Unconventional Baseball Pitching Styles, Part 1: Biomechanics and Pathology

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Unconventional throwing mechanics are utilized by some baseball pitchers, which include three-quarter arm, sidearm, and submarine styles (Figure 1). To minimize injury risk, detailed examination of muscle activation throughout the kinetic chain for each throwing style is necessary. The kinetic chain consists of interdependent links between body segments that are sequentially mobilized or stabilized during the performance of multisegmental athletic movement patterns.[1-3] During throwing, motion of the legs and torso generates kinetic forces that are transmitted sequentially through the scapula, upper arm, and lower arm segments. If a segment is not positioned properly, the athlete cannot adequately transfer energy to an adjacent segment.[4] This will result in a loss of energy transfer to the ball and will impose abnormal stress on ligaments and tendons. A compensatory strategy may involve greater reliance on the smaller, more distal segments of the upper extremity to maintain ball velocity.[1,2,5-8] We acknowledge that the lower extremities and the lumbar-pelvic-hip complex play important roles in baseball pitching, but we will focus on differing upper body and torso mechanics among the different pitching styles.

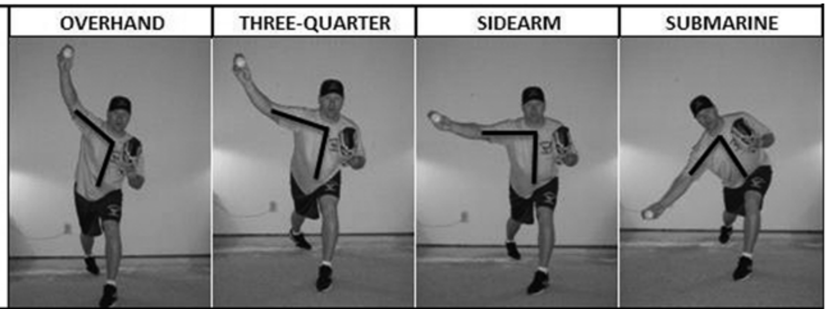
Key Points

- Four basic baseball pitching styles include overhand, three-quarter, sidearm, and submarine.
- Each pitching style produces a different lateral trunk tilt angle and shoulder abduction angle.
- The incidence of injuries associated with each pitching style may vary due to differing mechanics.

Knowledge of the biomechanics associated with different pitching motions can help an athletic trainer or therapist (AT) to objectively evaluate and successfully treat injured pitchers. Part 1 of this two-part report presents information pertaining to the biomechanics and injury pathology for the "submarine" throwing style. Part 2 will present information pertaining to the treatment and rehabilitation of a pitcher who uses an unconventional throwing style.

Biomechanics

The six phases of throwing include the windup, stride, cocking, acceleration, deceleration, and follow-through.[1,2,9,10] Pitching styles are differentiated by the lateral trunk tilt angle at the instant of ball release.[11] A pitcher's arm angle is defined by the combination of shoulder abduction and lateral trunk tilt at the instant of ball release.[12] The position of the arm and trunk segments at the instant of ball release has a profound effect on the distribution of forces throughout the kinetic chain.[11-16] Each pitching style is associated with a unique height of ball release above the ground (Figure 1).



Reported Findings	Overhand & Three-Quarter	Sidearm	Submarine
Matsuo et al. (2000)	N = 13	N = 2	N = 2
Ball Release Height (as % of subject height)	78.57%	53.10% and 47.83%	37.98% and 34.78%
Pitch Velocity (m/s)	36 ± 1	34 and 36	31 and 32
Lateral Trunk Tilt	-24° ± 5°	-10° and 0°	25° and 10°
Glenohumeral Abduction	105° ± 9°	95° and 84°	74° and 71°
Peak Elbow Varus Torque (% BW)	1.3 ± 0.7	1.4 and 1.2	0.7 and 1.1
Matsuo et al. (2002)	N = 9		N = 2
Peak Wrist Velocity (m/s)	16.2 ± 0.5		15.1 and 14.0
Glenohumeral Abduction	101° ± 13°		69.5° and 78.4°
Peak Elbow Varus Torque (Nm)	35.4 Nm ± 3.4 Nm		46.5 Nm and 33 Nm
Matsuo et al. (2006)	N = 33		
Lateral Trunk Tilt	-28.9° ± 5.7°		
Glenohumeral Abduction	93.3° ± 7.9°		
Peak Elbow Varus Torque (Nm)	65.0 Nm ± 13.0 Nm		

* Ball height calculated as a percentage of subject height [(mean subject height x mean ball height) x 100]

Figure 1 Pitching styles and relevant data.

Overhand and three-quarter arm pitchers demonstrate a "contralateral tilt" (i.e., the trunk is tilted toward the non-throwing side),[8,14,16,17] whereas a sidearm pitcher demonstrates a more vertical trunk orientation.[16,17] Submarine pitchers demonstrate substantial lateral flexion toward the throwing arm side and less arm abduction than that associated with other throwing styles.[17] A trunk tilt toward the throwing arm side has been described as an "ipsilateral tilt."[14-17] The combination of a high degree of lateral trunk flexion with a low degree of shoulder abduction produces a lower ball release point, which provides an unfamiliar delivery that may disrupt the batter's conditioned response to a more conventional pitching style.

Based on the available research, submarine pitchers utilize a lower shoulder abduction angle than overhand and three-quarter arm pitchers, despite having an ipsilateral trunk tilt.[14] Differences in measurement technique may exist between studies; however, the research highlighted in Table 1 refutes the previous idea that the arm remains abducted at approximately 90-94° throughout the throwing motion despite an ipsilateral trunk tilt.[18]

Scapular Mechanics

Scapular motion is necessary to maintain the position of the glenoid fossa for optimal contact with the moving humeral head.[19] Scapular force couples are generated by the coordinated activation of various scapular muscles, with the specific coactivation pattern depending on the type of athletic movement.[6] The three-dimensional scapular mechanics of "low-velocity" throwing has been analyzed;[9] no analysis of high-velocity scapular mechanics during baseball pitching could be found in the literature.

Meyer et al.[9] reported that the scapula was in a position of retraction, external rotation (ER), posterior tilt, and upward rotation at the start of the acceleration phase. At the end of the deceleration phase, the scapula was in a position of protraction, internal rotation (IR), anterior tilt, and downward rotation. Kibler[7] advocates that protraction of the scapula may occur in a slightly superior or inferior direction, depending on the position of the humerus in each particular throwing motion. For example, a tennis serve is associated with protraction that occurs in an anterior and superior direction, whereas a baseball throw is associated with protraction that occurs in a more anterior direction. During the follow-through phase, the hand of an overhand pitcher should approach the contralateral ankle, whereas the hand of a three-quarter pitcher should approach the contralateral knee, and the hand of a sidearm pitcher should approach the contralateral hip.[10] If the follow-through of a submarine baseball pitcher involves an upwardly directed motion of the arm, scapular protraction may occur in a more anterior and inferior direction (i.e., acceleration of an anterior and inferior direction). The follow-through of a submarine pitcher may end with the release hand near the contralateral shoulder. A submarine pitcher's upwardly directed follow-through may provide some degree of gravity assisted deceleration of the throwing arm, whereas other throwing styles involve downwardly directed throwing arm motions.

Spine Involvement

The spine and core musculature also play an important role in the throwing motion. During the arm cocking phase, lordosis of the lumbar spine increases to preload the spine stabilizing musculature prior to an eccentric contraction.[8] Coordinated activation of the core musculature creates lateral flexion and rotation of the spine, which contributes to demands placed on the shoulder musculature.[8] The majority of this required range of motion occurs in the thoracic vertebrae.[20] Due to the vertical orientation of the facets in this region, lateral flexion of the spine is always coupled with axial rotation of the vertebrae.[20] Thus, any alteration in the normal curvature of the thoracic spine could limit rotation, thereby diminishing the transfer of energy through the kinetic chain.[8] Fatigue or weakness of the trunk musculature also may change the body's positioning and muscle activation patterns in a manner that causes the pitching arm to lag behind the torso during the acceleration phase.[8]

Lower ball velocity has been documented among submarine pitchers compared to that generated by overhand, three-quarter, and sidearm pitchers.[16] The combination of ipsilateral trunk tilt and a lower shoulder abduction angle may result in a unique scapulothoracic rhythm and core muscle activation pattern. Thus, knowledge obtained from studies involving overhand and three-quarter style pitchers cannot necessarily be applied to pitchers who utilize sidearm and submarine styles.[16]

Injuries

The types of injuries associated with each throwing style may vary. In the follow-through phase of each throwing style, the humerus is adducted horizontally and the scapula is protracted. The further the scapula moves into protraction, the more the coracoacromial arch moves anteriorly and inferiorly.[7] If horizontal adduction is performed in a slightly upward manner by a submarine pitcher, impingement of the supraspinatus tendon and the long head of the biceps tendon may occur.

During the arm acceleration phase, submarine and sidearm pitchers exhibit a greater amount of maximum horizontal adduction, compared to overhead and three-quarter style pitchers.[16] Interestingly, submarine pitchers also exhibit less maximum shoulder horizontal adduction torque than overhand and three-quarter style pitchers.[16] Similar values for maximum shoulder IR angular velocity have been reported for each throwing style, but greater "maximum shoulder anterior forces" are experienced by submarine pitchers.[16]

Pitching style also differentially affects the level of stress imposed on the elbow. Matsuo et al.[15] reported that two sidearm pitchers and one submarine pitcher exhibited greater maximum elbow medial force when compared to overhand/three-quarter style pitchers. Other investigators have reported that a lower shoulder abduction angle was associated with lower peak elbow varus torque in submarine pitchers (i.e., the force generated to stabilize the elbow against valgus motion).[10,15]

Maximum elbow extension angular velocity of submarine pitchers have been reported as lower than that of overhand, three-quarter, and sidearm style pitchers.[16] Although elbow flexion angles have not been documented among submarine pitchers, the upwardly directed follow-through may place elevated demand on the biceps brachii in a manner similar to that imposed by softball pitching.[21] Among the muscles responsible for control of elbow flexion, the biceps brachii is of particular importance, because it crosses both the elbow joint and the shoulder joint, and it attaches to the anterior and superior aspects of the glenoid labrum. Repetitive imposition of tensile stress on the biceps brachii muscle is believed to play a role in the development of labral pathology.[22] During the arm acceleration phase, the biceps brachii contributes to both shoulder and elbow stability.[23] During the deceleration and follow-through phases, the biceps brachii resists glenohumeral joint distraction and rapid elbow extension through an eccentric contraction.[10,13,22]

The pitcher whose shoulder is "at risk" for injury displays either of the following conditions or a combination of the two: (a) acquired glenohumeral internal rotation deficit (GIRD) or (b) scapular malposition, inferior medial border prominence, coracoid pain and malposition, and dyskinesis of scapular movement (SICK).[24] The SICK scapula characterizes a patient who has insufficient muscle activation patterns and altered scapular kinematics, which predisposes the throwing shoulder to injury.[24] A malpositioned and dyskinetic scapula is associated with altered kinematics at the glenohumeral and acromioclavicular joints.[24] Specifically, excessive scapular protraction can be problematic during the acceleration and follow-through phases of throwing, as a result of decreased acromion clearance and rotator cuff impingement.[7]

No literature could be found identifying the physical characteristics (i.e., posture, range of motion, strength) associated specifically with a particular style of throwing. We assume that scapular dyskinesis is a concern for any baseball pitcher, because it alters normal scapular biomechanics and contributes to the development of postero-superior labral injuries.[24] Tightness in the postero-inferior capsule has been identified as the "ultimate culprit" contributing to the development of a superior labrum anterior-posterior (SLAP) lesion in throwers.[24]

Increased shoulder ER is believed to develop secondary to anterior capsuloligamentous stretching, and decreased IR is believed to be the result of a posterior capsuloligamentous contracture.[25,26] A contracture of the posteroinferior shoulder capsule may be the result of a healing response to the high distractive loading associated with the follow-through phase of throwing.[5,25,27] Cadaveric research has demonstrated that a surgically induced posterior capsule contracture caused the humeral head to translate posteriorly and superiorly on the glenoid during shoulder abduction and ER.[27,28] Elevation of shear forces on the posterior labrum during the throwing motion may result in development of a SLAP tear.[25,29]

The potential for shoulder and elbow injuries during both the acceleration and deceleration phases of throwing is great.[1,22,25] Because the follow-through of the submarine style pitcher is upwardly directed, we postulate that a lack of sufficient upward scapular rotation could result in compression of the soft tissues within the subacromial space. The glenohumeral joint distraction force associated with the deceleration phase may contribute to the development of SLAP tears, due to eccentric contraction of the long tendon of the biceps.[30,31] We postulate that the glenohumeral distraction force may be greater for submarine style pitchers due to the assistance of gravity during the acceleration phase.

Summary

Biomechanical differences exist between different baseball pitching styles. Further research is needed to clarify the effects of lateral trunk tilt and shoulder abduction on the amount of stress placed on the throwing arm. Future research should also investigate variations in pelvic orientation and its possible effect on muscle activation patterns in the pelvic, lumbar, and thoracic regions. Part 2 will present information relating to the treatment and rehabilitation of baseball pitchers who use unconventional throwing styles. ▮

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