed stride direction
  - Should be towards target and slightly closed
STRIDE PHASE – LE EMG

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Campbell et al. JSCR 2010
ARM COCKING PHASE

• Builds the potential energy that is used for the next phase
• Begins at lead foot contact and ends at maximum shoulder external rotation
• The pelvis and then upper trunk rotate to face the target while the throwing arm cocks back.
  • Lag between pelvis rotation and upper trunk rotation is critical for generating energy from the trunk
• Stride leg either maintains its degree of hip flexion or begins to extend
• Trail leg foot begins to lose contact with the pitching rubber
ARM COCKING PHASE

• Lasts between 0.10 and 0.15 seconds.
• Common faults:
  • Improper timing of pelvis and upper trunk rotation
  • Low ball speed and/or excessive loads in the shoulder and elbow.
• Uncontrolled fall
  • Altered positioning and timing of the trunk, pelvis, and/or lower extremities may affect shoulder and elbow kinetics
ARM ACCELERATION PHASE

• Transfer of potential energy into kinetic energy
• Begins at maximal external rotation of the throwing shoulder and ends at ball release.
• Stride leg continues to dynamically stabilize the hip, knee, and ankle as the center of mass of the body begins to move forward over the stride leg.
• At the time of ball release:
  • Front knee is flexed 35 +/-12 degrees.
  • Trail leg is completely off the ground for most pitchers.
  • Trunk is tilted 36+/−7 degrees forward and 23+/−10 degrees to the side.
ARM ACCELERATION PHASE

- Lasts only a few hundredths of a second (0.03-0.04 seconds)
- Common faults:
  - Increased knee flexion at foot contact and decreased knee extension
    - Associated with slower ball speeds
  - Improper timing of pelvis and upper trunk rotation
    - Low ball speed and/or excessive loads in the shoulder and elbow.
- Uncontrolled fall
  - Altered positioning and timing of the trunk, pelvis, and/or lower extremities may affect shoulder and elbow kinetics
ARM COCKING & ARM ACCELERATION PHASES – LE EMG

Campbell et al. JSCR 2010

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ARM DECELERATION PHASE

• Decelerates the rapidly moving humerus and scapula
• Begins at ball release and ends when the shoulder has reached its maximum internal rotation
• Lasts a few hundredths of a second.
• Common faults:
  • Abbreviated deceleration and follow-through
    • May not be using his body to dissipate the energy produced in throwing
FOLLOW-THROUGH PHASE

- Continuation of decelerating the shoulder and the rest of the body
- Begins at maximum shoulder internal rotation and ends when the pitcher regains a balanced position.
- The trunk continues to tilt forward and the back leg steps forward.
- Common faults:
  - Abbreviated deceleration and follow-through
  - May not be using his body to dissipate the energy produced in throwing
ARM DECELERATION & FOLLOW-THROUGH PHASES – LE EMG

Figure 3. Percentages of MVC mean electromyography (EMG) value (± SD) for the gastrocnemius (GAST), vastus medialis (VM), rectus femoris (RF), gluteus maximus (GM), and biceps femoris (BF) muscles of the stride leg during each of the phases of the pitch.
KINEMATIC VARIABLES
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- Foot Placement at SFC
- Stride Length
- Knee Flexion at SFC
- Trunk Forward Tilt
- Trunk Lateral Tilt
- Hip Rotation Mobility
- Pelvis/Trunk Angular Velocity and Timing
FOOT PLACEMENT AT SFC

- Stride foot should be closed at an angle of $15^\circ \pm 10^\circ$ - Fleisig (1994)

- Open position – prematurely initiates the arm-cocking phase, which results in the loss of kinetic energy:
  - Places greater torque being generated at the shoulder, in order to produce the desired ball velocity
  - 2.1 N of increased anterior GHJ force per degree of being open
  - Increases trail leg hip ER torque

- Closed position – pitcher is forced to pitch more across his body, which limits the kinetic energy transfer to the arm
  - Increases lead leg hip IR torque
  - Posterior shoulder eccentric overload

Wilk et al. SMAR 2010
STRIDE LENGTH

• Average stride length to be ~87% of body height - Fleisig (1994)
• This stride was directed toward the plate within 10cm in either direction
• 3.0 N of increased anterior GHJ force per cm open

• Increasing the stride length may increase in throwing velocity:
  • Reduces the duration spent in double support prior to the acceleration phase

• Greater flexion of the hip and knee of the trailing leg at the balance position may reduce the excursion of sagittal-plane movement of the trailing leg’s hip.

Whiteley JSSM 2007, Crotin et al. HMS 2015, Kung et al. AJSM 2017
• At the time of ball release, the front knee is flexed 35 +/-12 degrees.
• Critical to allow force transfer up the kinetic chain
• Altering knee flexion at ball release may impact pelvic, torso, and shoulder rotational timing, which can translate into higher shoulder and elbow torques

• The front knee is extending through ball release, which allows the athlete to stop the forward motion of his pelvis and transfer energy up his body to the ball.

• During Arm Acceleration, the rate of knee extension has been shown to be associated with an increase in ball velocity - Matsuo et al. (2001)

Chalmers et al. SH 2017
FORWARD TRUNK TILT

• During the arm acceleration phase, the trunk is tilted 36±/-7 degrees forward

• Trunk forward tilt has been shown to correlate with fastball velocity - Stodden et al. (2005)
  • Variable trunk tilt may produce inconsistent ball velocity

• Variability in trunk tilt may also affect pitch location.
  • Change in trunk forward tilt at the time of ball release might change the trajectory of the ball
  • Ball may cross the home plate at different heights

Whiteley JSSM 2007, Oyama et al. AJSM 2013, Fleisig et al. SB 2009
• Contralateral trunk tilt of 20-30° tends to create a shoulder abduction angle that minimizes the elbow varus torque
  • Early studies reported closer to 10° contralateral trunk tilt and 100° shoulder abduction

• Change in trunk lateral tilt might change the angle of the release
  • May affect the ball’s horizontal position as it crosses the plate.

• Greater contralateral trunk tilt (above 25°) resulted in increased ball velocity (~3.3 mph)
  • Produced greater elbow proximal force, greater shoulder proximal force, greater elbow varus moment, and greater shoulder internal rotation moment
  • Compensatory pattern due to weakness of the hip and abdominal musculature

Whiteley JSSM 2007, Oyama et al. AJSM 2013
HIP ROTATION MOBILITY

• Optimal orientation of the pelvis at lead foot contact requires sufficient hip ROM:
  • Internal rotation ROM of the trail hip is necessary to prepare for proper positioning of the lead leg
    • Insufficient internal rotation ROM may lead to throwing across the body and place unnecessary stress on the shoulder
  • Sufficient amount of external rotation ROM of the lead leg is required to position the lead foot
    • Excessive external rotation will result in decreased trunk rotation and decreased energy production.

Laudner et al. AJSM 2010, Robb et al. AJSM 2010, Saito et al. OJSM 2014
• Improper trunk rotational timing correlates with higher peak elbow valgus load, higher shoulder proximal force, and shoulder external rotation angle

• Closed-shoulder position - “opening up too soon”
  • Increase hyperangulation of the shoulder
  • Hyperangulation – horizontal abduction of the humerus beyond the plane of the scapula which can lead to injury in the throwing shoulder and elbow

• Desynchronization of trunk timing with stride and pelvic rotation may lead the peak of potential energy to pass through the shoulder and elbow
  • “flying open at the shoulders” or lacking “hip and shoulder separation”

Chalmers et al. SH 2017, Oliver et al. JSCR 2010


SNOOP, CARLY RAE, ... CARL LEWIS!!
THANK YOU