Throwing-arm injuries are frequently observed in baseball pitchers of all levels.1,2 The upper extremity is vulnerable to injury during throwing because of the repetitious nature of the motion, the extremes in range of motion, and the high angular velocities and joint loads generated at the shoulder and elbow. In 1986 Feltner and Dapena3 carried out a landmark high-speed, three-dimensional analysis of baseball pitching. Since then, the biomechanics of baseball pitching have been well documented in the literature. Following is a summary of what we know about baseball pitching from research and suggestions for applying this scientific knowledge.

In order to understand human motion, biomechanists first break down movements into phases. In baseball pitching, three temporal phases have been defined: (1) the cocking phase, occurring from stride-foot contact (SFC) to the instant of maximum shoulder external rotation (MER); (2) the acceleration phase, from MER to the instant of ball release; and (3) the follow-through phase, occurring after release. The motion that occurs from SFC to release is often defined as the delivery phase.

The average time from SFC until ball release is less than one quarter of a second (0.155–0.180 s) at all levels of pitching.3,4 Thus, baseball pitching requires high speeds of movement. During the acceleration phase, elbow-extension speeds as high as 3,000°/s have been observed, and shoulder internal-rotation angular velocities in excess of 8,000°/s have been reported.4,7 Coupled with these high speeds of movement with the extreme ranges of motion (160°–185° of shoulder external rotation at MER) incurred by the upper extremity during pitching and you have a recipe for injury. The forces and torques responsible for producing the high speeds of movement and excessive ranges of motion at the shoulder and elbow place tremendous stress on the soft tissues of the upper extremity.

In all throwing motions, a distraction force occurs at the shoulder joint as the energy in the throwing arm is dissipated quickly after the explosive instant of ball release.3-5,8 This force acts along the upper arm, tending to pull the arm away from the glenohumeral joint. Shoulder distraction has been implicated in injuries to the rotator cuff and glenoid labrum.5,9,10 At the professional level, the relationship between this destructive force and pitching mechanics has been explained.4 It was discovered that elbow angle at SFC, MER, elbow angle at ball release, peak shoulder external-rotation torque, and peak shoulder abduction torque combine to explain 72% of the variance in shoulder distraction. Thus, it appears that the magnitude of shoulder distraction can be decreased by increased elbow extension at SFC, decreased shoulder external rotation, increased elbow extension at MER, decreased external-rotation torque, and decreased abduction torque.

Injuries to the ulnar collateral ligament have been associated with the valgus load placed on the elbow at MER (the end of the cocking phase). At the professional level, four parameters of pitching mechanics combine to explain 97% of the variance in elbow valgus torque.7 The magnitude of elbow valgus stress can be decreased by decreased shoulder abduction at SFC, decreased horizontal-adduction angular velocity, increased elbow flexion at peak valgus torque, and increased external-rotation torque.

Although most of the baseball studies have focused on injury mechanism and prevention, biomechanical analysis can also be used to improve our athletes’ performance. In terms of performance, ball speed appears to be influenced by pitching mechanics. When we use statistics to explain the mechanical differences between low-velocity and high-velocity fastballs, five parameters of pitching mechanics are much different between the two groups. Pitchers who throw with higher ball speeds have longer strides, less horizontal abduction of the shoulder...
at SFC, more shoulder external rotation at the end of the cocking phase, higher internal-rotation angular velocity, and more elbow extension at release. So, if we combine what we know about the biomechanics of baseball pitching into a pitching checklist, it looks like Table 1.

Use side-view, front-view, and back-view videotape of the pitcher in order to be able to play back the pitch many times. Remember that the delivery phase lasts less than one quarter of a second, so it is almost impossible to break down the mechanics of a pitch with the naked eye in real time. Also, don’t focus on one individual part of a pitcher’s mechanics. It is the optimal combination of the checklist items that can improve performance and reduce the chance of injury. Good luck, and have fun putting science into practice!

**References**


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