

[Athletic Training]



Improvements in Shoulder Endurance Following a Baseball-Specific Strengthening Program in High School Baseball Players

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Background: The posterior shoulder muscles play key roles in maintaining shoulder function in throwing. Arm fatigue has been identified as a risk factor for shoulder and elbow pain in youth baseball pitchers. However, endurance of the posterior shoulder muscles in overhead athletes is not routinely examined or conditioned.

Hypothesis: Upper extremity muscular endurance can be improved in adolescent baseball players during a 20-week pre-season training program. Secondarily, strength will be improved. Finally, these improvements will be associated with maintenance of range of motion.

Study Design: Cohort study.

Methods: Fourteen baseball players (age, 16 ± 2 years) attended 3 supervised training sessions per week for 20 weeks. Strengthening of the upper extremity was performed with a specific progression that utilized readily available equipment. Testing was completed at baseline and at 4, 8, and 20 weeks. The posterior shoulder endurance test was performed to assess muscular endurance. Glenohumeral internal and external rotation range of motion and strength were measured.

Results: Posterior shoulder endurance improved from 30 ± 14 repetitions at baseline to 66 ± 26 at 4 weeks and 88 ± 36 at 20 weeks ($P < 0.05$). Glenohumeral internal rotation range of motion and the glenohumeral internal/external rotation strength ratio remained similar over the course of the program.

Conclusion: Implementation of a preseason training program effectively increased shoulder muscular endurance while maintaining strength ratios and range of motion throughout the 20-week program.

Clinical Relevance: This program improved a key parameter known to be associated with shoulder function and injury risk. This study describes a simple clinical tool to assess muscular endurance of the posterior shoulder.

Keywords: baseball, adolescent, resistance training

Shoulder injuries in high school baseball players are frequent, accounting for 17.6% of all reported injuries.⁶ Muscular strength, strength balance, and endurance deficits are among the causative factors cited and investigated in attempts to develop programs to reduce injury risk. Strength and strength balance are altered in this population. Adolescent pitchers with a history of shoulder pain demonstrated significantly less relative supraspinatus and middle trapezius strength compared with their healthy counterparts.³⁰ There is a demonstrated increase in internal rotation strength^{11,19} and decrease in external rotation strength¹⁹ in the throwing arm compared with the

nondominant arm in high school baseball players. Because of the high deceleration forces, concern has focused on the posterior shoulder muscles and their ability to generate maximum eccentric strength.

Muscular endurance is also required to maintain muscle function over many throws and long seasons. Injured pitchers aged 14 to 20 years reported pitching with arm pain and fatigue more often than their healthy counterparts.²⁰ Arm fatigue while pitching has been identified as a common risk factor for shoulder and elbow pain in youth baseball pitchers, with 32% of baseball pitchers aged 9 to 12 years reporting shoulder pain during their season.¹⁶

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Table 1. History and exposure demographics (N = 14)

	Mean ± SD
Age, y	16 ± 2
Height, cm	182 ± 8
Mass, kg	75 ± 11
Age began playing on an organized team, y	6 ± 2
Played baseball per year, mo	11 ± 2
Played baseball per week, d	4 ± 1

Preseason exercise programs for injury prevention among youth baseball pitchers have been advocated to optimally prepare athletes for throwing.^{19,28,30} A National Athletic Trainers' Association position statement on prevention of overuse injuries in pediatric athletes recommends that athletes aged 6 to 18 years should begin a program at least 2 months prior to the start of the season.³¹ Preseason programs are recommended to improve strength, increase endurance, reduce risk of injury, or improve performance, but evidence is limited to support the effectiveness of specific training programs on any or all of these functional parameters in a population of high school baseball athletes. To be most generally applied, the programs should be done with readily available equipment and at most readily accessible sites. The primary aim of this study was to evaluate change in posterior shoulder endurance during a 2-phase, easily conducted preseason training program; the secondary aim was to evaluate strength and flexibility of the glenohumeral joint internal and external rotators. The study hypotheses were that strength and endurance would increase with the preseason training session and flexibility would be maintained throughout the study period.

METHODS

Participants

Thirty adolescent baseball players voluntarily participated in this study. All participants read and signed informed consent forms, and parental consent was obtained when appropriate. This study was approved by the Institutional Review Boards at the University of Kentucky and the Lexington Clinic. All participants completed a medical history questionnaire to obtain demographic information, injury history, and previous participation in overhead sports.

Participants were asked to attend 4 testing sessions over a period of 5 months and attend 3 supervised training sessions per week. The program was initiated at the start of the fall baseball season and carried out during the winter conditioning season. Compliance was tracked by recording attendance at each training session. To be deemed compliant and included in

the data analysis, participants had to attend at least two-thirds of the sessions.^{24,26} Fourteen participants met this criterion, and only their data are used in the remainder of this study. Eleven of these participants classified themselves as pitchers or catchers, and 3 classified themselves as position players (Table 1). Four participants reported experiencing previous shoulder pain related to baseball at some point in their career, but none had seen a physician for previous shoulder pain. None of the participants were currently experiencing shoulder pain during sport activities. Not all participants were available to attend all follow-up testing sessions. Of the 14 participants with baseline data, we obtained follow-up data from 13 participants at 4 weeks, 9 participants at 8 weeks, and 12 participants at 20 weeks.

Procedures

Dependent variables were recorded at 4 times (baseline and 4, 8, and 20 weeks) over the course of the training program. Participants were followed for 20 weeks to measure them immediately prior to the start of the spring season. We did not have full control over the length of time that the coaches had the players participate in the program, and we wanted to measure them immediately prior to the start of the season while still having a true pretest measure at baseline. Additionally, weeks 11 to 20 incorporated more weight room training as opposed to a focus on the preventative program in weeks 1 to 10.

Posterior Shoulder Endurance Test

The Posterior Shoulder Endurance Test (PSET) was developed to measure endurance of the posterior shoulder muscles in the clinical setting with minimal equipment requirements. The position and motion of prone horizontal abduction were decided on based on electromyogram studies that demonstrated high activation levels of the middle trapezius, lower trapezius, infraspinatus, and supraspinatus in this maneuver.^{3,7,18,21} The PSET was modeled after the Canadian Physical Activity Assessment⁵ and other researchers,^{23,27} using a controlled cadence format. In the abdominal endurance literature, there were growing concerns that counting the number of repetitions completed during set time resulted in poor technique and raised concerns of potential injury to the lumbar spine. These same concerns apply to the shoulder, so a cadence to control arm motion and a mechanical block were used to prevent placing the shoulder in excessive hyperabduction. During the PSET, the participant was positioned prone, with the test shoulder off the table and the arm perpendicular to the floor (Figure 1). A quick-grip mini-bar clamp (546ZR, IRWIN, Quick-Grip tools, Wilmington, Ohio) was adjusted for each patient and fixed at the point that the participant's shoulder reached 90° of horizontal abduction, the point at which the participant was to hold the arm at the top of the arc of motion for 1 second. The participant held a weight equal to 2% of his body weight (rounded to the nearest half-pound) to account for variance among participants. Starting with the arm perpendicular to the floor, the participant

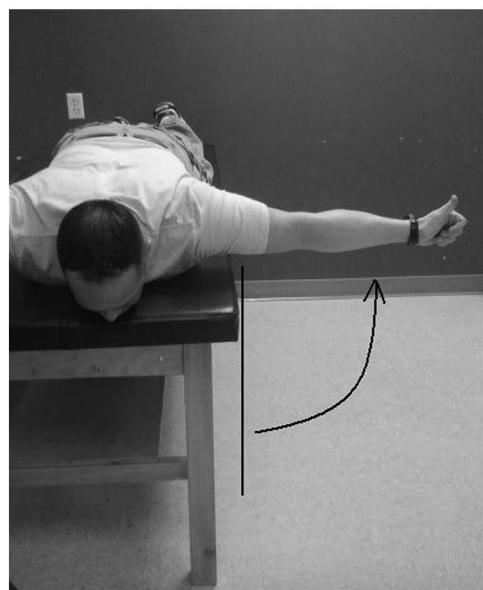


Figure 1. Arm position for the Posterior Shoulder Endurance Test.

horizontally abducted his arm to 90 degrees at a cadence of 30 beats per minute. Repetitions were performed until the participant was fatigued, indicated by one of the following conditions: the inability to hold the arm at the top of the arc for the required duration (1 second), compensation with elevation of entire upper torso, or verbal report of the inability to continue. An audio recording of a metronome with a voice-over of “up” and “down” was played during data collection of the PSET to help eliminate confusion for the participant. This also allowed the examiner to focus on counting repetitions and monitoring signs of compensation or fatigue. A mechanical pitch counter (Adidas Pitch Counter, Dick’s Sporting Goods) was used to keep track of repetitions performed. Test-retest reliability of the PSET was performed a priori by measuring 10 baseball players with 1 week between testing sessions (intraclass correlation coefficient = 0.85, standard error of measurement = 3 repetitions, minimal detectable change = 4 repetitions).

Shoulder Rotation Strength

Glenohumeral joint external rotator/internal rotator (GER/GIR) strength ratio was calculated to represent strength balance of the shoulder rotators. External and internal rotation strength was measured with a handheld dynamometer (Model 01163, Lafayette Instruments, Lafayette, Indiana). Rotational strength was measured with the participant supine, the shoulder abducted to 90°, the elbow flexed 90°, and the humerus in neutral rotation (hand pointing toward the ceiling).¹⁰ Maximum force for each of 2 maximal isometric 5-second contractions

was recorded and averaged for analysis (intraclass correlation coefficient = 0.942).

Glenohumeral Range of Motion

Total range of motion (ROM) is the sum of GIR and GER ROM. ROM was measured using a digital inclinometer (Dualer, JTech Medical, Salt Lake City, Utah). Passive internal and external ROM were measured with the participant supine and the arm abducted to 90° with the scapula stabilized and the humerus supported by a folded towel under the upper arm to maintain coronal plane alignment.²⁴ The clinician internally or externally rotated the shoulder to the end range, defined as perceived increased resistance to motion by the examiner (total ROM intraclass correlation coefficient = 0.87, standard error of measurement = 4.5°, minimal detectable change = 6.4°).

Intervention

A 2-phase preseason strengthening program was designed to be performed easily on the field (see online appendix, available at <http://sph.sagepub.com/content/suppl>). Strengthening of the scapular, rotator cuff, and forearm muscles was performed using a stair-step progression that emphasized endurance over strength by increasing repetitions with proper technique before increasing resistive load. The rationale for this approach is based in part on injury risk factors¹⁵ and that a low-load, high-repetition routine is recommended to increase endurance.¹ Additionally, basing a program on resistive loads in this age group results in a greater likelihood of the breakdown of proper form because of an increased emphasis on the amount of weight lifted. The first phase (weeks 1-10) consisted primarily of elastic resistance training on the field twice a week. Exercises were performed for a set time and progressed to longer durations on the basis of proper performance. The second phase (weeks 11-20) consisted primarily of weight room exercises twice per week incorporating both machine and free weight exercises. Exercises were progressed by repetitions until ability to perform 3 × 20, at which point the load was increased. Consistent throughout the 20-week program were 2 components: 1 training session per week performed in a sports medicine clinic and the elastic resistance series targeting the shoulder and scapular muscles, which were performed at every session and are the core of this program, regardless of location or phase. As part of a comprehensive program, additional conditioning for the trunk and lower extremity was implemented for major muscle groups using body weight and external elastic and weight resistance.

Statistical Analyses

As not all participants were available for all data collection periods throughout the study, mixed model linear analyses were employed. To determine change across time, a separate mixed model linear analysis (group by time) was used for each of the 3 dependent variables. When appropriate, a Fisher least significant difference post hoc analysis was performed. A priori α level was set at 0.05.

Table 2. Results from Mixed Model Linear Analysis

	Baseline (N = 14)	4 weeks (n = 13)	8 weeks (n = 9)	20 weeks (n = 12)	P
PSET, repetitions	30 ± 14	66 ± 26*	80 ± 27*	88 ± 36†	< 0.001
GIR/GER strength ratio	0.98 ± 0.17	1.08 ± 0.19	0.92 ± 0.15	0.98 ± 0.14	0.165
GIR range of motion, °	56 ± 11	50 ± 12	52 ± 10	53 ± 10	0.632
Total arc of motion, °	152 ± 12	150 ± 17	150 ± 11	150 ± 11	0.952

GER, glenohumeral external rotation; GIR, glenohumeral internal rotation; PSET, Posterior Shoulder Endurance Test.

*Significantly greater than baseline ($P \leq 0.001$).

†Significantly greater than baseline ($P < 0.001$) and 4 weeks ($P = 0.048$).

RESULTS

Data are described with means and standard deviations, with the means estimated from the mixed model linear analysis (Table 2). PSET repetitions increased significantly over the training program ($P < 0.01$). Post hoc analysis revealed an increase of 36 repetitions at 4 weeks ($P = 0.01$) relative to baseline and an increase of 22 repetitions from 4 to 20 weeks ($P = 0.05$). Shoulder total ROM and GER/GIR strength ratio did not change over the course of the training program ($P > 0.05$).

DISCUSSION

The aim of this study was to evaluate change in specific muscle parameters important to injury risk during a 2-phase preseason training program. It was hypothesized that endurance and strength would increase with the preseason training sessions with no loss of ROM. The results demonstrated that a preseason training program successfully improved posterior shoulder endurance and improvements were maintained to 20 weeks. Additionally, upper extremity strength and range of motion remained the same across the 20-week program.

Posterior shoulder muscular endurance increased over the course of the preseason training program at 4 weeks and was maintained to 20 weeks. Improvement in this parameter is important for several reasons. First, the demands of throwing require multiple pitches per game and per season. The physiologic demands of pitching 1 game of baseball are similar to continuous exercise at 45% maximal oxygen consumption.²² Second, arm fatigue has been associated with upper extremity injury and pain in baseball players,^{16,20} and adolescents tended to experience more fatigue than adults.¹² Finally, changes in muscle stiffness are frequently associated with repetitive eccentric exercise.¹⁷ Increased glenohumeral joint stiffness and capsular tightness have been observed in the throwing shoulder, which may develop as a result of the repetitive eccentric nature of throwing.²⁹

This program consisted of low-resistance, high-repetition exercises that emphasized endurance and proper technique.

This program was designed for high school athletes who may have never engaged in a training program before. It was designed to be carried out both in the field and in a clinical setting using common resources of elastic resistance, weights, and typical weight room equipment. The PSET was developed to measure the endurance capability of the posterior muscles, and it operates on the same principles to allow wide use. This test uses commonly available equipment and can be set up in athletic training rooms and clinics. It is reliable and appears to be sensitive to change over time, as demonstrated by our calculated minimal detectable change.

The lack of improvement in GER/GIR strength ratio is likely due to the fact that the participants started the program with a high ratio, leaving little room for improvement. Our observed mean GER/GIR strength ratio at the start of the study, which ranged from 0.92 to 1.08, is at the higher end of previously reported adolescent strength ratios that range from 0.71 to 1.06.^{12,13} Also, the emphasis on endurance principles of conditioning, with relatively higher repetitions and lower loads, mitigated against large gains in strength in this study.

GIR ROM and total ROM did not change significantly throughout the 20 weeks of training. This was also likely due to the specific emphasis of this program. The athletes were instructed to warm up, but there were no stretching exercises included as a part of the regimen. Additionally, the players were not actively participating in baseball play, which would place loads on the shoulder that have been shown to alter ROM. In our cohort, GIR ROM asymmetry was $10^\circ \pm 13^\circ$ at enrollment and the same at the 20-week follow-up, and total ROM asymmetry was $5^\circ \pm 10^\circ$ at enrollment and $2^\circ \pm 16^\circ$ at the 20-week follow-up.

The results show that this program did not improve GH ROM, and it is important to note that it had no negative effect on this important parameter. Our total ROM values are lower than those reported by Shanley et al²⁵ for noninjured high school baseball players. This may be due to the methods of ROM measurement, as our measurements were performed by a single person rather than a team of 2 investigators, or that our measurements were

taken in the off-season rather than before and after spring play. Another major conclusion is that this program did not deleteriously alter either strength ratios or range of motion, allowing it to be included in the overall conditioning program without concern of interference with other exercises.

The exercises utilized in this program are not novel, but their method of implementation in this age group and the results of the program have not been previously reported. Many of these exercises have been reported in the Thrower's Ten.^{9,32} This program included 17 upper extremity exercises performed on the field or in the clinic. Of these, 6 were from the Thrower's Ten, while 7 were slight modifications. This study could assess the effectiveness of only certain parameters of shoulder muscle function that are considered to be important in injury risk and prevention. By its design, the study cannot evaluate the effect of the exercise on injury, only that on change in strength, endurance, and range of motion. This program by itself should not be considered a comprehensive injury prevention program. The positive effect of the exercises and their relative ease of implementation suggest that they should be included in a more inclusive program, such as the Thrower's Ten³² or the Disabled Thrower's Shoulder program.¹⁴

Limitations

There are several limitations of the present study. First, the small sample size limited the ability to isolate pitchers, which required inclusion of both pitchers and position players in the same analysis. Additionally, the study did not include a control group for comparison to determine if the improvements were simply learning of the tests or true physiologic improvements. The PSET utilizes the motion of prone horizontal abduction. While electromyogram studies have identified that prone horizontal abduction activates the muscles of interest,^{3,7,18,21} further validation is necessary to demonstrate the ability of the PSET to distinguish between fatigued and nonfatigued states. Finally, in-season performance variables were not recorded, making evaluation of outcomes, such as ball velocity or game statistics, impossible.

Practical Applications

This study describes a series of easily performed preseason training exercises for high school baseball players that were found to positively change parameters of posterior shoulder endurance without adversely affecting shoulder strength or range of motion. This study provides some of the first empirical data indicating that preseason training can have a positive effect on some muscle characteristics in adolescent baseball players, and it adds to the previous findings that a training program can improve throwing performance parameters.^{8,9} In addition, the equipment for the exercises and measurement tools used to demonstrate the changes in muscle parameters are readily available in a clinical setting, are relatively simple and inexpensive, and can be used in the clinic or on the field. The exercises can be included in more comprehensive programs that can be designed to target and

improve the various kinetic chain parameters that have been identified as factors in injury risk, without concern that they may adversely affect other parameters.

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