Curveballs in Youth Pitchers: A Review of the Current Literature

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Abstract

As the number of young people playing baseball has increased, so have the number of injuries. Throwing arm shoulder and elbow injuries are most common, and lead to both short and long-term consequences. Recent efforts have been made to identify risk factors for injury with corresponding regulations created to protect youth pitchers. Unlike rules enforcing pitch counts, prohibitions against curveballs are based on minimal objective evidence.

Keywords

curveball; shoulder; elbow; Little League; youth; throwing; pitcher

Abbreviations

OCD = osteochondritis dissecans
UCL = ulnar collateral ligament

Background

The number of youth athletes participating in baseball has continued to increase over the years. Little League Baseball alone is comprised of almost 200,000 teams.[1] While this interest should be viewed positively, it has brought about a concomitant rise in injuries of the throwing arm. In two prospective cohort studies by Lyman, et al, about half of all participants developed shoulder or elbow pain at some point during the study period, with pain present in 15% of all pitching appearances.[2,3] The problem is exacerbated by year-round play, participation in multiple leagues, and one-sport specialization with an increase in training intensity.[2,4,5]

Throwing arm pain can hold significant consequences for youth athletes. A survey of 203 baseball players, ages 8-18 years-old, revealed that the majority experienced arm pain or fatigue throughout the season. 74% experienced arm pain with throwing, 80% had arm pain the day after throwing, and 83% had arm fatigue during a game or practice at some point in the season. This had a notable psychosocial impact on these young athletes, with 55% experiencing less fun while playing, 31% feeling that their parents/coaches were frustrated with their play, and 46% feeling pressured to play despite having pain.[6] Left unchecked, these problems can progress. Shoulder/elbow injuries necessitating surgery or retirement from baseball were noted to occur with an incidence of 5% in a study of 481 youth pitchers followed for up to 10 years.[7] Given the rising occurrence of throwing arm pain and injuries in young baseball players, there has been an attempt to identify modifiable risk factors to improve prevention.

Overall volume of pitches thrown has consistently been shown to be a risk factor for the development of arm pain and injury. In a systematic review by Grantham, et al, greater number of pitches was identified as a significant risk factor in all included epidemiological studies.[8] Pitching more than 100 innings in a year carried 3.5 times higher odds of serious arm injury in comparison to throwing less than that mark in the Fleisig, et al, 10 year follow-up study.[7] Other consistent risk factors include: pitching with a higher velocity, bigger (taller, heavier) athletes, and pitching while fatigued.[2,5] These findings have led to the institution of pitch count limitations and other recommendations by organizations such as Little League Baseball and USA Baseball. A collaborative study between the University of North Carolina, Little League Baseball and USA Baseball supports the benefit of pitch count limitations in the prevention of injury, however, their study design and data is not available for review. A prospective study performed in Japan demonstrated the protective effects of pitch count limitations. The study of 149 pitchers under the age of 12 showed that players who did not follow pitch count limits had higher odds, ranging from 2.04-2.47, of developing elbow pain during a single season.[9]

Pitch type, specifically curveballs, remains one of the most controversial potential risk factors for arm pain/injury. The idea that throwing curveballs can be detrimental to a young pitcher's arm has long been accepted by the baseball and sports medicine communities. However, both the American Sports Medicine Institute and Pitch Smart, a collaboration between USA Baseball and MLB, acknowledge that existing research does not support this widely held belief.[10,11] Despite the lack of evidence, both organizations continue to recommend that pitchers refrain from learning to throw curveballs until they reach maturity. This itself is an arbitrary threshold that has been described as anywhere from 13-14 years old to when boys start shaving.

Anatomy and Biomechanics of the Throwing Motion

Throwing is a motion that takes the shoulder from extreme external rotation and abduction to internal rotation and adduction. Variation exists regarding the exact phases of throwing, but in general, it is composed of wind-up, stride, arm cocking, acceleration, deceleration, and follow-through.

With respect to arm pathology, the focus has mainly been on the late cocking/early acceleration phases of throwing. At this point in the throwing motion, the shoulder is in its maximum position of external rotation and abduction, with the elbow in flexion and pronation. The supraspinatus and posterior rotator cuff muscles are at peak activation. A significant anteriorly directed force is concentrated at the shoulder. Acceleration results in rapid shoulder internal rotation and adduction coupled with elbow extension (Figure 1). The subscapularis exhibits high activity and creates a strong internal rotation torque.[12-15] In youth, the combination of an open proximal humeral physis with increased laxity of the joint capsule and ligaments leads to the development of unique changes at the shoulder versus adults.[12,16] Arm acceleration also places large valgus stresses on the medial elbow. The anterior bundle of the UCL is the primary static stabilizer of valgus stress at the elbow. The flexor-pronator mass also provides dynamic valgus stability.[12] Varus torque at the elbow acts to oppose valgus opening, placing tension on the medial structures and compression at the radiocapitellar and posteromedial ulnohumeral articulations.[12-18]

Injuries to the Shoulder and Elbow in Overhead Throwers

The majority of shoulder and elbow injuries sustained by young overhead athletes result from chronic overuse. The aptly named Little League Shoulder represents a proximal humeral epiphysiolysis often brought on by a recent increase in throwing regimen. Other shoulder pathology includes rotator cuff tendinopathies, instability, and impingement of the posterior rotator cuff due to maximum external rotation coupled with an internal rotation torque.[12,13,16,18] At the elbow, UCL injuries have garnered much attention within the baseball community despite its relatively uncommon occurrence in young athletes. Other conditions affecting the elbow include osteochondritis dissecans (OCD) of the lateral compartment, posteromedial compression secondary to valgus extension overload, and Little League Elbow, an umbrella term for medial epicondyle apophysitis, avulsions and accelerated growth with delayed physeal closure.[12,13]

Although nonoperative management with rest, followed by a gradual return to throwing with modification of mechanics, stretching and strengthening often results in good outcomes, the potential for long-term complications exists. The proximal humeral physis is responsible for 80% of longitudinal growth in the upper extremity.[12] Increased stresses may result in premature closure of the physis with subsequent limb length discrepancy or angular deformity, as well as physeal fractures.[4] Injury progression at the elbow may necessitate surgical intervention, especially as athletes get older. In addition to the physical consequences, the persistence/recurrence of symptoms may limit the ability of young athletes to compete in overhead sports, or even cause them to stop playing altogether. Heyworth, et al, noted that about 1/4th of youth baseball players in their study were instructed to change positions as a part of the treatment of Little League Shoulder.[4] An in-depth review of the evaluation and management of these injuries is beyond the scope of this article.

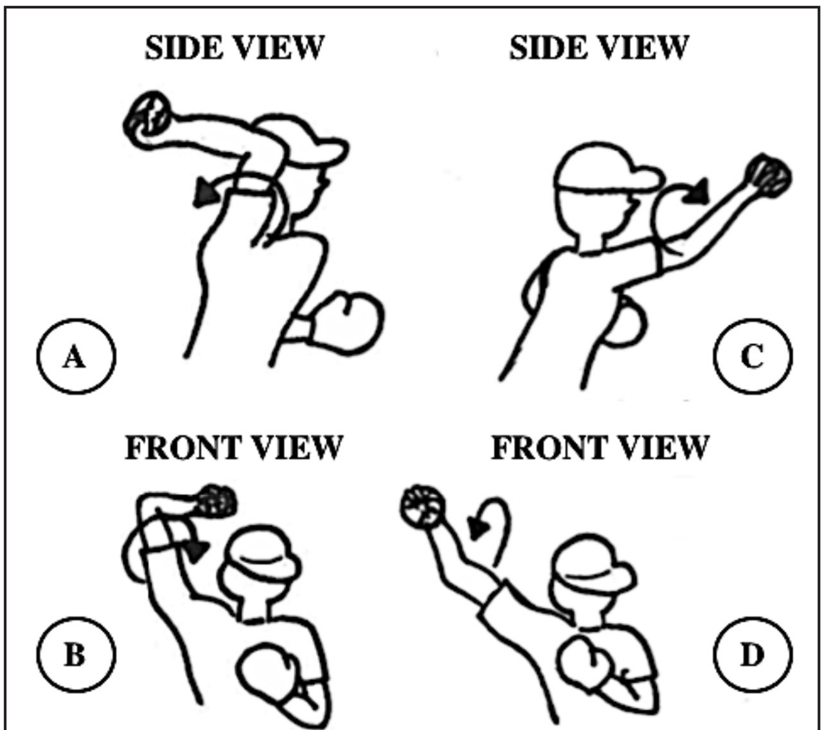

Figure 1. A and B, Side and Front Views Demonstrating Extreme External Rotation Seen During the Late Cocking Phase. C and D, Side and Front Views Demonstrating Sudden Shoulder Internal Rotation and Elbow Extension During Arm Acceleration.

Biomechanical Comparisons Between Fastballs and Curveballs

Understanding the unique stresses that each phase of throwing places on the shoulder and elbow is critical to evaluating the relative effects of throwing the curveball.

The fastball is thrown with consistently higher velocities than the curveball.[5,18-21] Therefore, a proportionally smaller amount of force is required to generate the lower velocities seen when throwing curveballs. This would place less stress on the shoulder and elbow, and in theory, be less harmful to the throwing arm. Several published studies substantiate this line of thinking. Grantham, et al, reviewed 10 biomechanical studies and found no differences in proximal force or torque at the shoulder or elbow when comparing curveballs to fastballs.[8] In one of the few biomechanical studies involving youth pitchers, Dun, et al, utilized 3D motion analysis to measure kinetic, kinematic and temporal parameters for fastballs, curveballs, and change-ups. They found increased proximal forces at the shoulder and elbow, as well as increased varus torque at the elbow and internal rotation torque at the shoulder when throwing fastballs.[18]

Nissen, et al, collected kinematic data on 33 pitchers with an average age of 16.6 years-old. They found that, compared to other pitches, fastballs produced increased internal rotation velocity at the shoulder, increased varus moment and increased extension velocity at the elbow.[20] Findings also included an increase in radial-to-ulnar wrist deviation of 3 degrees for the curveball, however this has not been linked to any injury risk.

Curveballs are associated with greater forearm supination (Figure 2).[8,18,20] It has been proposed that this particular forearm positioning leads to more injuries at the elbow. However, in a cadaveric study assessing strain with valgus loading on the anterior and posterior bundles of the UCL, only minimal differences were found with changes in forearm rotation.[22] These findings contradict the assertion that the increased forearm supination seen with curveballs elevates the risk of UCL injury.

Biomechanical studies evaluating different pitch types have not demonstrated higher stresses on the throwing arm with curveballs. In fact, the majority of studies concluded that fastballs place the greatest amount of stress on a pitcher's arm. Indicating that the curveball is less harmful than the first pitched learned by all young throwers.

Epidemiological Studies

Although evidence has been mixed, observational studies to this point have largely been unable to find a significant increase in arm pain/injury associated with throwing curveballs. Grantham, et al, noted that in 3 out of 5 of the epidemiological studies included in their systematic review, no significant difference was found between curveballs and fastballs with regards to arm pain/injury.[8] To further demonstrate the lack of conclusive evidence against curveballs, consecutive studies by Lyman, et al, produced contradictory results. A prospective cohort of 298 pitchers between 9-12 years old were followed for two seasons with phone-administered questionnaires after each game. There was no significant difference in the odds of elbow or shoulder pain between pitchers who threw curveballs and those who did not.[2] In a subsequent study with similar methods, the same group evaluated a cohort of 476 pitchers of slightly older ages (range 9-14 years old, mean of 12 years old). Again, questionnaires were given following each game throughout a single

Figure 2. Forearm Supination Seen While Throwing a Curveball (Left-handed Thrower Pictured).

season. Pitchers who threw curveballs were found to carry an odds ratio of 1.52 (P=.04) versus non-curveball throwers for the development of shoulder pain. The same did not hold true for elbow pain.[3] These conflicting findings in two studies that used similar methods, in similar populations, illustrates the equivocal nature of the research against curveballs.

Olsen, et al, performed a case-control study involving a retrospective cohort of 95 pitchers ages 14-20 years old who had sustained a pitching related injury requiring shoulder or elbow surgery. This group was matched with 45 controls who had no history of shoulder or elbow pain that was either recurrent, lasted > 2 weeks, or caused them to miss game or practice time. Questionnaires evaluating various risk factors were completed. Results showed no difference between cases and controls in both the chronological age and years prior to puberty that pitchers first started throwing breaking pitches. There was also no difference between groups in the frequency of breaking pitches thrown over the past year.[5]

In a large study with extended follow-up, Fleisig, et al, issued annual surveys to 481 pitchers aged 9-14 years old (at study initiation) for up to 10 years or until they retired. Throwing a curveball prior to age 13 was not found to be a significant risk factor for the development of a serious arm injury, defined as one requiring shoulder/elbow surgery or leading to retirement from baseball.[7]

Yang, et al, observed an odds ratio of 1.66 for the occurrence of arm pain in pitchers who threw curveballs. This was seen in a cross-sectional survey evaluating the events of the previous 12 months in 754 pitchers ages 9-18 years old (mean age of 14). There was no significant association between throwing curveballs and complaints of arm fatigue or arm injury, defined as causing a player to miss a game or practice.[23]

Forty-eight percent of youth baseball players were found to have elbow MRI abnormalities in a prospective cohort of 26 participants followed over one season. 1/3rd of these players had new/worsened MRI findings at season's end. These findings were primarily at the medial aspect, and although over half of pitchers in the study threw curveballs or sliders, these pitches were not found to be associated with MRI abnormalities.[24]

Discussion

It is possible the lack of definitive evidence against curveball use in young pitchers is due to the lack of adequately powered studies. Fleisig, et al, who completed one of the largest studies to date, felt that even they may not have had sufficient power to detect a difference in arm injuries in early curveball throwers. 60% of participants in their study threw curveballs.[7]

Studies that have found an association between curveballs and arm pain/injury are typically confounded. Pitchers who learn to throw curveballs, especially at younger ages, tend to be more skilled. These pitchers are often bigger athletes, who throw faster. Furthermore, pitchers of this caliber throw more often, accruing large pitch volumes.[3,8,23] All of these factors are independently associated with an increased risk of arm pain/injury.

Restrictions against curveballs in youth baseball rest on a paucity of scientific evidence, supported primarily by expert opinion. Current evidence remains limited, especially given the observational nature of the available studies. Obviously, causation cannot be determined. Recall and selection bias remain an issue, although the studies by Lyman, et al, attempted to reduce this by administering questionnaires after each game.[2,3] Long-term data is limited, as most studies (with the exception of Fleisig, et al, who had up to 10-year follow-up) only collected data for 1-2 seasons.

Ideally, a study comparing pre-pubertal pitchers from leagues that allow curveballs versus leagues that do not would offer the best opportunity to isolate the effects of breaking pitches. This would theoretically allow for matching by age, height/weight, as well as other typical confounding variables. Long-term follow-up would be desired to determine any lasting negative outcomes from early curveball use.

Conclusion

Longstanding taboos against teaching curveballs to pitchers before puberty remains ingrained in youth baseball. This is despite a deficiency of convincing evidence in both biomechanical and epidemiological research showing increased harm. Larger studies with improved control of confounding variables may eventually reveal curveballs to be the dangerous pitch that many believe it to be. However, at present, the sports medicine community has no good evidence to recommend against its use.

Conflicts of Interest

None of the authors identify a conflict of interest.

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