EFFECTS OF A FOUR WEEK BASEBALL CONDITIONING PROGRAM ON THROWING VELOCITY, SHOULDER STRENGTH, AND SHOULDER RANGE OF MOTION

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ABSTRACT

This study examined the effects of a 4 week youth baseball conditioning program on maximum throwing ball velocity and shoulder range of motion and strength. Thirty four youth baseball players (11-15 years of age) were randomly and equally divided into control and training groups. The training group performed three sessions (each 75 min) weekly for 4 weeks, comprising of a sport specific warm-up, resistance training with elastic tubing, a throwing program, and stretching. Throwing velocity, shoulder strength, and shoulder range of motion were assessed initially and at the end of the 4 week conditioning program for the control and training groups. The level of significance used was $p < 0.05$. After the 4 week conditioning program, throwing velocity was significantly greater in the training group (approximately 4%), but not in the control group (less than 1%). In the training group, two of the eight strength measurements (shoulder scaption and horizontal abduction) were significantly greater from pre-test to post-test, while in the control group, there were no strength measurements significantly different from pre-test to post-test. Moreover, shoulder internal rotation was significantly less in both the training and control groups, while shoulder flexion was significantly less in the training group. These results demonstrate that the short term 4 week baseball conditioning program was effective in increasing throwing velocity and shoulder strength in youth baseball players, but not effective in increasing shoulder range of motion, but rather resulted in a decrease in shoulder internal rotation and flexion range of motion.

INTRODUCTION

Of the roughly 2.5 million baseball players in the USA, approximately 80% participate at the 14 and under youth leagues and another 15-20% participate at the high school youth level (5). Less than 1% of all baseball players are at the collegiate or professional levels (5). With approximately 99% of baseball players participating in youth and high school leagues, it is important for strength and conditioning and rehabilitation specialists to be knowledgeable in performance enhancement, injury prevention, and training and rehabilitation in youth (under 18 years of age) baseball players.

There are limited studies that have investigated resistance training programs in youth baseball players. Szymanski et al. (26, 28) investigated the effects of a 12 week periodized training program, largely comprised of wrist and forearm training, on bat velocity in high school baseball players. Szymanski et al. (25, 27) investigated a 12-week medicine ball, torso rotation training, and a stepwise periodized resistance training program with bat swings on bat velocity and torso rotational and sequential hip-torso-arm rotational strength. Wooden et al. (30) investigated the effects of a 5 week resistance training program consisting of isolated shoulder internal and external rotation exercises on shoulder internal and external rotation shoulder torque and throwing ball velocity. However, there are no known studies that have investigated the effects of a baseball specific conditioning program on throwing velocity in youth baseball players.

One component of performance enhancement in baseball is throwing velocity. For example, a pitcher with a good fastball sets up other pitches that help fool the hitter, such as the changeup and curveball. Throwing the fastball pitch with greater throwing velocity allows less time for the batter to identify the pitch and decide whether or not to swing. Therefore, a fastball pitch thrown with greater velocity is often more difficult to hit compared to a fastball pitch thrown with less velocity, assuming similar ball movement and location over the plate.

Throwing velocity is also important to position players. For example, a ground ball softly hit to the short-stop or third baseman requires a hard throw with high velocity and accuracy to throw out the runner. Similarly, an outfielder trying to throw out a base runner at home plate requires high throwing velocity and accuracy. Throwing velocity may increase by improving throwing mechanics or by employing an effective baseball conditioning program, which can enhance muscular strength and power. While several studies have analyzed the throwing mechanics in youth pitchers (8, 15, 22), it is unclear how improving throwing mechanics affects throwing velocity.

It has been demonstrated that adult pitchers who throw with greater throwing velocity tend to have greater shoulder external rotation, forward trunk tilt, and knee angular velocity during the pitch compared to pitchers who throw with lower throwing velocities (7, 12, 23). Therefore, shoulder external rotation range of motion is an important variable to assess in baseball players, especially when a baseball player's goal is to enhance throwing velocity. Shoulder internal rotation and flexion have also been shown to change in adult pitchers as a result of throwing (3, 13, 21). However, there are no known studies that have examined the effects of an upper extremity stretching program on shoulder range of motion in youth baseball players.

At all levels of baseball it is estimated that there are over 50,000 injuries annually, most involving the upper extremity (5). Olsen et al. (16) reported that the factors with the strongest associations with shoulder and elbow injury in adolescent baseball pitchers were overuse and fatigue. Properly designed and implemented baseball conditioning programs have been shown to develop muscular strength or endurance in adult baseball players (4, 25-28), which may prevent upper extremity injuries and enhance the rehabilitation process once an injury has occurred. However, there are no known studies that have investigated the effects of a baseball specific conditioning program on enhancing muscular strength in youth baseball players.

The purpose of this study was to determine the effects of a 4 week youth baseball conditioning program (comprised of throwing, stretching, and resistance tubing exercises) on maximum throwing velocity and shoulder range of motion and strength. It was hypothesized that after a 4 week baseball conditioning program, the training group would exhibit a decrease in shoulder internal rotation range of motion, and an increase in throwing velocity and overall shoulder strength. It was also hypothesized that there would be no significant different between all pre-test and post-test measurements in the control group.

METHODS

Experimental Approach to the Problem:

This study examined whether a short term 4 week baseball conditioning program was effective in increasing throwing velocity, shoulder strength, and shoulder range of motion. While other studies have examined the effects of resistance training on bat velocity (25, 26), to our knowledge this is the first study that has examined the effects of a baseball conditioning program on throwing velocity, shoulder strength, and shoulder range of motion in youth baseball players. Because youth athletes increase musculature strength through maturation, which can affect throwing velocity, we used an age matched control group to compare to the experimental (training) group.

Subjects:

Thirty four youth baseball players between 11-15 years of age volunteered as subjects, and were randomly and equally divided into a control group and a training group. Both the control and training groups participated in their normal school activities (eg, physical education class) and extracurricular activities, such as running and playing school sports other than baseball, because baseball was off-season. When both the control and training groups were asked to list any activities or sports they performed during the 4 week period of the study, both groups listed similar activities and sports, such as running, playing basketball, soccer, or tennis, playing catch with a baseball, and performing push-ups and sit-ups in physical education class. The primary difference between the control and training groups is that the training group participated in a 4 week baseball specific conditioning program, while the control group did not. The subjects mean (SD) age, mass, and height were 12.5 (1.5) y, 52.4 (17.7) kg, and 159.7 (12.8) cm, respectively, in the control group, and 12.9 (1.7) y, 53.9 (20.7) kg, and 163.8 (14.0) cm, respectively, in the training group. Inclusion criteria for all subjects required each participant to be healthy baseball player without a history of any orthopaedic surgery, no shoulder pain for the past twelve months, no rehabilitation for the past twelve months, no participation in a formal resistance training program during the 4 week period of the study, such as a weight training class in school (not including push-ups, sit-ups, or related calesthetic exercises that may be a daily part of physical education class), and no participation in a school or league baseball program during the 4 week period of the study. All subjects and their parents provided written informed consent, and the protocol used for this study was approved by the Institutional Review Board at California State University, Sacramento.

Procedures:

Description of Baseball Conditioning Program:

The baseball conditioning program for the training group was approximately 75 min in duration three times per week for 4 weeks. Two experienced trainers at “A Change of Pace, Inc” (Davis, CA) trained all 17 subjects in the training group throughout the 4 week duration.

The initial 10 min of the program comprised of general warm-up and range of motion exercises, including arm circles in multiple directions, side stretch to the right and left sides, forearm supination and pronation range of motion exercises, and wrist flexion and extension range of motion exercises, each performed for 2 sets of 25 reps. The subsequent 30 min of the program consisted of using elastic tubing (“MVP Band”, formerly know as the “ACE Power Band”) for 19 upper extremity resistance exercises for muscular strength, power, and endurance. The MVP Band is different than most elastic tubing devices, because it is attached around the wrist instead of holding a handle in the hands. The 17 resistance exercises were performed for one set of 20-25 repetitions, and included the following exercises:

1) Elbow Extension - start with both hands behind head and elbows fully flexed and end with elbows fully extended with hands above head (Figures 1a and 1b);

2) Arm Extension - start with 90º shoulder abduction with elbows flexed 90º and end with 90º shoulder flexion and elbows fully extended (Figures 2a and 2b)

3) Chest Fly (Horizontal Adduction) – start with 90° shoulder abduction with elbows fully extension and end with shoulder flexed 90° with elbows fully extended - (Figures 3a and 3b)

4) Reverse Chest Fly (Horizontal abduction) – performed the opposite of Chest Fly

5) Rowing – start with shoulders flexed 90° and elbows fully extended and end with shoulders fully extended and elbows flexed 90° (Figures 4a and 4b)

6) Internal Rotation With Shoulder Flexed 90° - start with shoulder and elbow flexed 90° with forearm vertical with ground and internally rotate shoulder until forearm is parallel with ground (Figures 5a and 5b)

7) External Rotation With Shoulder Flexed 90° - performed the opposite of Internal Rotation With Shoulder Flexed 90° (Figures 6a and 6b)

8) Internal Rotation With Shoulder Abducted 0° - start with shoulder abducted 0° and elbow flexed 90°with forward pointing anterior, and end with full shoulder internal rotation (Figures 7a and 7b)

9) External Rotation With Shoulder Abducted 0° - performed the opposite of Internal Rotation With Shoulder abducted 0°

10) Internal Rotation With Shoulder Abducted 90° - start with shoulders abducted 90° and elbows flexed 90° with forearms vertical, and end with shoulder internal rotation until forearms are horizontal (Figures 8a and 8b)

11) External Rotation With Shoulder Abducted 90° - performed the opposite of Internal Rotation With Shoulder abducted 90°

12) Shoulder Abduction to 90° - start with hands together and arms in front of body and end with shoulder abduction to 90° (Figures 9a and 9b)

12) Shoulder Abduction to 180° - same as Shoulder Abduction to 90°, except abduct to 180° with shoulder external rotation

13) Biceps Curl – start with elbows fully extended and flex elbows (Figures 10a and 10b)

14) D2 Diagonal Pattern Flexion – start with shoulder extended and internally rotated and elbow straight with hand at opposite hip, and end with shoulder flexed and externally rotated and elbow flexed (Figures 11a and 11b)

15) Reverse Throw – same as D2 Diagonal Pattern Flexion, except start with hips and trunk flexed and trunk rotated (Figures 12a and 12b)

16) D2 Diagonal Pattern Extension – reverse of D2 Diagonal Pattern Flexion - start with shoulder flexed and externally rotated and elbow bent and end with shoulder extended and internally rotated and elbow straight with hand at opposite hip

17) Standard Forward Throw - same as D2 Diagonal Pattern Extension, except end with hips and trunk flexed and trunk rotated (Figures 13a and 13b)

Each exercise was performed in a 3-s repetition (1 s for the concentric phase and 2 s for the eccentric phase), except for the stretches and throwing motion exercises. Each subject was instructed how to perform each exercise with proper form and technique, and use enough resistance for each exercise that allowed them to perform 20-25 repetitions but no more. The subjects adjusted the tension in the MVP Band tubing to accommodate their improvements in strength throughout the 4 week duration.

The next 30 min consisted of a distance-based interval throwing long toss program, which has been shown to be effective in enhancing throwing performance in youth baseball players (1). After a five min warm-up throwing at a 50 ft distance, each subject performed pivot throws with an arc (no step allowed) for 15 min (60 ft throws for 5 min, 75 ft throws for 5 min, and 100 ft throws for 5 min). Subsequently, each subject performed long toss throws with an arc (one step allowed) for 10 min (100 ft throws for 5 min and 125 ft throws and beyond for 5 min). Subjects 13-15 years of age ended their throwing by performing 5 hard throws at 150 ft, 5 hard throws at 125 ft, and 5 hard throws at 100 ft. Subjects 11-12 years of age ended their throwing by performing 5 hard throws at 100 ft, 5 hard throws at 75 ft, & 5 hard throws at 50 ft. The final 5 min of the program consisted of shoulder external rotation stretches, which consisted of 15 repetitions for each arm for external rotation at 0° shoulder abduction, external rotation at 90° shoulder abduction, and external rotation at 0° shoulder flexion.

Pre-test/Post-test Assessment for Throwing Velocity, Shoulder Strength, & Shoulder Range of Motion:

Throwing velocity and shoulder range of motion and strength measurements were performed for all subjects at Results Physical Therapy and Training Center (Sacramento, CA) two days before the start of the baseball conditioning program (pre-test) and two days after the completion of the baseball conditioning program (post-test). For both the pre-test and post-test each subject's shoulder range of motion was assessed first, followed by shoulder strength and then throwing velocity assessments. Adequate rest was provided between all trials to prevent muscular fatigue from occurring.

Shoulder Range of Motion Assessment:

A licensed physical therapist served as range of motion tester and assessed shoulder flexion, shoulder external rotation, and shoulder internal rotation (in units of degrees) using a goniometer with the subject in a supine position. The same tester performed all measurements during both the pre-test and post-test. The 0° starting position for shoulder flexion was with the arm at the side and goniometer's axis of rotation positioned at the shoulder joint center. The therapist then moved the subject's arm in the direction of flexion until scapular motion was felt, and the angle between the mid-axillary line of the trunk and the mid-humerus was then recorded. The 0° starting position for internal and external rotation was with arm abducted 90°, the elbow flexed 90°, the forearm pointing vertical, and the goniometer's axis of rotation centered with a line through the shoulder and elbow joint centers. The therapist externally or internally rotated the shoulder until scapular motion was felt, and the angle between a vertical axis and the ulna was then recorded. Three trials were performed for each range of motion test (a forth measurement was taken if any two measurements were not with 5% of each other), which were performed in a randomized order for each subject. The same order used for the pre-test was also used for the post-test.

Shoulder Strength Assessment:

Standard manual muscle shoulder tests on the throwing arm side were used to assess shoulder isometric strength. A licensed physical therapist served as tester and performed all measurements during both the pre-test and post-test. The subject was instructed to move the arm into the position described below for each manual muscle test, and was then asked to hold that position and resist the therapist attempt to “break” the position and move the arm in the opposite direction. For each manual muscle test the Nicholas Manual Muscle Tester (NMMT) hand held dynamometer (Model 01160, Lafayette Instrument, Lafayette, IN) was used to quantify force, expressed in units of kilograms (kg). For internal and external rotation tests, the stirrup (component of NMMT that subject pushed against) was positioned at the distal forearm just proximal to a line connecting the radial and ulnar styloid processes. For the remaining six tests, the stirrup was positioned at the distal humerus just proximal to a line connecting the medial and lateral epicondyles. Force output was recorded once the therapist was able to “break” the arm and move it from its starting position. The testing physical therapist was able to “break” the subject’s arm in all strength positions tested. Three trials were performed for each manual muscle test (a forth measurement was taken if any two measurements were not with 5% of each other), which were performed in a randomized order for each subject. The same randomized order used for the pre-test was also used for the post-test.

The starting positions and physical therapist actions for the 8 shoulder manual muscle tests were as followed: 1) Seated Scaption – with the arm abducted 90° and horizontally adducted 30° with palm facing down, the tester pushed the arm down in scapular plane. The primary muscles assessed were the anterior and middle deltoids, supraspinatus, upper trapezius, and serratus anterior; 2) Seated Flexion – with the arm flexed 90° with palm facing down, the tester pushed the arm down towards extension. The primary muscles assessed were the anterior and middle deltoids, supraspinatus, and serratus anterior; 3) Prone Extension – with the arm extended to end range extension with palm facing up, the tester pushed the arm down towards flexion. The primary muscles assessed were the latissimus dorsi, teres major, and posterior deltoid; 4) Supine Horizontal Adduction – with the arm flexed 90° with palm facing inward, the tester pulled the arm towards horizontal abduction. The primary muscles assessed were the pectoralis major, anterior deltoid, subscapularis, and serratus anterior; 5) Prone Horizontal Abduction – with the arm abducted 90° and horizontally abducted to end range, and with the elbow flexed 90°, the tester pushed the arm down towards horizontal adduction. The primary muscles assessed were the rhomboids, middle trapezius, latissimus dorsi, teres major, posterior deltoid, infraspinatus, and teres minor; 6) Prone External Rotation – with the arm abducted 90°, the elbow flexed 90°, and the shoulder rotated externally to end range, the tester pushed the forearm down towards internal rotation. The primary muscles assessed were the infraspinatus, teres minor, and supraspinatus; 7) Prone Internal Rotation - with the arm abducted 90°, the elbow flexed 90°, and the shoulder rotated internally to end range, the tester pushed the forearm down towards external rotation. The primary muscles assessed were the pectoralis major, latissimus dorsi, teres major, and subscapularis; 8) Prone Horizontal Abduction with External Rotation and 135° Abduction - with the arm abducted 135° and horizontally abducted to end range with elbow fully extended and shoulder externally rotated with thumb pointing up, the tester pushed the arm down. The primary muscles assessed were the lower and middle trapezius, rhomboids, infraspinatus, teres minor, supraspinatus, and posterior deltoid.

Throwing velocity Assessment:

After a few minutes of a general warm-up and light to moderate effort throwing, each subject's throwing velocity was assessed. Each subject threw overhand from flat ground at maximal effort to a target positioned at approximately chest level and 13.7 m away. Each subject started with both feet on a line and was then allowed to take one stride towards the target as they threw the ball. Throwing velocity was recorded from a calibrated Jugs Tribar Sport radar gun (Jugs Pitching Machine Company, Tualatin, OR) as the ball left the pitcher's hand, and was accurate within 0.22 $m \cdot s^{-1}$. Five trials were performed for each maximal effort throw, with a sixth measurement taken if any two measurements were not with 5% of each other. The five fastest throwing velocities were averaged.

Questionnaire:

During the post-test each subject in the training group completed a questionnaire asking their satisfaction with the conditioning program, and their perception of how the conditioning program affected their throwing velocity and shoulder strength and range of motion. The questionnaire given to the training group asked them if they felt the conditioning program did not help, maybe helped, probably helped, or definitely helped increase throwing velocity and shoulder strength. Each subject in the control group and training group also completed a post-test questionnaire answering questions regarding what activities and sports they participated in during the 4 week period between the pre-test and post-test.

Statistical Analysis:

Independent t-tests were used assess significant differences in age, mass, and height between the control and training groups. A two-way (timing, group) mixed-model analysis of variance (ANOVA) was used to assess differences in throwing velocity, strength parameters, and range of motion parameters. For any parameter with a clinically significant interaction between timing (pre-test vs. post-test) and group (training vs. control), differences in timing were analyzed separately for each group with a paired t-test. A difference in a t-test or ANOVA was considered significant if p was less than 0.05. In order to analyze all potentially relevant comparisons, an interaction was considered clinically significant if it was less than 0.2.

RESULTS

There were no significant differences in age, mass, and height comparisons between control and training groups. Mean (±SD) throwing velocity comparisons between pre-test and post-test measurements for the control and training groups are shown in Table 1. In the training group, throwing velocity was significantly greater after the conditioning program (post-test measurements) compared to before the conditioning program (pre-test measurements), while in the control group there were no significant differences between pre-and-post test throwing velocity measurements.

Mean (±SD) shoulder strength comparisons between pre-test and post-test measurements for both control and training groups are shown in Table 2. In the training group, post-test strength measurements were significantly greater compared to pre-test strength measurements for shoulder scaption and horizontal abduction, while in the control group there were no significant strength differences between pre-test and post-test strength measurements. When collapsed across both groups, a significant increase in prone extension, internal rotation, external rotation, and horizontal abduction with external rotation and 135° abduction strength occurred from pre-test to post-test.

Mean (±SD) shoulder range of motion comparisons between pre-test and post-test measurements for the control and training groups are shown in Table 3. In the training group, post-test range of motion measurements were significantly less compared to pre-test range of motion measurements for shoulder flexion and internal rotation, while in the control group the only post-test range of motion measurement significantly less than the pre-test measurement was shoulder internal rotation.

All subjects in the training group did not miss any training sessions, except two subjects, who missed 1 session, demonstrating excellent compliance with the training program. Moreover, all subjects in the training group were satisfied with the conditioning program. Approximately 80% of the training group subjects responded to the questionnaire by saying they felt the conditioning program definitely helped increase their throwing velocity and shoulder strength, while the remaining 20% of the subjects said the conditioning program maybe helped or probably helped increase their throwing velocity and shoulder strength.

DISCUSSION

As hypothesized, throwing velocity increased in the training group after the 4 week baseball conditioning program. These results demonstrate that even a short term conditioning program can result in increased throwing velocity in youth baseball players. Because youth are often involved in multiple sports and activities, and often have a shorter attention span compared to older athletes, a short term baseball conditioning program may an attractive alternative compared to a longer duration program (e.g., 6-12 weeks), especially since the results of the current study demonstrate that baseball performance variables can be enhanced in a short term program.

Carter et al. (4) investigated the effects of 8-weeks of upper extremity plyometric training on the isokinetic strength and throwing velocity in collegiate baseball players. Compared to a control group that participated in off-season non-plyometric strength and conditioning activities, a plyometric training group exhibited significantly greater throwing velocity at the end of the 8 week plyometric program (83.2 mph in pre-training versus 85.2 mph in post-training). There were no significant differences in any of the strength measurements between the plyometric and control groups from pre-training to post-training. These data imply that both resistance training and plyometric training results in strength gains, but plyometric training only influences throwing velocity. Moreover, these results are supported by data from Grezios et al. (9), who reported that the stretch-shortening cycle, which is the foundation of plyometric training, is the type of muscle contraction that primarily occurs in overhead throwing, such as in throwing a baseball. Wooden et al. (30) reported that youth who performed a 5 week resistance training program consisting of isolated shoulder internal and external rotation exercises increased throwing velocity by 2.06 mph. The 2 mph and 2.06 mph increases in throwing velocity reported by Carter et al. (4) and Wooden et al. (30), respectively, are similar to the 2.2 mph increase in throwing velocity reported in the current study. Although the current study demonstrated a throwing velocity increase in the training group, it is unknown which components of the baseball conditioning program (the resistance training or the throwing program, which is plyometric in nature) was most influential in producing the increased throwing velocity, and further research is needed to investigate this.

As hypothesized, shoulder strength increased in the training group after the 4 week baseball conditioning program, but not in the control group. Given the short duration of the conditioning program, it was not surprising that only two of the eight strength measurements increased from pre-test to post-test in the training group. Seated scaption strength increased approximately 12% and prone horizontal abduction strength increased approximately 19%. Part of the explanation for limited increases in shoulder strength is the short duration of the program. Nevertheless, the overall increase in strength measurements demonstrates that even a short term conditioning program can be effective in improving shoulder strength in youth baseball players. Limited strength gains likely also occurred because of the low training intensity and training volume employed. Using only 1 set of 20-25 repetitions is more conducive for maximizing muscular endurance improvement, and to a lesser extent improving muscular strength (24). However, the trainers at “Change of Pace, Inc” that trained the training group have had good feedback from the parents and the youth baseball players that go through their training program that employs 1 set of 20-25 repetitions. In addition, when using elastic resistance it is common and more practical to employ lower resistance with higher repetitions (it part because elastic tubing typically does not offer high resistance), while it is easier to employ higher resistance and lower repetitions using free weights. Nevertheless, both muscular strength and endurance are important components to achieve for baseball players. Future studies are needed to examine the effects of the training program used in the current study on muscular endurance.

Strength gains in youth may occur simply from normal aging and maturation, which may indicate why some strength variables (extension, internal rotation, external rotation, and horizontal abduction with external rotation and 135° abduction) increased from pre-test to post-test in all subjects (control group and training group combined), but did not increase from pre-test to post-test in the training group only. Moreover, certain school activities, such as performing push-up and sit-ups in physical education class, and extracurricular activities, such as participating in sport, may also help increase strength in youth, and these activities were not controlled in either the control or training groups. Given the random assignment of the subjects within the 2 groups, with the baseball conditioning program the only variable that differed between the groups, it can be concluded that the conditioning program did enhance shoulder strength improvement in the training group to a greater extent compared to the control group.

Like the current study, other studies have also reported improvements in strength from youth resistance training. Szymanski et al. (26, 28) reported that 12 weeks of a periodized training program, largely comprised of wrist and forearm training, resulted in an increase in wrist, forearm, squat, and bench press strength in high school baseball players. Moreover, Szymanski et al. (25, 27) reported that a 12-week medicine ball and torso rotation training program, in addition to a stepwise periodized resistance training program, resulted in improvements in torso rotational and sequential hip-torso-arm rotational strength in high school baseball players. Wooden et al. (30) reported that youth who performed a 5 week resistance training program consisting of isolated shoulder internal and external rotation exercises increased shoulder external rotation shoulder torque.

Because a correlation has been reported between arm strength and underhand throwing velocity (19), it is reasonably to hypothesis that such as relationship may also exist between arm strength and overhand throwing velocity. Additional studies are recommended in youth baseball players to determine the extent that resistance training affects throwing velocity.

Lyman et al. (10, 11) evaluated the association between pitch counts, pitch types, and pitching mechanics and shoulder and elbow pain in young pitchers, and recommended limiting the number of pitches thrown in a game and in a season to reduce the risk of shoulder and elbow pain, and to not throw when in a fatigued state. Moreover, Petty et al. (18) emphasized the importance of adequate rest days between pitching outings. Olsen et al. (16) reported that overuse and fatigue were the two factors with the strongest association with shoulder and elbow injury in adolescent baseball pitchers were.

These data provide credence to the importance of resistance training to enhance both muscular strength and endurance, which may prevent upper extremity injuries and enhance the rehabilitation process once an injury has occurred. More studies are needed to address the effects of resistance training on injury prevention.

A 14° decrease in shoulder internal rotation occurred in youth baseball players after 4 weeks of the conditioning program, which involved repetitive baseball throwing. Decreased shoulder internal rotation has also been demonstrated in adult pitchers following baseball throwing. For example, Reinold et al. (21) reported a 9-10° decrease in shoulder internal rotation in professional baseball pitchers both immediately following a single pitching outing and 24 hours after the pitching outing. It has been suggested that the stress of repetitive throwing can result in posterior shoulder tightness from the posterior rotator cuff or posterior capsule, which may help explain these relatively large decreases in shoulder internal rotation in 24 hours or less (3, 14). Because the control group in the current study participated in overthrowing activities during the 4 weeks of the study, such as playing tennis and baseball throwing, this may help explain why the control group also exhibited an 8° decrease in shoulder internal rotation from pre-test to post-test. If posterior shoulder tightness is excessive, such as an internal rotation loss of greater than 10-15° in the throwing shoulder compared to the non-throwing shoulder, an increased risk of shoulder pathology has been demonstrated, such as internal impingement of the infraspinatus and supraspinatus, or tears to the posterior or superior labrum (14).

While shoulder internal rotation measurements in the current study were nearly identical to shoulder internal rotation measurements in the same age group reported by Meister et al. (13), shoulder external rotation and flexion measurements in the current study were 30-40° less compared to shoulder external rotation and flexion measurements reported by Meister et al. (13). These large variations between studies are due to methodological differences in how flexion and external rotation measurements were performed between these two studies. Nevertheless, in the current study, the same range of motion measurement techniques were used for both the pre-test and post-test.

There are several questions that remain unanswered regarding the loss of shoulder internal rotation and flexion in the current study. Firstly, it is unknown how temporary these decreases in shoulder internal rotation and flexion are, and to what degree and when these range of motion losses are restored to their original values after the completion of baseball conditioning program. Further research is needed to answer these questions. Secondly, it is unclear of the exact cause the 10-15° loss in shoulder internal rotation and flexion after 4 weeks of baseball conditioning program, and how much was due to resistance training and how much was due to the throwing program. Lastly, because the subjects in the current study were largely pre-pubescent (11-15 years old), the mechanism that caused these losses in shoulder internal rotation and flexion is unclear. Specifically, it is unknown how much, if any, the diminished shoulder internal rotation and flexion range of motion was from humeral head and glenoid retroversion (6, 17, 20), how much was due to posterior capsule tightness (29), and how much was due to tightness in posterior shoulder musculature (29). If the loss of shoulder internal rotation (and to a lesser extent, shoulder flexion) resulted from humeral head and glenoid retroversion, it is unlikely the loss of shoulder internal rotation will be restored, because this mechanism is believed to be an osseous adaptation in the humeral head and glenoid that occurs in pre-pubescent youth due to torsional stress on the humeral head and glenoid from repetitive throwing (6, 17, 20). However, with humeral head and glenoid retroversion a loss in shoulder internal rotation is accompanied by an increase in shoulder external rotation (6, 29). Meister et al. (13) reported that in a group of 11-15 year old baseball players (same ages as the current study), internal rotation was on the average approximately 7° less in the throwing arm compared to the non-throwing arm, while external rotation was on the average approximately 7° greater in the throwing arm compared to the non-throwing arm. These data imply that humeral head and glenoid retroversion may have contributed to the loss of internal rotation and the increase in external rotation, but a tight posterior musculature and capsule may also have contributed to these changes in shoulder internal and external rotations. However, in the current study the short term conditioning program did not result in an increase in shoulder external rotation. This implies that the decrease in shoulder internal rotation may more likely be due to soft tissue adaptation, such as tightness in the posterior musculature or posterior capsule, rather than humeral head and glenoid retroversion. It is unclear how long it takes for osseous changes to take place, such as humeral head and glenoid retroversion, as a result of repetitive throwing, but it does appear that these osseous changes are more likely to occur in pre-pubescent overhead throwers compared to adult overhead throwers.

Repetitive forces on the posteroinferior capsule may cause hypertrophy in the posteroinferior capsular with a concomitant decrease in shoulder internal rotation (2). This can lead to the so-called dead arm syndrome, a superior labrum anteroposterior (SLAP) lesion, or a rotator cuff tear (2). If conservative treatment, such as stretching the posteroinferior capsule, fails, a selective posteroinferior capsulotomy may improve motion, reduce pain, and prevent further shoulder injury (2). Shoulder internal rotation stretching may also be beneficial in individuals with tightness in the posterior musculature, which may restore flexibility to the posterior shoulder and prevent potential posterior shoulder pathology. A better understanding of the mechanisms involved in the loss of shoulder internal rotation will help trainers and clinicians be able to prescribe appropriate treatment options in managing the shoulder of the overhead throwing athlete.

One limitation in the current study is the short duration of the conditioning program, and a longer program may have resulted in greater strength and throwing velocity increases. However, this is also one of the strengths of the study, which showed that significant increases in throwing velocity and strength could occur in only a few weeks of training. This is important because many youths may not be as compliant with a long term conditioning program. Because youths are also very active in both school and extracurricular activities, a shorter conditioning program may be preferred over a longer program.

Because the baseball conditioning program in the current combined warm-up, stretching, resistance training, and throwing, further research is needed in this area to determine the relative contribution of each of these training components with respect to increasing throwing velocity, strength, and range of motion. Further research is also needed in older youth, because the average age in the current study was approximately 13 years of age.

PRACTICAL APPLICATIONS

The results of this study demonstrates that a short term baseball conditioning program is effective in enhancing throwing velocity and shoulder strength in youth baseball players, but also results in decreased shoulder internal rotation and flexion range of motions. In only 4 weeks, throwing velocity increased approximately 4% in the group that participated in the baseball conditioning program, but changed less than 1% in the group that not participate in the baseball conditioning program. Increased throwing velocity may be helpful for a pitcher, as the batter will have less time to make a decision in whether or not to swing at the pitch, and may help position players, such as a catcher, infielder, or outfielder trying to throw out a runner attempting to advance to the next base. Shoulder strength also increased as a result of the conditioning program. Increased strength may be helpful in both throwing performance (e.g., throwing the ball faster) and batting performance (e.g., hitting the ball further). The baseball conditioning program also resulted in decreased shoulder flexion and internal rotation range of motions. Decreased shoulder internal rotation has been observed in overhand throwing athletes who engage in baseball throwing, and this range of motion loss may be due to a tight posterior cuff or posterior capsule. Stretching the posterior cuff or posterior capsule may be helpful in minimizing shoulder internal rotation range of motion loss, which if excessive has been shown to increase the risk of shoulder pathology, such as internal impingement of the supraspinatus and infraspinatus, or posterior or superior labrum injuries. Stretching the inferior shoulder capsule or shoulder extensor musculature may be helpful in minimizing shoulder flexion range of motion loss.

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Table 1. Mean ± standard deviation data are shown between pre-test and post-test throwing velocity for the training and control groups. Because there was a clinically significant interaction ($p<0.2$) between timing (pre-test vs. post-test) and group (training vs. control), data were analyzed separately for the training group (n=17) and the control group (n=17).

	Group	Pre-test (m/s)	Post-test (m/s)
Throwing Velocity	Training*	25.1 ± 2.8	26.1 ± 2.8
	Control	24.2 ± 3.6	24.0 ± 3.9

*Significant difference ($p < 0.05$) between pre-test and post-test

Table 2. Mean ± standard deviation data are shown between pre-test and post-test shoulder strength for the training and control groups. For any parameter with a clinically significant interaction ($p<0.2$) between timing (pre-test vs. post-test) and group (training vs. control), data were analyzed separately for the training group (n=17) and the control group (n=17).

Maximum muscle test	Group	Pre-test (N)	Post-test (N)
Seated Scaption	Training*	134±48	150±62
	Control	123±43	127±49
Seated Flexion	All	130±49	133±51
Prone Extension	All*	121±40	130±42
Supine Horizontal Adduction	All	150±63	142±64
Prone Horizontal Abduction	Training*	102±38	121±46
	Control	92±28	101±34
Prone External Rotation	All*	63±29	84±30
Prone Internal Rotation	All*	93±38	108±40
Prone Horizontal Abduction with External Rotation and 135° Abduction	All*	65±19	72±25

* Significant difference ($p<0.05$) between pre-test and post-test.

Table 3. Mean ± standard deviation data are shown between pre-test and post-test range of motion for the training and control groups. Because each parameter had a clinically significant interaction ($p<0.2$) between timing (pre-test vs. post-test) and group (training vs. control), data were analyzed separately for the training group ($n=17$) and the control group ($n=17$).

Range of motion	Group	Pre-test (°)	Post-test (°)
Flexion	Training*	138.7 ± 7.1	128.0 ± 6.6
	Control	132.5 ± 11.5	131.2 ± 9.8
External Rotation	Training	110.4 ± 11.9	109.8 ± 10.6
	Control	103.7 ± 11.2	98.2 ±7.7
Internal Rotation	Training*	38.7 ± 8.9	24.1 ± 7.1
	Control*	36.3 ± 8.3	28.6 ± 7.6

* Significant difference ($p<0.05$) between pre-test and post-test.

Figure Legends

Figures 1a and 1b - Elbow Extension

Figures 2a and 2b - Arm Extension

Figures 3a and 3b - Chest Fly (Horizontal Adduction)

Figures 4a and 4b - Rowing

Figures 5a and 5b - Internal Rotation With Shoulder Flexed 90°

Figures 6a and 6b – External Rotation With Shoulder Flexed 90°

Figures 7a and 7b - Internal Rotation With Shoulder Abducted 0°

Figures 8a and 8b - Internal Rotation With Shoulder Abducted 90°

Figures 9a and 9b - Shoulder Abduction to 90°

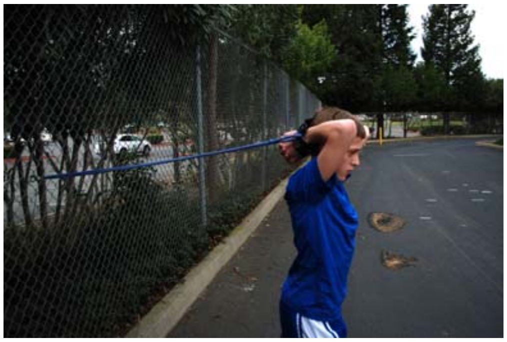
Figures 10a and 10b - Biceps Curl

Figures 11a and 11b - D2 Diagonal Pattern Flexion

Figures 12a and 12b - Reverse Throw

Figures 13a and 13b - Standard Forward Throw

Figures 1and 1b - Elbow Extension .



1a

1b

Figures 2a and 2b - Arm Extension

2a

2b

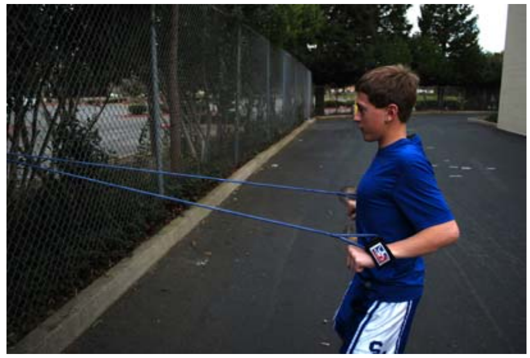
Figures 3a and 3b - Chest Fly (Horizontal Adduction)

3a

3b

Figures 4a and 4b - Rowing

4a



4b

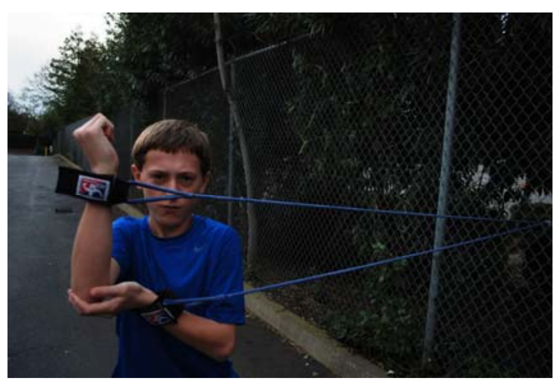
Figures 5a and 5b - Internal Rotation With Shoulder Flexed 90°

5a

5b

Figures 6a and 6b – External Rotation With Shoulder Flexed 90°

6a



6b

Figures 7a and 7b - Internal Rotation With Shoulder Abducted 0°

7a 7b

Figures 8a and 8b - Internal Rotation With Shoulder Abducted 90°

8a 8b

Figures 9a and 9b - Shoulder Abduction to 90°

9a 9b

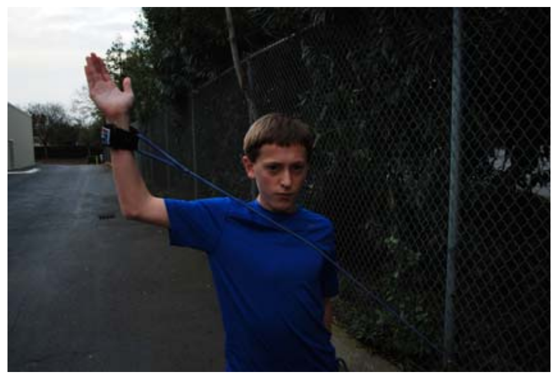
Figures 10a and 10b - Biceps Curl

10a

10b

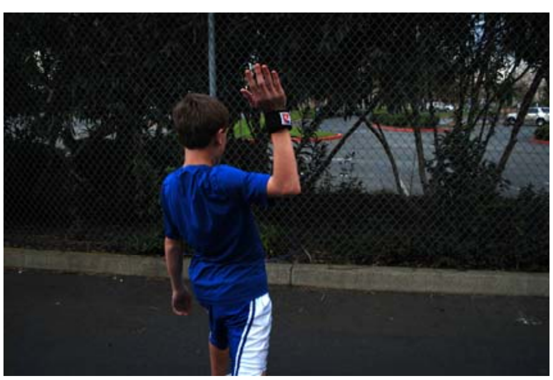
Figures 11a and 11b - D2 Diagonal Pattern Flexion

11a

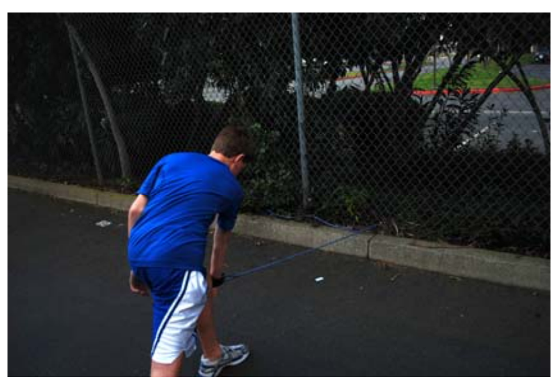


11b

Figures 12a and 12b - Reverse Throw



12a



12b

Figures 13a and 13b - Standard Forward Throw

13a 13b