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Rehabilitation Programs and Prevention Strategies in Adolescent Throwing Athletes

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Abstract

A specific and early diagnosis must be made in the injured skeletally immature throwing athlete. A well-outlined program of rest, rehabilitation, and proper throwing techniques should be implemented and continued. Overuse injuries are preventable when biomechanics are sound and pitch counts are done with the limits enforced. Guidelines for inning limits, number of pitches, rest intervals, and throwing programs should be followed for adolescent pitchers because adolescents differ from adults. Information is included for specifications of the ball and helmet, as well as chest protective equipment. The goal should be for the Little League players to have fun and be injury free as they are competing, which gives them the best experience and allows continuation of athletic activities for a lifetime.

Injuries to the upper extremity of children and adolescents are often caused by either macrotrauma or repetitive microtrauma. Macrotrauma or accidents may not be preventable. However, overuse injuries to the upper extremity of children may be preventable. Prevention comes with increasing awareness and knowledge of the pathophysiology and etiology injuries.

The majority of adolescent upper extremity overuse injuries occur in baseball. Prevention strategies should be implemented through education of coaches, players, and parents. In the growing child, most of these injuries represent the result of repetitive stress to the open growth plate. In most instances, any pathologic condition is preceded by pain. It is important to educate the parents, coaches and players that pain is abnormal and should not be ignored. Parents and coaches should avoid the use of pain medications for the sole purpose of enabling the player to throw or participate without a thorough evaluation.

Harbingers of injury include pain at rest, pain at night, increasing pain despite rest, and pain that is not relieved by applying ice or with other modalities. A physical examination and radiographs of both extremities should be obtained when any of the preceding conditions are present. These recommendations are made for any sport, particularly those requiring multiple repetitious motions during practice, such as gymnastics, baseball, softball, or tennis.

Throwing Recommendations for Little League Baseball Players

Prevention strategies must be a high consideration in Little League baseball players. A program of prevention and emergency management of Little League baseball and softball injuries developed in association with the American Orthopaedic Society for Sports Medicine was instituted in 1989.[1] This program is presented by health care professionals to coaches and parents before the playing season begins.

In the throwing athlete, recommendations regarding the number of innings pitched per week have helped decrease the incidence of these injuries[2] and are outlined in Table 1. Unfortunately, enforcing the number of innings pitched may prove difficult for children playing in more than one league or who may practice daily with parents or friends. As a result, a more effective approach may be to limit the number of pitches thrown during a given week. Although there is no scientific support for absolute numbers of pitches thrown, at the professional level the general belief is that 100 to

Table 1
Inning Limits Currently Used In Youth Baseball

	Maximum Innings/Game				Maximum Innings/Wk			
Age (years)	Pony League	Little League	Dixie Youth	American Legion	Pony League	Little League	Dixie Youth	American Legion
8 to 10	3	6	6	NA	6	6	6	NA
11 to 12	7	Unlimited	6	NA	10	6	6	NA
13 to 14	7	Unlimited	9	NA	10	9	10	NA
15 to 16	7	Unlimited	10	12	10	9	14	12
17 to 18	9	Unlimited	NA	12	Unlimited	9	NA	12

NA = not applicable (Reproduced with permission from Andrews JR, Fleisig G: Medical and Safety Advisory Committee: Special Report: How many pitches should I allow my child to throw? *USA Baseball News* 1996, April.)

Table 2
Maximum Number of Pitches Recommended (Mean ± SD)

Age (years)	Maximum Pitches/Game	Maximum Games/Wk
8 to 10	52 ± 15	2 ± 0.6
11 to 12	68 ± 18	2 ± 0.5
13 to 14	76 ± 16	2 ± 0.4
15 to 16	91 ± 16	2 ± 0.4
17 to 18	106 ± 16	2 ± 0.6

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Table 3
Minimum Number of Pitches Thrown That Should Require Specific Rest (Mean ± SD)

Age (years)	1-Day Rest	2-Day Rest	3-Day Rest	4-Day Rest
8 to 10	21 ± 18	34 ± 16	43 ± 16	51 ± 19
11 to 12	27 ± 20	35 ± 20	55 ± 23	58 ± 18
13 to 14	30 ± 22	46 ± 21	56 ± 20	70 ± 20
15 to 16	25 ± 20	38 ± 21	62 ± 23	77 ± 20
17 to 18	27 ± 22	45 ± 25	62 ± 21	69 ± 22

(Reproduced with permission from Andrews JR, Fleisig G: Medical and Safety Advisory Committee: Special Report: How many pitches should I allow my child to throw? *USA Baseball News* 1996, April.)

Table 4
Age (In Years) Recommended for Learning Various Pitches

Fastball	8 ± 2
Change-up	10 ± 3
Curveball	14 ± 2
Screwball	17 ± 2
Slider	16 ± 2
Forkball	16 ± 2
Knuckleball	15 ± 3

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120 pitches thrown in competition during a 5-day period should be the maximum allowed to any pitcher.

In a survey of baseball experts (orthopaedists, surgeons, and coaches) regarding pitching limits, 28 of 85 individuals responded; results are summarized in Table 2.[3] The consensus was that the number of pitches thrown was much more important than the number of innings pitched when determining rest requirements. For a given age group, the minimum number of pitches thrown that should require a specific rest period of 1, 2, 3, or 4 days was recommended (Table 3). Although it is important to realize that these guidelines are the opinion of a small but expert group and not based on scientific study, they serve as a starting point for counseling families and players.

In a study of the responses to a prospective questionnaire collected preseason and postseason from 467 young baseball pitchers, the association between pitch counts, types, and mechanics and shoulder and elbow pain have been reported.[4] Half of the subjects age 9 to 14 years experienced shoulder or elbow pain during the season. The slider-type pitch was most commonly associated with shoulder and elbow pain. The greater the number of pitches thrown, the higher the rate of joint pain. Recommendations from this study were to limit the number of pitches to 75 per game and 600 per season, limit the number of batters faced during the game to 15 and during the season to 120, and have young pitchers throw fastballs and change-ups exclusively.

A survey by the Medical and Safety Advisory Committee for USA Baseball recommended the appropriate ages for children to learn various pitches (Table 4). For example, the recommended age for an athlete to pitch a fastball is 8 years, change-up 10 years, and curveball is 14 years. Other pitches should not be introduced until high school.[3]

One difficulty in making recommendations about pitch counts and the number of innings thrown is that it is not

known who is most at risk for developing pitching-related shoulder and elbow problems. A recent study of 298 youth baseball pitchers (9- to 12-year-olds) over two seasons found the frequency of elbow pain was 26% and of shoulder pain, 32%. Risk factors for arm pain were throwing more than 75 pitches in a game, more than 600 pitches during a season, and arm fatigue during a game.[5] It is unknown how many of these individuals needed treatment, and it is unlikely that many of them experienced long-term sequelae. There is little doubt that the symptomatic player should be pitching less and not more.

It has been observed that the children who develop overuse injuries to the shoulder and elbow are typically the best players, particularly the pitchers. Biomechanical data support this contention based on several studies.[6-8] These studies were begun with the belief that the player at risk was probably the child with poor mechanics, but results from these studies suggest that the player at greatest risk for overuse is the one who everyone wants on the team. This information has implications not only for children and adolescents but also for players of any age with closed growth plates.

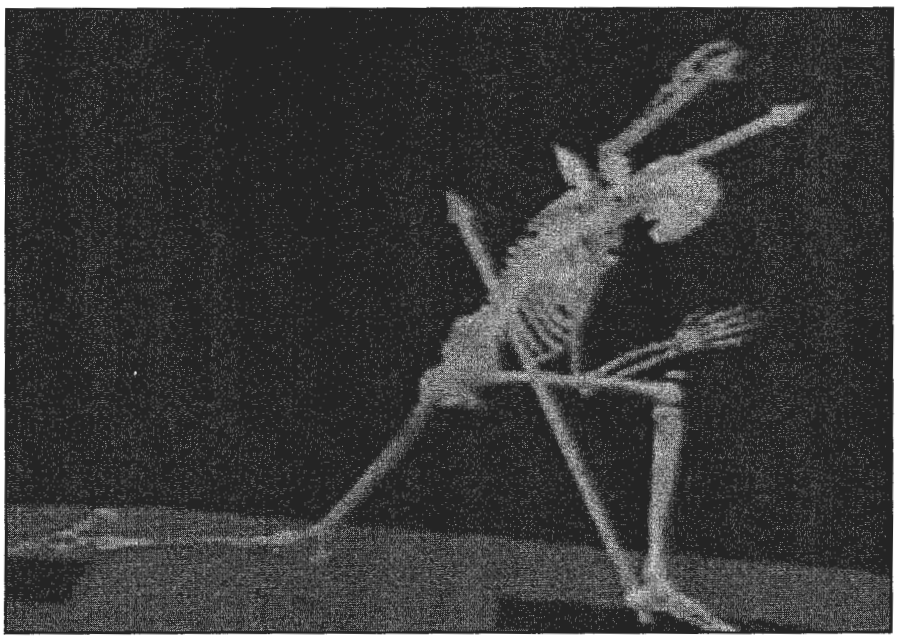

Fig. 1 Computerized model of a collegiate baseball player demonstrating the forces and moment on the shoulder and elbow at the time of ball release. The size of the arrow is proportional to the size of the forces seen. The large arrows demonstrate a large distraction force axially along the arm and also a large anteriorly directed force at the shoulder joint. There is a large ground reaction force at the lead leg demonstrated by the large arrow. This figure demonstrates the need for good lower extremity and trunk strength to resist these large forces.

Biomechanics and Kinematics of Throwing

Motion analysis of the act of throwing has been frequently reported.[8-12] Reflective markers are placed on a variety of locations on the extremities and trunk, and the pitching motion of the athlete is recorded with high-speed cameras. The motion can then be analyzed using computers. The analysis consists of the study of the motion (kinematics) and/or the forces generated at different joints or segments of the body (kinetics).

An understanding of the six phases of throwing—windup, early cocking, late cocking, acceleration, deceleration, and follow-through allows correlation of biomechanics to injury patterns. At the elbow, the compressive forces on the radiocapitellar compartment and tensile forces over the medial humeral epicondyle can result in injuries.

The skeletally immature thrower commonly has forces transmitted to the proximal humeral physes because of less muscle development of the shoulder. With shoulder pain, the more likely involved structures are the capsuloligamentous complex and/or rotator cuff.

The first studies done on the throwing motion established that the forces on the adult shoulder and elbow are quite high during pitching.[10,13,14] The highest strain on the elbow is just after maximum cocking when the arm is beginning to come forward. This valgus stress (or varus torque) approaches 65 Nm, with the ulnar collateral ligament absorbing about half of the valgus load. The highest loads in the shoulder are seen at the time of ball release, when a distraction force is applied to the arm as it is essentially pulled away from the body[15] (Fig. 1). This distraction force can be as high as 1,090 Nm and is resisted by the ligaments and muscle. There are also high anterior shear forces at the shoulder at the time of cocking that may contribute to repetitive shoulder injuries. These forces (380 Nm) are approximately 35% of the distraction force at ball release.

Studies have shown that the kinematics of how children throw are surprisingly similar to those of adult throwers.[6-8] In a study comparing 55 Little League pitchers (age 9 to 12 years), 55 adolescent pitchers (age 13 to 16 years), and 39 college and professional pitchers, there was no significant difference among the groups for factors such as pitch duration (time spent in the throwing motion), stride length, knee flexion angles, and arm abduction angles.[6] The Little League pitchers did have a more closed foot angle, more open stride direction, slower trunk angular velocities, and slower hip

Table 5
Guidelines for a Throwing Program

If sore when throwing, take the day off and drop down one level the following day.
If sore after throwing and soreness does not improve after warm-up, take that day off and drop down one level the following day.
If not sore while throwing but sore the following day and soreness disappears after warm-up, continue with the program at that level.
Do not advance more than two levels per week.
Shoulder strengthening exercises should follow throwing program.

(Reproduced with permission from Axe MJ, Snyder-Mackler L, Konin JG, Strube MJ: Development of a distance-based interval throwing program for Little League-aged athletes. *Am J Sports Med* 1996;24:594-602.)

rotation velocities. They were found to have greater horizontal adduction in the cocking phase, slower shoulder external rotation velocities, and less arm abduction during acceleration and reached maximum shoulder external rotation earlier. The arm motion is not synchronized with the body, and the player throws as if he/she is aiming a dart. It was concluded that these players might be at increased risk of injury.

However, a subsequent analysis of the kinetics of these players led to an opposite conclusion; the players with poor form actually generated lower forces and torques than the better players who generated more ball velocity.[7] Similar differences between Little League pitchers and those participating in other levels of baseball were found by Fleisig and associates.[8] They found that joint forces and torques increased with level of play but that the exact relationship to injury remained unclear.

A study by Escamilla and associates[16] evaluated the forces on the shoulder and elbow by the type of pitch. Using similar technology they studied four pitches: the fastball, slider, curveball, and change-up. The fastball and slider produced the highest forces on the shoulder and elbow. The only exception was the varus torque (valgus stress) on the elbow, which was highest with the curveball, but the difference was not statistically significant. Their study would suggest that the curveball may have some influence upon the elbow forces but not the shoulder. They also cautioned that these results could not be extrapolated to children or adolescents.

It has been observed that children who throw the most are the best pitchers and frequently are the ones who pitch fastballs and curveballs. Because they are the better players, they may play on more teams and pitch more often. These observations require further study, but these studies reinforce the notion that the best way to decrease the forces on the developing arm is to limit the volume of pitching.

Treatment Plans/Rehabilitation Programs

In general, the rehabilitation of upper extremity injuries in children and adolescents is similar to that for adults.[17] For the adolescent patient who develops shoulder pain and has a closed physis, a balanced therapy program designed to strengthen the rotator cuff and scapular stabilizers has been recommended.[17,18] These exercises should be done in a pain-free range and should focus on providing a stable scapular platform for the arm. Because a significant amount of the force applied to the upper extremity is generated in the lower extremities, an evaluation of lower extremity strength and stability may be indicated.[18] This evaluation can be done by the physician or therapists with a special interest in throwing athletes.

For proximal humeral stress fracture (epiphysitis), the patients typically can be involved in any sport activity or any exercise that does not involve throwing. These patients can lift weights, bat, swim, ride bicycles, and remain active with little concern for damage to the growth plate. Rotator cuff exercises are of little benefit in this age group but might be considered in some cases where the patient would like more sport-specific exercises.

A distance-based interval throwing program for Little League-aged athletes has been developed for patients age 9 to 12 years old.[19] The interval throwing program was designed to be functional, practical, progressive, and safe. The guidelines for progression in the throwing program are summarized in Table 5. The program lasts 45 minutes and consists of long and short distances, with the athlete completing 70 throws or the equivalent of three innings. This interval throwing program based on data collected should encourage more studies in this area. The more mature pitcher who can throw a fastball at an early age is more likely to injure an elbow or shoulder than the less mature underdeveloped pitcher with poor biomechanics.

In children with elbow pain related to throwing, the most important rehabilitation strategy is rest. In patients with no radiographic or MRI changes, strengthening exercises may be beneficial, but the origin of the pain must be established. In patients who had osteochondritis or valgus overload syndrome, strict rest from compressive forces is recommended. Any activity that places compressive loads on the radiocapitellar joint should be eliminated until there are signs that the lesion is resolving. Range-of-motion exercises are recommended during the resolving phase, but strengthening or weight-bearing exercises should be avoided. Although some authors have suggested that brace treatment may allow children with these lesions to participate, there is no scientific evidence to support taking a

chance that the increased activity will not further damage the elbow. General aerobic fitness should be encouraged in the injured athlete.

General Protection: Gear and Equipment

Rule changes have been implemented to reduce or prevent injuries. These rules limit innings pitched and standardize base distances and the circumference and weight of the ball. Acceptance and enforcement of these standards by coaches, officials, and health care professionals will reduce injury rates. Protective headgear is mandatory on deck, at bat, running bases, and in the coaches' box during practice and games.

Balls and helmets must meet National Operating Committee on Standards for Athletic Equipment specifications and bear its stamp. These standards specify that the ball shall weigh not less than 5 oz or more than 5¼ oz and shall measure not less than 9 inches nor more than 9¼ inches in circumference in Pony League (age 13 to 14 years), Little League (age 9 to 12 years), and T-Ball (age 5 to 8 years).[2] The hardness of the baseball influences the impact transmitted to body parts. Baseballs that are 20% of major league ball hardness have been recommended for youth baseball. The softer balls reduce injury rate and severity of injury to the unprotected eye.[20] The American Society for Testing and Materials (ASTM) has a safety committee that recommends the standards for sports eye protectors (ASTM F910).[21]

Commotio cordis is sudden death due to chest wall impact.[22] If the ball strikes the chest at the critical time in cardiac cycle, asystole or arrhythmia can occur. The athlete who is likely to suffer commotio cordis has no history of heart problems and is struck by a ball thrown, pitched, or hit at low velocity. The cause of death is ventricular fibrillation. Chest protectors and softer balls are suggested. In an experimental model, ventricular fibrillation was induced when a blow to the chest occurred during upstroke of the T wave.[23] The incidence of ventricular fibrillation was decreased when safety baseballs were used. Emergency cardiopulmonary resuscitation (CPR) and/or an external automatic defibrillator by trained personnel may reduce the risk of death from commotio cordis.[24] Survival is rare and is possible only after rapid CPR is instituted.[25,26]

Summary

Further study on overuse injuries in adolescent throwing athletes are needed to answer the following questions: Is the incidence of osteochondritis dissecans of the elbow truly reduced? Do these players remain active in athletics throughout high school and beyond? Health care providers should continue to educate coaches on acute care issues, but the more important issue for coaches is how to help their players remain healthy. The influence of coaches on their young athlete's behavior patterns, self-esteem, confidence, manners, and reactions to what happens during practice and games cannot be overemphasized.

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