

Data-Based Interval Throwing Programs for Collegiate Softball Players

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Objective: To construct interval throwing programs followed by a simulated game for collegiate softball players at all positions. The programs are intended to be used as functional progressions within a comprehensive rehabilitation program for an injured athlete or to augment off-season conditioning workouts.

Design and Setting: We collected data over a single season of National Collegiate Athletic Association softball at the University of Delaware and Goldey Beacom College. We observed 220 half-innings of play and 2785 pitches during data collection.

Subjects: The subjects were collegiate-level softball players at all positions of play.

Measurements: We recorded the number of pitches for pitchers. For catchers, we recorded the number of sprints to back up a play, time in the squat stance, throws back to the

pitcher, and the perceived effort and distance of all other throws. We also collected the perceived effort and distance of all throws for infielders and outfielders.

Results: Pitchers threw an average of 89.61 pitches per game; catchers were in the squat stance 14.13 minutes per game; infielders threw the ball between 4.28 times per game and 6.30 times per game; and outfielders threw distances of up to 175 feet.

Conclusions: We devised the interval throwing programs from the data collected, field dimensions, the types of injuries found to occur in softball, and a general understanding of tissue healing. We designed programs that allow a safe and efficient progressive return to sport.

Key Words: simulated game, college softball conditioning, rehabilitation for softball, softball injuries

College softball and women's collegiate sport participation have seen incredible growth over the last 2 decades. The number of female National Collegiate Athletic Association (NCAA) athletes has more than doubled over this time period. During the 1998-1999 academic year, 14 943 of the 145 832 NCAA female athletes were softball players.^{1,2} Serious injuries in collegiate softball rarely happen, but less serious injuries, which may cause time loss from sport, occur frequently. From NCAA Injury Surveillance System (ISS) data over the last 13 years of softball, the average practice injury rate was 3.3 per 1000 athlete-exposures, and the average game injury rate was 5.0 per 1000 athlete-exposures.³ An athlete-exposure is defined as one athlete participating in one practice or game in which she is exposed to the possibility of athletic injury. Of the injuries sustained, the most common type of injury was sprains (25%), followed by contusions (24%) and strains (13%). In addition, during the 1999 season, 28% of injuries resulted in 7 or more days of time loss.³ Powell and Barber-Foss⁴ studied sex-related injury patterns in high school sports. They found that 22.9% of softball injuries were classified as forearm, wrist, or hand injuries, while 16.3% of softball injuries were to the upper arm or shoulder. They also noted that throwing accounted for 28.1% of practice injuries and 12.2% of game injuries.⁴

Very little research has been conducted differentiating fast-pitch softball players from baseball players. The available literature groups the athletes together as throwing athletes and

does not account for differences in the games. In contrast to NCAA baseball, NCAA softball contests are played on a smaller field, with a larger ball, in fewer innings of play.^{5,6} Softball players are injured more frequently than baseball players. Powell and Barber-Foss⁴ noted differences in injuries over the course of a season between baseball and softball players at the high school level. Softball players had a 27% higher injury rate than baseball players.⁴

While the differences between baseball and softball encompass players of all positions, the largest difference is in pitching style. Fast-pitch softball players use a windmill style, which is accomplished with the humerus remaining in the plane of the body. Baseball pitchers throw overhead from an abducted position.^{7,8} The power in the windmill pitch comes from adduction of the arm across the body. Baseball pitchers generate power during internal rotation of the humerus. While the power is attained through different motions, the same muscle, the pectoralis major, is responsible for most of the power in both pitches.⁷⁻⁹ The eccentric follow-through phase of the baseball pitch demonstrates high activity of the external rotators to slow the arm down.¹⁰ In contrast, the role of the posterior rotator cuff (external rotators) in the windmill pitch is lessened as the forearm strikes the lateral thigh at ball release, dissipating the energy.^{7,8,11} Most high-level baseball pitchers throw a high percentage of fastballs. This is not the case in softball. Pitching at

the collegiate level of softball usually involves the mastery of 5 different pitches (fastball, rise, curve, drop, change-up). The fastball is not as effective as the other pitches and, therefore, is not thrown as often as it is in baseball.¹²

A common assumption prevalent in softball is that the pitching style used by softball pitchers does not place significant stress on the athlete. The result is pitchers throwing too many pitches without the benefit of rest. They may pitch in consecutive games and batting practice.^{13,14} Loosli et al¹⁵ observed injury patterns in collegiate softball pitchers from 8 college teams ranked in the top 15 teams in the country in 1989. Nearly half (11 of 24, or 45%) of the players contracted a time-loss injury (modified or missed activity) at some point during the season. Of the 11 time-loss injuries, 9 involved the upper extremity. Also, the pitchers with grade I and II injuries (had pain or complaints but continued to play) averaged more innings per season than those who were uninjured.¹⁵

The conventional exercises for shoulder rehabilitation focus on strengthening and endurance training of the dynamic stabilizers of the shoulder in order to decrease the stress placed on the passive structures of the joint. Treatment programs include capsular stretching (especially the posterior capsule in overhand throwers), rotator cuff strengthening, multidirectional strengthening, dynamic stabilization techniques, plyometrics, open and closed kinetic chain exercises, and concentric and eccentric exercises.^{13,16–26} While these traditional therapies are necessary, the only way to imitate the forces and torques placed on the joints of the upper extremity and trunk during softball is by pitching and throwing.²¹

Conventional rehabilitation exercises used for the injured throwing athlete should include a structured throwing program. The purpose of an interval throwing program (ITP) is to return an injured player to preinjury status through a step-wise functional progression without overstressing the healing tissues. Throwing too much too soon goes against this principle and may cause an athlete to heal more slowly.²¹ Few examples of ITPs exist in the literature.^{13,16,21,27–29} Most are based merely on how quickly the authors believe an athlete should return to play. Axe et al^{21,29} have developed 2 ITPs based on data that consider the stresses placed on the athlete during a game situation as well as the type of injury a player has incurred. One of these programs is devised for Little League (9- to 12-year-old) baseball pitchers, and the other was designed for baseball pitchers at all other levels (Senior Little League to professional).^{21,29} We found no published data-based ITPs for fast-pitch softball players. In addition, we found no published data-based ITPs designed for position players other than the pitcher for baseball or softball at any level.

The culmination of an ITP is a simulated game. A true simulated game is derived from game-specific data of athletes at a particular level of competition (ie, college). The injured athlete must complete this simulated game before being cleared to return to competition. No descriptions of data-based simulated games have been published for softball players at any position. Coleman et al³⁰ reviewed data collected from 3 professional baseball seasons in order to determine an injured pitcher's readiness for return to play. They used a simulated game that included number of pitches per inning, innings pitched per game, time between innings, and preinjury pitch mix utilized by the player in question.³⁰ While the simulated game is excellent for testing a pitcher for game worthiness, it does not include a step-wise progression building toward the simulated game.²¹

The purpose of our study was to develop data-based ITPs followed by simulated games for collegiate fast-pitch softball players at all positions. These ITPs are based on the game data collected, rules of the game at the collegiate level, and the type of injury sustained.

METHODS

Data Acquisition

We collected pitching data for the pitcher's throwing program over 220 half-innings and 2785 pitches of NCAA softball during a single season. We recorded number of pitches per inning and per game. We used these data and NCAA softball rules (eg, innings per game, pitcher to home plate distance)⁵ to construct the pitcher's throwing program.

We collected catcher data over 219 half-innings. We recorded time in the squat stance, throws to the pitcher (43 ft [13.11 m]),⁵ throws to base (throws involving an attempt to put out an opposing runner), distance of throws to base, the intensity (percentage effort) of throws to base, and sprints to first or third base (60 ft [18.29 m]).⁵ We then assessed the time in the squat stance, throws to the pitcher, throws to base, and sprints by number per inning and number per game. We calculated the mean distance of throws and intensity of throws. Intensity of throws was estimated by the observer based on the game situation (eg, live plays were always recorded as 100%). We used these data and NCAA softball rules⁵ to construct the catcher's throwing program.

We collected the infielder and outfielder data over 219 half-innings. We recorded number of throws, distance of throws, and intensity of throws for each position. We calculated the mean distance of throws and intensity of throws and assessed the number of throws per inning and per game. We then constructed the infielder and outfielder throwing programs from these data and NCAA softball rules.⁵

Data Management

In order to construct the ITPs, we considered dimensions of the collegiate-level softball field, the data we collected, the types of injuries found in collegiate softball players, and a general understanding of tissue healing times and properties. We developed separate programs for the catcher and pitcher because the stresses placed on these players during a game situation vary greatly from those placed on infielders and outfielders. In addition, we constructed one program for the infielders and one for the outfielders. These programs reflect the maximums of all infielders and outfielders, respectively. This type of design allows an infielder to be cleared for play at any position in the infield and the outfielder to be cleared for play at any position in the outfield. We used the ranges, instead of means, to devise the throwing programs because in any given contest, the athlete may have to perform at the maximum level. Therefore, the simulated games represent the maximums at each position.

RESULTS

Pitchers

During data collection, no pitchers were removed from a game due to injury, and no other pitching changes were noted within games. However, in all recorded cases, pitchers were replaced

Table 1. Softball Catchers' Data (Throws to Base Not Included)

	Mean/ Inning	Mean/ Game*	Range/ Game*	Total Observed
Throws back to the pitcher	7.5	52.6	31–100	1647
60-ft (18.29-m) sprints	0.13	1	0–5	29
Time in squat stance (min)	2.0	14.1	8.1–23.2	442.1

*All per-game data based on 7 innings of play.

between doubleheaders. The pitchers averaged 12.7 pitches per inning and 89.6 pitches per game. The range of pitches was 60 to 141 per game; 2785 pitches were recorded. We recorded no pick-off attempts during data collection because, unlike baseball, the runners in softball are not allowed to lead off.

Catchers

We found the catchers to be in the squat stance for an average of 14.1 minutes. They threw to the pitcher an average of 52.6 times per game. Live throws, or throws to base, were made an average of 3.2 times per game at an average distance of 65.7 ft (20.03 m) and an average effort of 97.65%. In addition, we calculated 1 sprint of approximately 60 ft (18.29 m) for each game (Tables 1 and 2).

Fielders

The shortstops averaged the most throws per game (6.3). The highest average effort of throws (93.1%) was exhibited by the third basemen, who only threw the ball an average of 4.3 times per game, while the second basemen averaged the lowest average effort per throw (80.6%). The longest throws (average, 63.8 ft [19.45 m]) were from the third basemen, while the shortest throws (46.2 ft [14.08 m]) were made by the second basemen. Even though they averaged the shortest throwing distances, the first and second basemen had the largest ranges (10 to 110 ft [3.05 to 33.53 m] and 10 to 130 ft [3.05 to 39.62 m], respectively) (see Table 2).

The left fielders averaged the most plays (2.8) per game, and had a low average distance of throws (77.5 ft [23.62 m]), a small range of distances of throws (10 to 140 ft [3.05 to 42.67 m]), and the lowest average effort (87.8%). Right and center fielders had larger and more similar average distance of throws (87 and 85.8 ft [26.52 and 26.15 m], respectively) and ranges of distance of throws (25 to 165 ft [7.62 to 50.29 m] and 20 to 175 ft [6.10 to 53.34 m], respectively) (see Table 2).

Program Design

Within a given ITP, an athlete progresses from no throwing to the volume and intensity present in a game situation. Each program includes long tosses designed to increase endurance and strength throughout the progression. All long tosses should be thrown with the "crow-hop" method, which employs a hop, skip, and throw to incorporate the use of the lower extremities and trunk. The "crow-hop" minimizes the risk of improper mechanics and enables the body to gain momentum from the lower extremities and trunk.²⁸ Total throwing volume (number of throws \times distance \times intensity) is progressed slowly throughout each program.²¹ During each step and portion of each step of the

Table 2. Softball Fielders' Data

	Throws/ Game*	Mean Distance of Throws ft (m)	Range of Throws ft (m)	Mean Effort of Throws (%)
Catcher†	3.2	65.7 (20.03)	35–90 (10.67–27.43)	97.7
First base	5.1	49.9 (15.21)	10–110 (3.05–33.53)	83.7
Second base	5.8	46.2 (14.08)	10–130 (3.05–39.62)	80.6
Third base	4.3	63.8 (19.45)	30–90 (9.14–27.43)	93.1
Shortstop	6.3	56.4 (17.19)	10–95 (3.05–28.96)	88.2
Left field	2.8	77.5 (23.62)	10–140 (3.05–42.67)	87.8
Center field	2.5	85.8 (26.15)	20–175 (6.10–53.34)	90.3
Right field	2.1	87 (26.52)	25–165 (7.62–50.29)	93.2

*All per-game data based on 7 innings of play.

†Does not include throws back to the pitcher.

throwing programs, one of the 3 components of the total throwing volume is increased, thereby increasing the total throwing volume. For instance, the total throwing volume of the field practice in step 3 of the infielder's program is $(5 \times 60 \times .75) + (10 \times 75 \times .75) = 787.5$, while the total throwing volume of the field practice in step 4 is $(5 \times 60 \times .75) + (5 \times 84 \times .75) + (5 \times 120 \times .75) = 990$. The pitching program consists of 4 phases; the catching program has 3 phases; and the infielder and outfielder programs have 2 phases each.

The 4 phases of the pitching program are early throwing, initiation of pitching, intensified pitching, and a simulated game. We designed these phases to slowly progress the loads applied to the throwing arm. The program begins with short throws to tolerance (up to 50% effort) as well as long tosses up to 120 ft (36.58 m) to increase arm strength and endurance (early throwing). No pitching is instituted in this phase. The next phase, initiation of pitching, includes pitching up to 75% effort as well as continuation of the long-toss component. The intensified pitching stage takes the pitcher from the initiation of pitching to the simulated game. Off-speed pitches (curve, rise, drop, change-up) and rest intervals, which correspond with a game situation, are incorporated in this phase. The pitcher chooses the mix of pitches that compare with her preinjury pitch preference. The final stage of this phase is for the athlete to pitch batting practice. Before being cleared for return to play, the pitcher pitches a simulated game. The simulated game is based on the maximums of all inning and game data collected (Appendix A).

The catcher's program has 3 phases: beginning throwing, catching practice, and a simulated game. First, the catcher throws only up to 50% of perceived effort, with long tosses to 90 ft (27.43 m). This phase (beginning throwing) allows the catcher to build the strength and endurance that are necessary for intensified activity. With progression, sprints are incorporated as in a game situation when backing up throws. Additionally, the athlete simulates throwing to second base as well as throwing the ball back to the pitcher (catching practice). Eventually, the athlete completes a simulated game before she is cleared for return to play (Appendix B).

The infielder and outfielder programs consist of only 2 phases: throwing and a simulated game. The infielder's throwing phase begins with short throws at 50% of maximum intensity and long tosses up to 60 ft (18.29 m). It then progresses, over 5 steps, to throws at 100% effort and long tosses up to 150 ft (45.72 m). Fielding practice and sprints are included in the program (Appendix C). Before returning to play, the athlete must complete the simulated game. The outfielder's throwing program consists of the return-to-throwing phase and a simu-

lated game. Initially, the fielders only throw up to 50% of maximum effort and up to distances of only 60 ft (18.29 m). The final stage includes long tosses of up to 180 ft (54.86 m) and throws of up to 100% effort. Fly and ground balls are included in all stages, and rest intervals correspond with rest between innings (Appendix D). The final step is for the athlete to complete a simulated game.

PROGRAM PROGRESSION

Soreness Rules

Axe et al²¹ defined soreness rules (Table 3) for baseball pitchers in an ITP. Their rules allow the athlete to modify progression according to symptoms. Athletes may heal at different rates and, therefore, need to progress at different paces. The soreness rules are used to prevent overstressing the soft tissues during progressive return to play. They dictate when an athlete may progress to a higher step, remain at the same step, or drop down one step. They also help dictate the amount of rest time indicated between throwing days.²¹

Injuries

In the return-to-play phase of rehabilitation, we use an injury classification scheme to modify the program: specifically when to begin throwing, how many days of rest are needed between days of throwing, and how quickly the athlete may progress through the ITP. The classification is hierarchical. Injuries to body parts other than the throwing arm require the least modification, followed by injuries to the throwing arm that do not involve the joints (bruises), mild injuries to the throwing arm that involve the joints (tendinitis), and injuries to the throwing arm that are severe (postoperative, torn ligament) (Appendices E–H). Before initiation of throwing, the physician and any rehabilitation specialist involved must determine that the healing structures are ready to withstand the stresses of throwing.²¹ Once throwing has begun, the athlete can progress as the classification of her injury and the soreness rules allow.

DISCUSSION

No data-based ITPs developed for collegiate softball players at any position have previously been published. Furthermore, no published data-based ITPs for positional players other than pitchers have been developed for baseball or softball. The ITP being suggested is not intended to replace traditional rehabilitation but instead to augment those treatments. Within rehabilitation programs, it is imperative to include a functional progression that allows a speedy and safe return to sport.

Despite the cited differences between baseball and softball, the upper extremity injuries found in softball players other than the pitcher (overhead throwers) are similar to those of baseball players.^{4,31} The shoulder injuries that occur in overhead throwers include, but are not limited to, impingement,^{7,20,23–26,32} instability,^{7,8,13,20,23–26} undersurface rotator cuff tears,^{7,8,16,20,23,25,26} and glenoid labrum tears.^{7,8,16,20,23,25,26} Common elbow problems in overhead throwers are medial epicondylitis,^{33,34} partial or complete tearing of the flexor musculature,³⁴ osteochondral defects of the capitellum,^{20,26,33,34} ulnar collateral ligament laxity or rupture,^{20,26,27,33,34} olecranon osteophytes and loose bodies,^{20,26,32,33} and ulnar neuritis.^{20,26,33,34}

Softball pitchers do, however, have specific injury patterns

Table 3. Soreness Rules

1. If no soreness, advance 1 step every throwing day.
2. If sore during warm-up but soreness is gone within the first 15 throws, repeat the previous workout. If shoulder becomes sore during this workout, stop and take 2 days off. Upon return to throwing, drop down 1 step.
3. If sore more than 1 hour after throwing or the next day, take 1 day off and repeat the most recent throwing program workout.
4. If sore during warm-up and soreness continues through the first 15 throws, stop throwing and take 2 days off. Upon return to throwing, drop down 1 step.

linked to the dynamics of the windmill pitch. Most of these injuries occur in the shoulder and elbow. Shoulder injuries include instability,^{13,14} rotator cuff tendinitis,¹⁵ bicipital tendinitis,^{14,15} subscapularis strain,¹⁴ pectoralis strain,¹⁴ biceps-labrum degeneration,^{13,14} and trapezius strain.¹⁵ Elbow injuries include ulnar neuritis,^{13,14} ulnar collateral ligament damage,¹⁴ and tendinitis.¹⁵

The injuries to softball pitchers are a result of the forces and torques imparted upon the upper extremity during the windmill pitch. The forces, torques, and speed with which the windmill pitch occurs are responsible for the incidence and type of injuries sustained.¹⁴ The athlete must be rehabilitated successfully to withstand the listed values imparted on the upper extremity during windmill pitching.

Clearing an athlete to begin the ITP is the responsibility of the health care professionals as a team. They must be sure that the healing tissues can withstand the forces applied to the joints during the early stages of the throwing program. The athlete's personal healing characteristics, the incurred injury, the treatment being administered, and the player's softball position all dictate the decision of the health care team.²¹ The early stages of the throwing programs only allow the athlete to throw to tolerance but at no greater effort than 50%. Baseball players are not usually accurate in attempting to duplicate a desired effort level. Fleisig et al³⁵ studied 27 healthy college baseball pitchers. When requested to throw at 50% effort, the pitchers averaged ball speeds of 85% of their maximum and forces and torques of 75% of their maximum. When requested to throw at 75% effort, the ball speeds reached 90% and the forces and torques reached 85%.³⁵ These findings indicate the need for early supervision of the program by the rehabilitation professional or athletic trainer.

Our goal was to develop data-based ITPs for collegiate-level softball players in all positions. We intend these programs to be used as functional progressions within traditional rehabilitation programs for injured softball players. In addition, the programs are useful for training and conditioning regimens used during the off-season and preseason. Our objective is for the programs to be useful for all health care professionals, coaches, and their respective athletes. The programs are designed to allow the athlete and coach or athletic trainer to continue the program once formal rehabilitation has ended. The throwing or pitching athlete is slowly progressed from no throwing to game situation levels of throwing through a gradual increase in intensity and total throwing volume step by step. The goal we are proposing for the ITPs for collegiate softball players is to promote efficient and safe return to sport.

ACKNOWLEDGMENTS

We thank Chris Kuchta and Robbin Wickham, MPT, for their assistance.

REFERENCES

- National Collegiate Athletic Association. NCAA Online. Available at: http://www.ncaa.org/participation_rates/1982-99_overall.html. Accessed February 8, 2001.
- National Collegiate Athletic Association. The Research Staff. Available at: http://www.ncaa.org/participation_rates/1998-99_women'sparticipationrates.html. Accessed February 8, 2001.
- The National Collegiate Athletic Association News. NCAA Injury Surveillance System. <http://www.ncaa.org/news/19990927/active/3620n07.html>. Accessed February 8, 2001.
- Powell JW, Barber-Foss KD. Sex-related injury patterns among selected high school sports. *Am J Sports Med.* 2000;28:385-391.
- National Collegiate Athletic Association. *NCAA 2000 Softball Rules*. Indianapolis, IN: National Collegiate Athletic Association; 1999.
- National Collegiate Athletic Association. *NCAA 2000 Baseball Rules*. Indianapolis, IN: National Collegiate Athletic Association; 1999.
- Meister K. Current concepts: injuries to the shoulder in the throwing athlete, part one: biomechanics/pathophysiology/classification of injury. *Am J Sports Med.* 2000;28:265-275.
- Altchek DW, Dines DM. Shoulder injuries in the throwing athlete. *J Am Acad Orthop Surg.* 1995;3:159-165.
- Jobe FW, Moynes DR, Tibone JE, Perry J. An EMG analysis of the shoulder in pitching: a second report. *Am J Sports Med.* 1984;12:218-220.
- Jobe FW, Tibone JE, Perry J, Moynes D. An EMG analysis of the shoulder in throwing and pitching: a preliminary report. *Am J Sports Med.* 1983;11:3-5.
- Maffet MW, Jobe FW, Pink MM, Brault J, Mathiyakom W. Shoulder muscle firing patterns during the windmill softball pitch. *Am J Sports Med.* 1997;25:369-374.
- Ford D. *An Introduction to Softball Pitching Mechanics*. Dubuque, IA: Wm C Brown; 1990:32-33.
- Hurd W. Special population: rehabilitation considerations for the female softball player. *Sports Med Update.* 1999;14:10-13.
- Barrentine SW, Fleisig GS, Whiteside JA, Escamilla RF, Andrews JR. Biomechanics of windmill softball pitching with implications about injury mechanisms at the shoulder and elbow. *J Orthop Sports Phys Ther.* 1998;28:405-415.
- Loosli AR, Requa RK, Garrick JG, Hanley E. Injuries to pitchers in women's collegiate fast-pitch softball. *Am J Sports Med.* 1992;20:35-37.
- Pappas AM, Zawacki RM, McCarthy CF. Rehabilitation of the pitching shoulder. *Am J Sports Med.* 1985;13:223-235.
- Wilk KE, Arrigo CA, Andrews JR. Closed and open kinetic chain exercise for the upper extremity. *J Sport Rehabil.* 1996;5:88-102.
- Pezzullo DJ, Karas S, Irrgang JJ. Functional plyometric exercises for the throwing athlete. *J Athl Train.* 1995;30:22-26.
- Lephart SM, Pincivero DM, Giraldo JL, Fu FH. Current concepts: the role of proprioception in the management and rehabilitation of athletic injuries. *Am J Sports Med.* 1997;25:130-137.
- Fleisig GS, Barrentine SW, Escamilla RF, Andrews JR. Biomechanics of overhand throwing with implications for injuries. *Sports Med.* 1996;21:421-437.
- Axe MJ, Wickham R, Snyder-Mackler L. Data-based interval throwing programs for Little League, high school, college and professional baseball pitchers. *Sports Med Arthrosc Rev.* 2001;9:24-34.
- Johansen RL, Callis M, Potts J, Shall LM. A modified internal rotation stretching technique for overhead and throwing athletes. *J Orthop Sports Phys Ther.* 1995;21:216-219.
- Litchfield R, Hawkins R, Dillman CJ, Atkins J, Hagerman G. Rehabilitation for the overhead athlete. *J Orthop Sports Phys Ther.* 1993;18:433-441.
- Wilk KE, Arrigo C. Current concepts in the rehabilitation of the athletic shoulder. *J Orthop Sports Phys Ther.* 1993;18:365-378.
- Meister K, Andrews JR. Classification and treatment of rotator cuff injuries in the overhead athlete. *J Orthop Sports Phys Ther.* 1993;18:413-421.
- Anderson TE. Shoulder and elbow problems occurring with throwing in softball or baseball. Presented at: *Sports Medicine for the Athletic Trainer*; June 20-21, 1991; Cleveland Clinic Foundation; Cleveland, OH.
- Azar FM, Andrews JR, Wilk KE, Groh D. Operative treatment of ulnar collateral ligament injuries of the elbow in athletes. *Am J Sports Med.* 2000;28:16-23.
- Wilk KE, Arrigo CA. Interval sport programs for the shoulder. In: Andrews JR, Wilk KE, eds. *The Athlete's Shoulder*. New York, NY: Churchill Livingstone; 1994:669-671.
- 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.
- Coleman AE, Axe MJ, Andrews JR. Performance profile-directed simulated game: an objective functional evaluation for baseball pitchers. *J Orthop Sports Phys Ther.* 1987;9:101-105.
- Andrews JR, Carson WG Jr, McLeod WD. Glenoid labrum tears related to the long head of the biceps. *Am J Sports Med.* 1985;13:337-341.
- Tibone JE, Jobe FW, Kerlan RK, et al. Shoulder impingement syndrome in athletes treated by an anterior acromioplasty. *Clin Orthop.* 1985;198:134-140.
- Azar FM, Wilk KE. Nonoperative treatment of the elbow in throwers. *Oper Tech Sports Med.* 1996;4:91-99.
- Jobe FW, Nuber G. Throwing injuries of the elbow. *Clin Sports Med.* 1986;5:621-636.
- Fleisig GS, Barrentine S, Zheng N. Kinematic and kinetic comparison of full-effort and partial-effort baseball pitching. *Conference Proceedings of the Twentieth Annual Meeting of the American Society of Biomechanics*; October 17-19, 1996; Atlanta, GA.

Appendix A. Softball Pitcher's Program

Phase I. Early throwing

—All throws are to tolerance to a maximum of 50% effort.

—All long tosses begin with a crow-hop.

Step 1	Warm-up toss to 30 ft (9.14 m) 10 throws @ 30 ft (9.14 m) Rest 8 min 10 throws @ 30 ft (9.14 m) 10 long tosses to 40 ft (12.19 m)	Step 4	Warm-up toss to 75 ft (22.86 m) 10 throws @ 75 ft (22.86 m) Rest 8 min 10 throws @ 75 ft (22.86 m) 10 long tosses to 90 ft (27.43 m)
Step 2	Warm-up toss to 45 ft (13.72 m) 10 throws @ 45 ft (13.72 m) Rest 8 min 10 throws @ 45 ft (13.72 m) 10 long tosses to 60 ft (18.29 m)	Step 5	Warm-up toss to 90 ft (27.43 m) 10 throws @ 90 ft (27.43 m) Rest 8 min 10 throws @ 90 ft (27.43 m) 10 long tosses to 105 ft (32.00 m)
Step 3	Warm-up toss to 60 ft (18.29 m) 10 throws @ 60 ft (18.29 m) Rest 8 min 10 throws @ 60 ft (18.29 m) 10 long tosses to 75 ft (22.86 m)	Step 6	Warm-up toss to 105 ft (32.00 m) 10 throws @ 105 ft (32.00 m) Rest 8 min 10 throws @ 105 ft (32.00 m) 10 long tosses to 120 ft (36.58 m)

Appendix A. Continued

Phase II. Initiation of pitching

- All pitches are fast balls (no off-speed pitches).
- All pitches to tolerance or maximum effort level specified.
- All long tosses begin with a crow-hop.

Step 7	Warm-up toss to 120 ft (36.58 m) 10 throws @ 60 ft (18.29 m) (75%) 10 pitches @ 20 ft (6.10 m) (50%) Rest 8 min 10 throws @ 60 ft (18.29 m) (75%) 5 pitches @ 20 ft (6.10 m) (50%) 10 long tosses to 120 ft (36.58 m)	Step 9	Warm-up toss to 120 ft (36.58 m) 10 throws @ 60 ft (18.29 m) (75%) 10 pitches @ 46 ft (14.02 m) (50%) Rest 8 min 10 throws @ 60 ft (18.29 m) (75%) 10 pitches @ 46 ft (14.02 m) (50%) 15 long tosses to 120 ft (36.58 m)
Step 8	Warm-up toss to 120 ft (36.58 m) 10 throws @ 60 ft (18.29 m) (75%) 10 pitches @ 35 ft (10.67 m) (50%) Rest 8 min 10 throws @ 60 ft (18.29 m) (75%) 10 pitches @ 35 ft (10.67 m) (50%) 10 long tosses to 120 ft (36.58 m)	Step 10	Warm-up toss to 120 ft (36.58 m) 10 throws @ 60 ft (18.29 m) (75%) 10 pitches @ 46 ft (14.02 m) (50%) Rest 8 min 10 pitches @ 46 ft (14.02 m) (50%) Rest 8 min 10 throws @ 60 ft (18.29 m) (75%) 10 pitches @ 46 ft (14.02 m) (50%) 15 long tosses to 120 ft (36.58 m)

Phase III. Intensified pitching

- Pitch sets 11–15 consist of 1 fastball to 1 off-speed pitch at the effort level specified.
- Pitch sets 16–21 consist of a percentage of pitches that match the preinjury pitch mix specific to the athlete at the effort level specified.
- Begin each step with warm-up toss to 120 ft (36.58 m).
- End each step with 20 long tosses to 120 ft (36.58 m).

Step 11	2 throws to each base (75%) 15 pitches (50%)* 15 pitches (50%)* 1 throw to each base (75%) 15 pitches (50%)*	Step 17	1 throw to each base (100%) 15 pitches (100%)* 20 pitches (75%)* 15 pitches (100%)* 15 pitches (100%)* 20 pitches (75%)*
Step 12	2 throws to each base (75%) 15 pitches (50%)* 15 pitches (50%)* 15 pitches (50%)* 1 throw to each base (75%) 15 pitches (50%)*	Step 18	1 throw to each base (100%) 20 pitches (100%)* 15 pitches (100%)* 20 pitches (100%)* 15 pitches (100%)* 20 pitches (100%)* 1 throw to each base (100%) 15 pitches (100%)*
Step 13	2 throws to each base (75%) 15 pitches (50%)* 15 pitches (75%)* 15 pitches (75%)* 1 throw to each base (75%) 15 pitches (50%)*	Step 19	1 throw to each base (100%) 20 pitches (100%)* 15 pitches (100%)* 20 pitches (100%)* 15 pitches (100%)* 20 pitches (100%)* 15 pitches (100%)* 1 throw to each base (100%) 15 pitches (100%)*
Step 14	2 throws to each base (75%) 15 pitches (50%)* 15 pitches (75%)* 15 pitches (75%)* 20 pitches (50%)* 1 throw to each base (75%) 15 pitches (50%)*	Step 20	Batting practice 100–120 pitches 1 throw to each base per 25 pitches
Step 15	2 throws to each base (100%) 15 pitches (75%)* 15 pitches (75%)* 15 pitches (75%)* 15 pitches (75%)* 1 throw to each base (75%) 15 pitches (75%)*	Step 21	Simulated game 7 innings 18–20 pitches/inning 8-min rest between innings preinjury pitch mix
Step 16	1 throw to each base (100%) 15 pitches (100%)* 20 pitches (75%)* 15 pitches (100%)* 20 pitches (75%)* 1 throw to each base (75%) 20 pitches (75%)*		

*Rest 8 min after these sets.

Appendix B. Softball Catcher's Program

Phase I. Beginning throwing (throws to 50% effort)

—All long tosses begin with a crow-hop.

Step 1	Warm-up toss to 30 ft (9.14 m) 10 throws @ 30 ft (9.14 m) Rest 8 minutes 10 throws @ 30 ft (9.14 m) 10 long tosses to 45 ft (13.72 m)	Step 3	Warm up toss to 60 ft (18.29 m) 10 throws @ 60 ft (18.29 m) Rest 8 minutes 10 throws @ 60 ft (18.29 m) 10 long tosses to 75 ft (22.6 m)
Step 2	Warm-up toss to 45 ft (13.72 m) 10 throws @ 45 ft (13.72 m) Rest 8 minutes 10 throws @ 45 ft (13.72 m) 10 long tosses to 60 ft (18.29 m)	Step 4	Warm-up toss to 75 ft (22.86 m) 10 throws @ 75 ft (22.86 m) Rest 8 minutes 10 throws @ 75 ft (22.86 m) 10 long tosses to 90 ft (27.43 m)

Phase II. Catching practice

—Complete warm-up lap around the field before each step.

—All throws completed to tolerance, not to exceed the effort level specified.

—All throws made after squatting 8 seconds to simulate receiving a pitch.

—All long tosses begin with a crow-hop.

Step 5	Warm-up toss to 90 ft (27.43 m) 10 throws to pitcher (50%)* 10 throws to pitcher (50%)* 10 throws to pitcher (50%)* 10 long tosses to 120 ft (36.58 m)	Step 9	Warm-up toss to 90 ft (27.43 m) 10 throws to pitcher (75%)* 2 throws to 1st and 3rd base (75%)* 10 throws to pitcher (75%)* 15 throws to pitcher (75%)* 10 throws to pitcher (75%)* 15 throws to pitcher (75%)* 20 long tosses to 120 ft (36.58 m)
Step 6	Warm-up toss to 90 ft (27.43 m) 10 throws to pitcher (50%)* 15 throws to pitcher (50%)* 10 throws to pitcher (50%)* 15 throws to pitcher (50%)* 15 long tosses up to 120 ft (36.58 m)	Step 10	Warm-up toss to 90 ft (27.43 m) 10 throws to pitcher (75%)* 2 throws to 1st and 3rd base (100%)* 10 throws to pitcher (75%)* 3 throws to 2nd (75%)* 15 throws to pitcher (75%)* 10 throws to pitcher (75%)* 15 throws to pitcher (75%)* 20 long tosses to 120 ft (36.58 m)
Step 7	Warm-up toss to 90 ft (27.43 m) 10 throws to pitcher (75%)* 1 throws to 1st and 3rd base (50%)* 15 throws to pitcher (50%)* 10 throws to pitcher (75%)* 15 throws to pitcher (50%)* 20 long tosses to 120 ft (36.58 m)	Step 11	Simulated game Warm-up toss to 90 ft (27.43 m) 10 throws to pitcher (75%)* 2 throws to 1st and 3rd base (100%)* 15 throws to pitcher (75%)* 10 throws to pitcher (75%)* 15 throws to pitcher (75%)* 10 throws to pitcher (75%)* 3 throws to 2nd base (100%)* 10 throws to pitcher (75%)* 10 throws to pitcher (75%)* 20 long tosses to 120 ft (36.58 m)
Step 8	Warm-up toss to 90 ft (27.43 m) 10 throws to pitcher (75%)* 2 throws to 1st and 3rd base (75%)* 15 throws to pitcher (75%)* 10 throws to pitcher (75%)* 15 throws to pitcher (75%)* 20 long tosses to 120 ft (36.58 m)		

*Complete 60-ft (18.29-m) sprint, then rest 8 minutes after these sets.

Appendix C. Softball Infielder's Program

General Guidelines

- Complete a warm-up lap around the field before each step.
- Complete an 60-ft (18.29-m) sprint before each set of throws.
- Rest 8 minutes between sets.
- All throws are limited arc.
- All long tosses begin with a crow-hop.

Step 1	Warm-up toss to 45 ft (13.72 m) 15 throws @ 40 ft (12.19 m) (50%) Field practice (50%) 5 throws @ 35 ft (10.67 m) 5 throws @ 45 ft (13.72 m) 20 long tosses to 60 ft (18.29 m)	Step 4	Warm-up toss to 90 ft (27.43 m) 20 throws @ 60 ft (18.29 m) (75%) Field practice (75%) 5 throws @ 60 ft (18.29 m) 5 throws @ 84 ft (25.60 m) 5 throws @ 120 ft (36.58 m) 20 long tosses to 120 ft (36.58 m)
Step 2	Warm-up toss to 60 ft (18.29 m) 20 throws @ 45 ft (13.72 m) (50%) Field practice (50%) 5 throws @ 45 ft (13.72 m) 10 throws @ 60 ft (18.29 m) 20 long tosses to 75 ft (22.86 m)	Step 5	Warm-up toss to 120 ft (36.58 m) 20 throws @ 60 ft (18.29 m) (75%) Field practice (100%) 5 throws @ 60 ft (18.29 m) 5 throws @ 84 ft (25.60 m) 5 throws @ 120 ft (36.58 m) 20 long tosses to 150 ft (45.72 m)
Step 3	Warm-up toss to 75 ft (22.86 m) 20 throws @ 60 ft (18.29 m) (50%) Field practice (75%) 5 throws @ 60 ft (18.29 m) 10 throws @ 75 ft (22.86 m) 20 long tosses to 90 ft (27.43 m)	Step 6	Simulated game Warm-up toss to 120 ft (36.58 m) 20 throws @ 60 ft (18.29 m) (100%) Field practice (100%) 5 throws @ 60 ft (18.29 m) 5 throws @ 84 ft (25.60 m) 5 throws @ 120 ft (36.58 m) 1 throw to each base from position (100%) 20 long tosses to 150 ft (45.72 m)

Appendix D. Softball Outfielder's Program

General Guidelines

- Complete a warm-up lap around the field before each step.
- All tosses with limited arc.
- All long tosses begin with a crow-hop.

Step 1	Warm-up toss to 45 ft (13.72 m) Catch fly balls or field ground balls and throw to cutoff at 45 ft (13.72 m) (50% effort); repeat 5 times with 1-minute rest between throws. 15 tosses to 60 ft (18.29 m)
Step 2	Warm-up toss to 60 ft (18.29 m) Catch fly balls or field ground balls and throw to cutoff at 60 ft (18.29 m) (50% effort); repeat 5 times with 1-minute rest between throws. 15 tosses to 90 ft (27.43 m)
Step 3	Warm-up toss to 90 ft (27.43 m) Catch fly balls or field ground balls and throw to cutoff at 90 ft (27.43 m) (75% effort) repeat 5 times with 1-minute rest between throws. 15 tosses to 120 ft (36.58 m)
Step 4	Warm-up toss to 120 ft (36.58 m) Field ground balls and throw to cutoff at 90 ft (27.43 m) (75% effort); repeat 5 times. Catch fly balls and throw to base at 120 ft (36.58 m) (75% effort); repeat 5 times with 1-minute rest between throws. 15 tosses to 150 ft (45.72 m)
Step 5	Warm-up toss to 120 ft (36.58 m) Field ground balls and throw to cutoff at 90 ft (27.43 m) (100% effort); repeat 5 times. Catch fly balls and throw to base at 120 ft (36.58 m) (75% effort); repeat 5 times with 1-minute rest between throws. 20 tosses to 180 ft (54.86 m)
Step 6	Warm-up toss to 150 ft (45.72 m) Catch fly balls and throw to base at 150 ft (45.72 m) (100% effort); repeat 5 times with 1-minute rest between throws. Field ground balls and throw to cutoff at 90 ft (27.43 m) (100% effort); repeat 5 times. 20 tosses to 180 ft (54.86 m)
Step 7	Simulated game Warm-up toss to 180 ft (54.86 m) Field ground balls and throw to cutoff at 120 ft (36.58 m) (100% effort); repeat 5 times. Catch fly balls and throw to base at 180 ft (54.86 m) (100% effort); repeat 5 times with 1-minute rest between throws. 20 tosses to 180 ft (54.86 m)

Appendix E. Softball Pitcher's Instructions

General rules

1. Break a sweat
2. Shoulder stretches
3. Throwing program
4. Rotator cuff strengthening
5. Shoulder stretches
6. Ice for 20 min

Warm-up

Begin at 20 ft (6.10 m) and advance 20 ft (6.10 m) at a time, throwing 3–5 times at each distance at 50% effort until reaching the warm-up distance for that workout. Begin all throws with a crow-hop.

Soreness rules

If sore more than 1 hour after throwing or the next day, take 1 day off and repeat the most recent throwing program workout.

If sore during warm-up but soreness is gone within the first 15 throws, repeat the previous workout. If shoulder becomes sore during this workout, stop and take 2 days off. Upon return to throwing, drop down 1 step.

If sore during warm-up and soreness continues through the first 15 throws, stop throwing and take 2 days off. Upon return to throwing, drop down 1 step.

If no soreness, advance 1 step every throwing day.

A. Baseline/preseason

To establish a base for training and conditioning, begin with step 4 and advance 1 step daily to step 19, following soreness rules.

B. Nonthrowing arm injury

After medical clearance, begin step 4 and advance 1 step daily to step 21, following soreness rules.

C. Throwing arm: bruise or bone involvement

After medical clearance, begin with step 1 and advance program as soreness rules allow, throwing every other day.

D. Throwing arm: tendon/ligament injury (mild)

After medical clearance, begin with step 1 and advance program to step 6, throwing every other day as soreness rules allow. Throw every third day on steps 7–10 as soreness rules allow. Return to throwing every other day as soreness rules allow for steps 11–21.

E. Throwing arm: tendon/ligament injury (moderate, severe, or post-operative)

After medical clearance, begin throwing at step 1. For steps 1–6, advance no more than 1 step every 3 days, with 2 days' active rest (warm-up and long tosses) following each workout. Steps 7–10 advance no more than 1 step every 3 days, with 2 days' active rest (warm-up and long tosses) following each workout. Advance steps 11–21 daily as soreness rules allow.

Appendix F. Softball Catcher's Instructions

General rules

1. Break a sweat
2. Shoulder stretches
3. Throwing program
4. Rotator cuff strengthening
5. Shoulder stretches
6. Ice for 20 min

Warm-up

Begin at 20 ft (6.10 m) and advance 20 ft (6.10 m) at a time, throwing 3–5 times at each distance at 50% effort until reaching the warm-up distance for that workout. Begin all throws with a crow-hop.

Soreness rules

If sore more than 1 hour after throwing or the next day, take 1 day off and repeat the most recent throwing program workout.

If sore during warm-up but soreness is gone within the first 15 throws, repeat the previous workout. If shoulder becomes sore during this workout, stop and take 2 days off. Upon return to throwing, drop down 1 step.

If sore during warm-up and soreness continues through the first 15 throws, stop throwing and take 2 days off. Upon return to throwing, drop down 1 step.

If no soreness, advance 1 step every throwing day.

A. Baseline/preseason

To establish a base for training and conditioning, begin with step 3 and advance 1 step daily to step 11, following soreness rules.

B. Nonthrowing arm injury

After medical clearance, begin at step 1 and advance 1 step daily to step 11, following soreness rules.

C. Throwing arm: bruise or bone involvement

After medical clearance, begin with step 1 and advance 1 step every other day to step 11, following soreness rules.

D. Throwing arm: tendon/ligament injury (mild)

After medical clearance, begin with step 1 and advance program to step 4, throwing every other day as soreness rules allow. Throw every third day for steps 5–8 as soreness rules allow. Return to throwing every other day as soreness rules allow for steps 9–11.

E. Throwing arm: tendon/ligament injury (moderate, severe, or post-operative)

After medical clearance, begin throwing at step 1. For steps 1–4, advance no more than 1 step every 3 days, with 1 day of active rest* following each workout day. For steps 5–11, advance no more than 1 step every 3 days, with 2 days of active rest (see below) following each workout day.

*Active rest workout: Warm up to 60 ft (18.29 m). Catch 5 pitches in squat, but do not throw ball to pitcher. Complete 25 easy long tosses to 60–90 ft (18.29–27.43 m); begin each of these throws with a crow-hop. Run 90-ft (27.43-m) sprint after every 5 long tosses.

Appendix G. Softball Infielder's Instructions

General rules

1. Break a sweat
2. Shoulder stretches
3. Throwing program
4. Rotator cuff strengthening
5. Shoulder stretches
6. Ice for 20 min

Warm-up

Begin at 20 ft (6.10 m) and advance 20 ft (6.10 m) at a time, throwing 3–5 times at each distance at 50% effort until reaching the warm-up distance for that workout. Begin all throws with a crow-hop.

Soreness rules

If sore more than 1 hour after throwing or the next day, take 1 day off and repeat the most recent throwing program workout.

If sore during warm-up but soreness is gone within the first 15 throws, repeat the previous workout. If shoulder becomes sore during this workout, stop and take 2 days off. Upon return to throwing, drop down 1 step.

If sore during warm-up and soreness continues through the first 15 throws, stop throwing and take 2 days off. Upon return to throwing, drop down 1 step.

If no soreness, advance 1 step every throwing day.

A. Baseline/preseason

Begin with step 1 and advance 1 step daily as soreness rules allow.

B. Nonthrowing arm injury

After medical clearance, begin with step 1 and advance 1 step daily as soreness rules allow.

C. Throwing arm: bruise or bone involvement

After medical clearance, begin with step 1 and advance 1 step every other day to step 5 as soreness rules allow.

D. Throwing arm: tendon/ligament injury (mild)

After medical clearance, begin with step 1. Throw every other day, but do not advance beyond step 1 for the first week.

After the first week, continue to throw every other day, repeating each step through step 5 as soreness rules allow. On off days, use active rest program below for workout.

E. Throwing arm: tendon/ligament injury (moderate, severe, or post-operative)

After medical clearance, begin with step 1. On days 1–14, throw every 3–4 days. Do not advance beyond step 1.

For days 15–28, throw step 1 every 2–3 days, but do not advance.

From day 29 on, throw every third day, advancing program as soreness rules allow. On off days, use active rest program below for workout.

Active rest program—begin all throws with a crow-hop.

Warm-up toss to 120 ft (36.58 m).

5 throws each at 60, 90, and 120 ft (18.29, 27.43, and 36.58 m) at 50% effort.

20 long tosses to 120 ft (36.58 m).

Appendix H. Softball Outfielder's Instructions

General rules

1. Break a sweat
2. Shoulder stretches
3. Throwing program
4. Rotator cuff strengthening
5. Shoulder stretches
6. Ice for 20 min

Warm-up

Begin at 20 ft (6.10 m) and advance 20 ft (6.10 m) at a time, throwing 3–5 times at each distance at 50% effort until reaching the warm-up distance for that workout. Begin all throws with a crow-hop.

Soreness rules

If sore more than 1 hour after throwing or the next day, take 1 day off and repeat the most recent throwing program workout.

If sore during warm-up but soreness is gone within the first 15 throws, repeat the previous workout. If shoulder becomes sore during this workout, stop and take 2 days off. Upon return to throwing, drop down 1 step.

If sore during warm-up and soreness continues through the first 15 throws, stop throwing and take 2 days off. Upon return to throwing, drop down 1 step.

If no soreness, advance 1 step every throwing day.

A. Baseline/preseason

To establish a base for training and conditioning, begin with step 1 and advance 1 step daily to step 6, following soreness rules.

B. Nonthrowing arm injury

After medical clearance, begin with step 1 and advance 1 step daily, following soreness rules.

C. Throwing arm: bruise or bone involvement

After medical clearance, begin with step 1 and throw every other day for the first week, following soreness rules. Do not advance beyond step 2.

Beginning the second week, throw every other day, advancing steps as soreness rules allow. On off days, you may throw the warm-up and ending tosses of the previous day's workout.

D. Throwing arm: tendon/ligament injury (mild)

After medical clearance, begin with step 1. For the first week, throw every third day and do not progress beyond step 1.

Beginning on day 8, advance program as soreness rules allow, with 1 day of active rest between workout days. (On active rest days, you should throw the warm-up and ending tosses of the previous day's workout.)

E. Throwing arm: tendon/ligament injury (moderate, severe, or post-operative)

After medical clearance, begin with step 1. For the first 2 weeks (days 1–14), throw every 3–4 days and do not advance beyond step 1.

On days 15–28, begin throwing every 2–3 days, but do not advance beyond step 1.

On days 29–42, use soreness rules to advance program, throwing every third day. (On days between workouts, you should throw the warm-up and ending tosses of the previous day's workout.)