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Can Throwing Cords or Arm Ergometry Enhance Throwing Velocity in Collegiate Baseball Players?

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CAN THROWING CORDS OR ARM ERGOMETRY ENHANCE THROWING VELOCITY IN COLLEGIATE BASEBALL PLAYERS?

by

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Chairperson

Dean
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This study was conducted to determine the effects of supplementing a traditional baseball throwing program with Throwing Cords (TC) or arm ergometry (AE) on throwing velocity, internal rotator (IR) strength, and shoulder external rotation (ER) ROM. Twenty-three Division II Varsity baseball players (mean age = 19.5) were tested on throwing velocity, IR strength of the throwing arm, and shoulder ER ROM of the throwing arm. Subjects were randomly assigned to one of three training groups: traditional (T), traditional plus Throwing Cord (TC), and traditional plus arm ergometry (AE). Training consisted of throwing five times per week for the first two weeks, then four times per week for the remainder of the five week training period. Subjects in the T group followed the team program while the TC and AE groups substituted the traditional training two sessions per week with either the TC or AE. Training sessions with the TC and AE involved performing the throwing motion for six sets of 10 repetitions while overcoming the added resistance. Statistical analysis using a single factor ANOVA revealed a significant difference ($P < .05$) between groups prior to training. For this reason, an ANCOVA using the pre study values as the covariate was used to analyze the data. No significant differences ($P < .05$) were found either within or between groups for the three dependent variables (average ball velocity, shoulder ER ROM, and IR peak torque). A moderate correlation was found when post-test values for ER ROM and IR peak torque were compared with post-test ball velocity ($p = .01$, $r = .60$, $R^2 = .36$, RMS = 3.2) Ball velocity was correlated with ER ROM ($r = .35$, $p >$,10) and IR peak torque ($r = .47$, $p < .02$). Although a statistically significant correlation was found for IR peak torque, only 22% of the total variability of ball velocity can be explained by IR peak torque. This added to the SEM of ± 3.4 mph, makes IR peak torque of little practical use in predicting ball velocity with any accuracy. To learn more about the relationships between IR strength, shoulder ER ROM and ball velocity, additional research with a longer training period, greater control of the amount of throwing being done and more subjects per group is needed.

May 1997
Month Year

Approved by Research Committee:

David W Bacharach (signature)
David Bacharach Chairperson

DEDICATION

This thesis is dedicated first to my parents. Dad and Mom, your guidance, love and support have made possible all that I am and all I have accomplished. Thank you for everything.

To my fiancé, GeNae - You've been a pillar of strength for me for a long time and I'm sure for a long time to come. Thanks for giving me that little bit of confidence, love, motivation, determination or whatever else I needed to keep me going. I couldn't have done it without you.

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CHAPTER I

REVIEW OF LITERATURE

In the sport of baseball, perhaps the players with the greatest impact on a team's win/loss record are the pitchers. For this reason many studies have been done to try and improve the performance of pitchers (9,30,11,28,32). One of the greatest assets a pitcher can possess is a good "heater" or fast ball. Some studies have shown that specificity of training is important when choosing a training program (33,14,21,7). The greatest positive transfer of training occurs when the elements of supplementary training are similar to the desired activity or movement, in this case, throwing a baseball (7,31). This is often referred to as the specific adaptation to imposed demands (SAID) principle (31).

The following review of literature will discuss some important issues to be considered when designing a training program to increase throwing velocity. Throwing mechanics, muscle physiology, training specificity and a review of current methods used to enhance throwing velocity will be discussed. Two relatively new products that will be discussed are the "Freestyle" arm ergometer and the Throwing Cord.

A lack of research using resistance cords, and arm ergometers suggests a need for studies to quantify the effect these products may have on throwing velocity.

This document follows the style of *The Jourrnal of Strength and Conditioning Research.*

THROWING MECHANICS

High pitching velocity is dependent upon the sequential acceleration of muscles of the lower extremities, trunk, shoulder, elbow, wrist and fingers (29,17). The throwing motion can be separated into six components: wind-up, stride, arm cocking, arm acceleration, follow-through and arm deceleration (38). These six parts have been combined into three phases: arm cocking, arm acceleration, and arm deceleration or follow-through (29,31). The three phase method divides the throwing motion into clear, concise phases providing a good understanding of the pitching motion and therefore will be used in this document. Along with the description of each phase, muscles of the shoulder girdle, chest and back which are involved in each phase of the throwing motion will be included.

The arm cocking phase is composed of the wind-up and stride components of the pitching motion. The cocking phase has three purposes: 1) it establishes a rhythm to aid in correct timing of movements 2) it conceals the ball and distracts the hitter and 3) most importantly, the cocking phase puts the body in a position so that all segments of the body can contribute to the propulsion of the ball (28). The cocking phase occurs in approximately 1.5 sec and accounts for approximately 80% of the time required to complete the entire pitching motion (29). The cocking phase is begun by the opposite leg to the pitching arm pushing-off from behind the rubber. The push-off begins to move the center of gravity in a forward direction (29,38). When the shoulder reaches maximum external rotation the cocking phase is complete. At the end of the cocking phase the scapula is retracted, the elbow flexed, the trunk extended, and the humerus is abducted, externally rotated, and horizontally extended (29,38,10,17). Reaching maximum external shoulder rotation in the arm cocking phase increases the distance force may be applied to the ball and allows greater arm acceleration (31). External rotation has been shown to be positively correlated (r= .86) with faster ball velocity (36,37). Increased arm acceleration may then result in greater ball velocity at release. The shoulder reaches a position of approximately 90° abduction, 30° horizontal extension and 150-160° of external rotation at the termination of the cocking phase (29,37).

The prime movers in the cocking phase at the shoulder are the middle deltoid muscle, supraspinatus, infraspinatus, and the teres minor. The middle deltoid concentrically contracts causing shoulder abduction. The supraspinatus, infraspinatus, and teres minor are three of the four rotator cuff muscles and are responsible for external rotation (23,17). The subscapularis, pectoralis major, and latissimus dorsi are active eccentrically to help control external rotation and protect the anterior and inferior bony and ligamentous structures of the glenohumeral joint (31). The biceps brachii muscle is also moderately active during the late cocking phase to flex the elbow approximately 90 degrees (20,17).

The arm cocking phase is followed by the arm acceleration phase. The arm acceleration phase begins with the shoulder in maximum external rotation and ends with ball release (29,10,36). The arm acceleration phase takes place in a very short time period (.04-.06 sec in major league pitchers) and accounts for approximately 2% of the time required for an entire pitching sequence (29). This phase is very explosive with internal rotation angular velocities at the shoulder ranging from 3,300-9200°/sec, and an average of 6,000°/sec (29,30). Peak accelerations approaching 600,000°/sec/sec have been found in the final .01 sec prior to ball release as the shoulder rotates from approximately 120° to 50° of external rotation (29). At ball release, the shoulder is in a position of 90° shoulder abduction, the elbow is near 43° extension and the wrist is in a neutral position (neither flexed or extended) (29).

Muscles in the chest and shoulder that are partially responsible for the high velocity movement of the acceleration phase are the pectoralis major, latissimus dorsi, subscapularis, anterior deltoid, teres major, triceps and the flexor carpi muscles of the forearm (23,20,36,17).

Once the arm has reached maximum external rotation the shoulder is brought forward followed by the arm and elbow. The forearm and hand lag behind gathering momentum. The transfer of momentum theory states that as a proximal segment is slowed, part of its momentum is transferred to the distal segment increasing the distal segment's velocity (37). Research by Wang et al. (37), has shown wrist velocities and accelerations to decrease and hand velocities and accelerations to increase just prior to release of the ball. The deceleration of the wrist and acceleration of the hand may increase ball velocity due to the transfer of momentum theory. The flexor carpi muscles in the forearm which cross the elbow joint help stabilize the elbow and flex the wrist to add speed to the ball at release (36).

After the extremely fast movement in the acceleration phase, a reduction of angular rotation of the arm is necessary to reduce potential injury to the shoulder complex. This reduction in angular velocity is accomplished in the deceleration phase by eccentric activity of the external rotators and the posterior deltoid. The deceleration or follow-through phase takes approximately .35 sec, accounting for 18% of the time required for the entire pitching sequence (29). The deceleration phase begins at ball release and ends when the arm reaches approximately zero degrees internal rotation (10). During this phase the shoulder continues to internally rotate and horizontally adduct (31). Muscles active eccentrically to decelerate the arm include the posterior deltoid, supraspinatus, infraspinatus, and teres minor (31,17). The biceps brachii is also active to flex the elbow and decelerate the forearm (20). When the pitcher assumes a fielding position the deceleration phase is complete.

CHARACTERISTICS OF MUSCLE FIBERS

Throwing is a dynamic and powerful motion. In a very short period of time, the musculature of the shoulder must create large forces. The speed and force of the contraction are controlled by the selective recruitment of specific motor units (MU). A MU is composed of a motoneuron and the muscle fibers it innervates. The number and size of the MUs recruited controls the speed and force of the contraction (33).

Motor units can be classified by the characteristics of the muscle fibers innervated. Originally, muscle fibers were classified as either fast twitch or slow twitch. More recently, muscle fibers have been separated into four classes - slow twitch (I), fatigue resistant (IIA), fast intermediate (IIAB), and fast fatigue (IIB) (33). Slow twitch MUs are generally smaller, have longer contraction times (time from neural stimulation to contraction) and greater endurance (ability to maintain muscle tension with repeated stimulation). Progressing from type I to IIA to IIAB to IIB, the muscle fibers get larger, with increased glycogen storage, decreased myoglobin content (oxygen available), shorter contraction times (faster twitch rate), less resistance to fatigue, and fewer mitchondria (23,24,16).

The high velocity of the pitching motion is achieved by the selective recruitment of the correct MUs. Specific recruitment of the fast twitch, type IIB fibers has not been demonstrated; however, integrated electromyography (IEMG) recordings have shown a decrease in muscle electrical activity as the velocity of contraction increases (33). A "dropping out" of type I MUs was proposed to explain the decreased IEMG at higher velocities (3). Contrary to the proposed dropping out of type I MUs by Barnes (3), Edstrom and Grimsby (13) and Sale and MacDougall (34) suggest activation of all motor units simultaneously is preferrable when a large force must be generated quickly.

The force of a contraction is controlled not only by the type of MU activated but also by the size of the somatic nerve and axon innervating the MU. The recruitment of MUs according to the size of their force output and type is called the "size principle" (25,14). Motor units with larger somatic nerves and axons are associated with type II muscle fibers and a greater number are recruited for high velocity, forceful movements such as throwing. Whereas, type I fibers have smaller somatic nerves and axons and are recruited for less intense, longer duration activities. Recruitment of MUs according to the size principle also means, "that weak, slowly contracting and fatigue-resistant motor units are recruited before strong, rapidly contracting fatigable units" (14, p. 105). This selection and recruitment process allows for graded movements and prolonged work.

SPECIFICITY

According to the principle of specificity, "specific exercise stress such as strength-power training induces specific strength-power adaptations" (25, p. 347). A training exercise that simulates the desired task provides a greater transfer of the learning and coordination that occurs in the training while stimulating the appropriate MUs (33). Due to the high velocity and powerful movement involved in a throwing motion, it seems logical that a program designed to increase throwing velocity should closely simulate the pitching motion.

Neural factors are one reason the principle of specificity is thought to be important. It has been established that, in addition to muscle structural changes, improvements in neural function also occur (33,34,7,26). This seems to be especially obvious in the early stages of a training program when significant gains in strength occur without necessarily increasing muscle mass (27,33). A study by Ikai and Fukunaga (19), showed an increase of 92% in maximal strength and only a 23% increase in muscle cross-sectional area. The large difference may indicate that strength gains were largely due to improvements in neural drive and/or improved recruitment patterns (6,34).

The pattern of recruitment of MUs is also important when trying to achieve the greatest effect from a training program. Different activities require a specific pattern of recruitment with MUs contracting at the appropriate time and angle to create proper velocity when performing a specific function (22). Sale (34) suggests two reasons for designing a task-specific training program. First, the location of a MU within a muscle may allow it to produce a greater force when the contractions are in a specific direction. Second, changes in the recruitment order of MUs caused by changes in posture and limb positioning allows rotation of MU activity allowing a "rest" period and delaying fatigue of the individual MUs (33). Training the muscle fibers in the specific direction followed during the throwing motion may allow the MUs to produce a greater force.

The velocity of the contraction also has an effect on MUs. As stated earlier, there is a difference in firing rate of MUs between fast and slow contractions (33,7). In a maximal ballistic movement such as the pitching or throwing motion, firing rates of the MUs are the highest. For this reason it may be valuable to simulate not only the movement pattern but also the velocity of the movement in the training program. A study involving the knee extensor muscles by Kanehisa and Miyashita (21), showed that velocity-specific training effects do exist. Twenty-one subjects were randomly assigned to one of three groups: group S (slow) trained at 1.05 rad/sec (n=8); group I (intermediate) trained at 3.14 rad/sec (n=8); and group F (fast) which trained at 5.24 rad/sec (n=5). Pre and post-testing was done at 1.05, 2.09, 3.14, 4.19, and 5.24 rad/sec. Statistically significant increases in average power for groups S and I were found at all test speeds. Group F showed statistically significant increases only at the faster test speeds of 4.19 and 5.24 rad/sec. Groups I and F showed statistically greater increases in power than group S. A study by Coyle (7) showed a significant enlargement of type II muscle fibers in the knee extensor muscles at a velocity of 300°/sec. Results of these studies suggest that velocity of training may be important when trying to optimize the applicability of a training program to a specific movement.

PROGRAMS FOR INCREASING THROWING VELOCITY

Researchers have evaluated the effects of isokinetic and isotonic strength training programs on throwing velocity, high speed strength, endurance and flexibility (32). Some have found an increase in throwing velocity and others no increase or a drop in throwing velocity (28,32). These studies all attempted to increase the strength of the shoulder muscles involved in the throwing motion, specifically the rotator cuff muscles (supraspinatus, infraspinatus, teres minor, and subscapularis) (28,30). The disadvantage to this type of training program is the relatively slow movement in which the exercises were performed.

In spite of relatively slow training movements, a positive correlation between pitching velocity and internal and external rotator strength using an isokinetic dynamometer at a velocity of 240°/sec was shown by Pawlowski et al. (30). "While these findings do not establish a cause-and-effect relationship, they do suggest a specificity of exercise for the shoulder internal and external rotator muscle groups" (30, p. 129). In a study by Wooden (40), 27 volunteers were randomly assigned to one of three groups - isokinetic, isotonic or a control group. The isokinetic and isotonic training groups trained for five weeks, three sessions per week while the control group did no training. The results indicated the isotonic group increased pitching velocity significantly more than the isokinetic group (2.06 vs. .86 mph), while the control group decreased (-.34 mph) (40). Intense muscular effort against high resistance provides the stimulus to increase the strength and cross-sectional area of muscle fibers (14). The ballistic nature of the throwing motion however, suggests the need for a program that allows for greater velocities to be attained during training while trying to strengthen the muscles involved.

Since the 1960s researchers have studied the effects of using various weighted baseballs on pitching velocity. Many earlier studies have shown an increase in throwing velocity using baseballs weighing seven to 12 ounces (a standard baseball weighs five ounces) (9). However, the throwing distance for these studies was always less than the regulation 60′ 6" and often resulted in an exaggerated throwing motion or arcing flight path. With specificity of training proving to be more and more important in achieving muscular and neural adaptations, these programs have changed to using baseballs ranging from 4-6 ounces to help maintain a normal throwing motion and distance (9,10). In a study by DeRenne (12), 30 male high school varsity baseball pitchers were randomly assigned to one of three groups: over-weighted implement(OITG), under-weighted implement (UITG), or a control group (CON). During the 10 week training period, the implement groups threw balls that varied from 5-6 ounces or 4-5 ounces and the CON group used the standard weight ball of five ounces. Each group showed improvement in throwing velocity. However, the implement groups showed significantly greater improvement in throwing velocity. Mean velocity improvement for the OITG was 3.75 +/- 2.42 mph. The UITG improved throwing velocity 4.72 +/-2.1 mph, while the CON group increased only .88 +/-.77 mph. Increases in throwing velocity have ranged from 1.5-4.7 mph using various weighted baseballs in a training program (11,9,12).

Throwing Cords (TC) or elastic tubing connected to the throwing arm during the throwing motion is another type of training program being used in an attempt to increase throwing velocity. Currently only five studies have used the TCs and none have been published. Combined, these studies have involved approximately 150 subjects and have shown increases in pitching velocity from 2-4 mph.[1] In each of the experiments the subjects participated in two throwing sessions per week for 6-8 weeks. The sessions consisted of an individual warm-up session then six sets of 10 repetitions with the TC providing resistance to the arm. In addition, to strengthen the external rotators, each of the subjects was given a lifting program to be completed at the end of each session.

The ideology behind the TC lies in the overload principle and the principle of specificity. By subjecting the musculature to more work than it is accustomed to, changes in the morphology of the muscle occur making the muscle capable of producing more force. (33, 7, 18) These changes take place during the same direction of movement and at a velocity that is somewhat slower than the normal motion but closer than the methods previously discussed. Maintaining the same direction of movement and attempting to maintain the velocity may enhance the transfer of learning and coordination from the training program to a real life situation. With the TC, an athlete is able to closely approximate the normal internal (7-9,000°/sec) and external rotation velocity and still achieve a strengthening or overload effect on the shoulder musculature. Type II (fast twitch) muscle fibers are largely responsible for the powerful and fast throwing motion. Resistance training at high speeds such as with the TC most prominently affects type II motor units. (14) The specificity of this training method may then promote an increase in throwing velocity.

Arm ergometers (AE) are a new addition to products being used to increase throwing velocity. At the present time no research has been published regarding the effect the AE may have as a method to increase throwing velocity. The advantages an AE has

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[1] Interview with John Frappier, MS, Exercise Physiologist, June, 1996.

over isokinetic and isotonic training programs also relates to the principles of overload and specificity. As with the Throwing Cords, an AE can apply resistance to the throwing arm in the normal direction and approximate the normal velocity of the throwing motion.

SUMMARY

The mechanics of throwing and ways to increase throwing velocity have been studied quite extensively. However, with the advent of new products for increasing pitching velocity comes the necessity for further research. Two relatively new products that may effectively increase throwing velocity are TCs and AEs. Both the AE and TC products are based on the principles of overload and specificity. The lack of research on both the TC and AE products suggests a need for quantification of their effects on ball velocity. Also, if both programs do cause an increase in ball velocity, which elicits the greatest increase? An answer to this question would certainly broaden the body of knowledge currently available on programs designed to increase throwing velocity.

CHAPTER II

METHODOLOGY

Previous methods to improve throwing velocity have produced modest improvements in pitching velocity from 1-4 mph (40, 10). Given the importance of pitching to a baseball team, coaches, trainers, and athletes have continually sought to find the best program to provide an edge over others. Along with pitchers, position players may also benefit from a program to increase the speed and distance they can throw a baseball.

Previous programs to increase throwing velocity have included using various under and overweighted balls as well as isokinetic and isotonic strength programs (10,31,40). Although these methods have been shown to elicit modest improvements in throwing velocity, the relatively slow movement often associated with isokinetic and isotonic programs may be responsible for their limited effectiveness.

The principle of specificity has shown to be an important component for most training programs (33,40,7,22,21). Simulating a movement including the velocity and direction in a training program appears to be important when trying to maximize effectiveness. By maintaining an appropriate range for velocity and direction of movement, the correct neural and muscular components are stimulated and improved (33,7,21).

The overload principle is also an important component when designing a training program. To increase the contractile strength of a muscle, the muscle must be forced to work harder than it is used too (18,16). Using the overload principle in conjunction with the principle of specificity correctly stimulates the muscle to promote increased strength while more closely approximating the velocity and direction of contraction.

Two relatively new products for increasing throwing velocity are Throwing Cords (TC) manufactured by Acceleration Products, Inc., and the "Freestyle" arm ergometer (AE) manufactured by Ergometrx, Inc. Both of these devices give the athlete freedom of movement and permits him/her to go through the pitching or throwing motion without making changes in their normal motion. Resistance is added in both instances as the athlete brings the arm forward in the acceleration phase. The principles of specificity and overload appear to be better met by these devices than traditional weight training or isokinetic exercise and therefore may provide positive results for increasing throwing velocity.

Little research has been conducted using the TC and none has been done using the AE. With the advent of new technology that has been applied to increasing throwing velocity, comes the need to test this new technology and determine it's effectiveness on improving throwing velocity. Further testing of both methods with documented results would broaden the current body of knowledge on training programs for throwing. This increased knowledge would benefit coaches, trainers, and athletes when choosing a program to increase throwing velocity.

PURPOSE

The purpose of this study was to determine the effects supplemental training with the TC and the "Freestyle" AE have on throwing velocity compared to a traditional throwing program.

HYPOTHESES

The following null hypotheses were tested in this investigation:

1. There will be no difference in effect on throwing velocity between the supplemented TC and AE training programs or the traditional throwing program after five weeks of training.

2. There will be no difference (% change) in internal rotator peak torque measured by an isokinetic dynamometer between the supplemented TC and the AE training groups or the traditional training group after five weeks of training.

3. There will be no difference in effect on shoulder external rotation range of motion (ROM) measured by goniometry between the supplemented TC and AE training groups or the traditional training group after five weeks of training.

LIMITATIONS OF THE STUDY

1. A five week training period may not be long enough to see significant improvements in throwing velocity or internal rotator strength.

2. Subjects may not give a full effort on isokinetic strength testing and/or throwing velocity trials.

3. All subjects may not follow the traditional program in its entirety.

4. Due to the high level of variability of the subjects, warm-up before testing and training was on an individual basis rather than standardized which may affect results.

METHODS

Subjects

Twenty-seven Division II Varsity baseball players (mean age, 19.5 ± 1.1 yrs; height, 182 ± 6.6 cm; weight, 83.5 ± 10 kg) were recruited from the St. Cloud State University baseball team. Each subject was chosen to participate given he signed an informed consent form, had a doctor's approval if he had past history of throwing arm injury, and had been throwing a baseball at least three times a week for a minimum of four weeks prior to beginning the program. The athletes had just finished fall baseball practice and were entering a winter training program before spring practice began in January. Using a random number table athletes were assigned to one of three training groups: traditional (T), traditional plus Throwing Cord (TC), or traditional plus arm ergometer (AE).

Instrumentation

Internal rotator (IR) strength was determined using a Biodex (Biodex Corp., Shirley, NY) isokinetic dynamometer. Maximum ball velocity was determined using a JUGS (Jugs Gun Corp., Tualatin, OR) radar gun. Shoulder external rotation ROM (ER ROM) was measured with a goniometer (Therapeutic Equipment Corp., Clifton, NJ).

Throwing cords (Acceleration Products Inc., Fargo, ND) made of elastic tubing with neoprene velcro sleeves were used to provide resistance to the throwing arm. The "Freestyle" AE (Ergometrx Inc., Minneapolis, MN) and the computerized program provided with the AE was used to apply resistance during AE training.

A load cell (Transducer Techniques model MLP-200, Temecula, CA), Panasonic video camera, and IBM computer were used to approximate the average and peak resistance being applied to the arm as well as to approximate the amount of work being done at each resistance setting during the throwing motion for all three groups.

Data analysis was performed on a Macintosh (Macintosh, Cupertino, CA) computer.

Procedures

Before beginning the study, a written and oral explanation of all procedures was given to each subject. Each subject then read and signed an informed consent form (Appendix B) and a physical activity readiness questionnaire (Appendix C). If there were no contraindications and the athlete had met the four week active throwing period requirement, he was selected as a subject. Subjects were assigned to either the traditional training group or traditional training plus TC or AE supplementation using a random number table.

All range of motion (ROM) measurements were taken using a passive-assisted approach. One of two testers took all measurements to minimize inter-tester error. Measurement of shoulder ER ROM was determined according to Esch and Lepley (15). The goniometer axis was placed on the center of the elbow with the shoulder abducted 90°, the elbow flexed to 90°, and the palm facing the ground. The anterior-posterior plane served as a reference for determining ROM. Zero degrees was on the anterior side and 180° on the posterior side. Ninety degrees of rotation was located on the superior-inferior axis.

Isokinetic strength evaluation of the IRs of the throwing arm took place at Orthopaedic Sports Center in St. Cloud, MN. The dynamometer was calibrated according to the established protocol by Biodex. To facilitate warm-up and familiarization with the dynamometer, each subject performed five submaximal and one maximal repetition at the test speed of 180°/sec (4). The testing position was the modified neutral testing position described by Davies (8), with the subject standing, the shoulder at 0° abduction and the elbow at 90° flexion. This position was chosen to promote a full effort at the designated test speed. A test speed of 180°/sec was selected as recommened by Brown (4) that showed isokinetic testing of the IRs and ERs of 41 professional baseball players produced highest peak torques at that speed. Subjects completed three maximal trials of five repetitions in accordance with procedures by Arrigo (2), involving isokinetic testing of 191 professional baseball players. Arrigo's study showed IR and ER peak torque is attained between the second and fourth repetition. A 60 second rest period was given between each set. The peak torque achieved during the three trials was recorded for both pre and post testing. Care was taken to avoid selecting the "overshoot" torque which typically appears as an initial spike in the subject's torque output (35).

After a minimum rest period of 24 hours and maximum of two days following the IR strength testing, each subject performed the throwing velocity test. Each subject warmed-up to his own satisfaction before beginning the trials as if preparing to play or pitch a game. All subjects threw from a level surface to a target positioned 18.5 meters (appr. 60" 6') away. In order for the trial to be recorded, the throw had to hit in the area characterized as the strike zone (76 cm wide x 91.5 cm high). A maximum of 20 attempts was allowed to hit the strike zone 10 times. A JUGS radar gun was held by the tester behind the target to determine the velocity of the ball. The ball velocity of each of the throws in the strike zone (up to 10) was recorded along with the average, maximum, and minimum velocity of the 10 trials for pre and post-training. Appendix D shows the pre and post-training results for average ball velocity, IR peak torque and ER ROM.

Both the TC and AE supplemented training groups trained two times per week for five weeks with the appropriate device. Preliminary research by Frappier has shown increases in throwing velocity after six weeks of training with the TC.[2] However, in order to implement the training program between fall and spring baseball, only a five week training period was available.

Subjects were encouraged to begin all training sessions with stretching exercises for both the upper and lower body, concentrating on the shoulder, chest and back muscles. Throwing warm-up was on an individual basis with a minimum of 50 throws. Additional throwing on an individual basis was allowed until the athlete felt he was ready to throw with the TC or AE. In addition to the two days training with the TC and AE, subjects trained using the traditional throwing program provided by the baseball coach. The

[2] Interview with John Frappier, MS, Exercise Physiologist, June, 1996.

traditional throwing program provided by the coach for both position players and pitchers, including throwing and running is in Appendix E. The team weight training program can be found in Appendix F. For the first two weeks of the training period, subjects threw five times per week. The final three weeks consisted of four throwing sessions per week. The reason for decreasing the number of throwing sessions was to minimize arm soreness and facilitate recovery of the shoulder muscles as resistance was increased with the TCs and AE.

Once training began, subjects in the TC supplemented group performed their throwing motion for six sets of 10 repititions with the TC attached to the arm. The TCs were attached to the arm when the shoulder was abducted 90° and the elbow flexed to 90°. The attachment sites were one-half inch proximal to the radial and ulnar styloids on the forearm and midway between the olecranon process and the acromion on the upper arm. In both instances, the elastic tubing was on the posterior or dorsal side of the arm. At the completion of the deceleration phase, subjects using the TC began a three second count to slowly return the arm to the starting position. Subjects in the AE supplemented group also went through six sets of 10 repetitions of their throwing motion with the arm attached to the AE. The athlete stood with the throwing arm closest to the front of the AE and wrist strap around the throwing arm wrist (Figure 1). As the athlete began his motion he strided away from the AE pulling on the wrist strap until he completed his motion. No ball was released when using the AE or the TCs. Both the TC and AE groups had a 1-2 minute rest period between sets to facilitate recovery of the shoulder musculature.

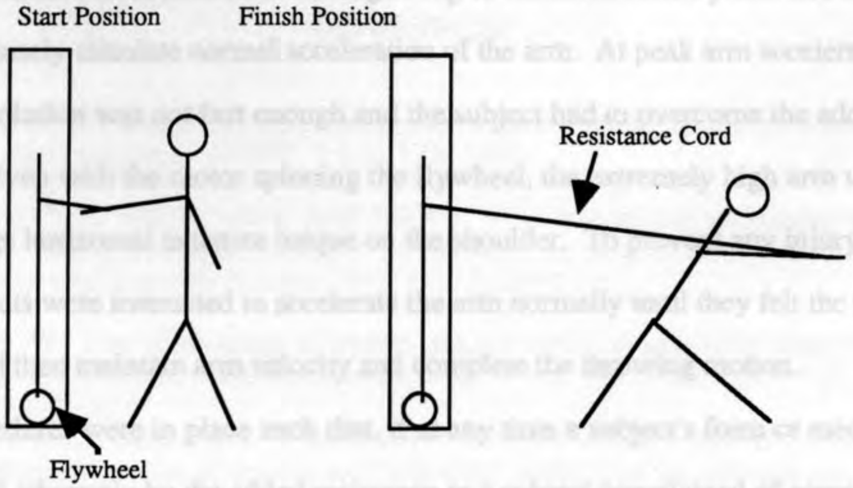

Figure 1. Start and finish positions while using the arm ergometer.

Resistance was applied for the TC and AE supplemented training groups according to Appendix G. Resistance was added progressively from sets 1-6 for each session. The amount of resistance applied by the TC is determined by the amount of stretch of the cord. A load cell was used to determine the amount resistance applied at distances of stretch ranging from 15-122 cm. The load cell was calibrated using various weights and a regression equation obtained. Voltage readings from the load cell while stretching the TC could then be converted to kilograms of resistance. Horizontal displacement during the throwing motion was determined during pilot testing to be the subject's stride length plus 5 cm (± 2 cm). This was used to establish the correct starting point to obtain the desired resistance applied by the TC.

The resistance setting on the AE was set using the digital reading on the AE. Pilot testing with the AE demonstrated an elevated arm force required to overcome the moment of inertia of the flywheel at rest. To reach normal arm velocities and accelerations encountered during throwing, a motor was attached to the flywheel via a "V" belt attached to the flywheel shaft to keep it spinning at all times. With the flywheel spinning, the moment of inertia was decreased at the beginning of the acceleration phase and allowed the subjects to closely simulate normal acceleration of the arm. At peak arm accelerations the flywheel revolution was not fast enough and the subject had to overcome the added resistance. Even with the motor spinning the flywheel, the extremely high arm velocities caused a large horizontal extensor torque on the shoulder. To prevent any injury from this torque, subjects were instructed to accelerate the arm normally until they felt the resistance being applied then maintain arm velocity and complete the throwing motion.

Procedures were in place such that, if at any time a subject's form or mechanics were affected adversely by the added resistance or a subject complained of soreness in the elbow or shoulder, the resistance would be reduced to a level that would allow him to complete that day's session. No adjustments of this nature were necessary.

After completing resisted throws with the TC or AE, each subject threw an additional 40 times to a target unresisted. The unresisted throws were an accuracy practice and cooldown period. Only on very limited occasions when subjects missed a training day were successive training sessions on the TC or AE allowed. All training was supervised by the researcher and/or his associates to ensure uniformity of training.

Data Analysis

An ANOVA showed differences in average throwing velocity between groups prior to training so an ANCOVA using the pre training data as the covariate was used to analyze the data. Training group - T, TC or AE was the independent variable, with dependent variables being internal rotator peak torque, shoulder external rotation ROM and average ball velocity. Post-test ball velocity values were correlated with IR peak torque and ER ROM individually and a multiple correlation with IR peak torque and ER ROM.

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APPENDICES

APPENDIX A

Manuscript

MANUSCRIPT

Introduction

Throwing velocity is a vital element of success for any baseball player. For this reason, ways to improve throwing velocity have continually been sought by coaches and athletes. Although throwing velocity is usually discussed only when talking about pitching, it is also important for position players. Previous ways to improve throwing velocity have included under and over-weighted implement training, isokinetic strength programs, isotonic strength training, Theraband's, and traditional throwing programs. Improvements in throwing velocity have ranged from 1-4 mph (5,16). Except for traditional throwing programs and under-weighted implement training, a fault of these programs is the relatively slow angular velocity involved compared to the extremely fast angular velocity (6000-9000°/sec) during throwing (8,9). Specificity is important when training to develop the neural component as well as muscular component of the muscles involved in the action (11). The common factor in a program designed to increase throwing velocity is an attempt to strengthen the shoulder musculature involved in the throwing motion.

Two relatively new devices that can be used to more closely simulate the direction and velocity of the throwing motion are the "Throwing Cord" (TC) and "Freestyle" arm ergometer (AE). The TC and AE (slightly modified) allow the user to more closely simulate the typical throwing arm motion and velocity than isokinetic, isotonic, and over-weighted implement programs while still applying resistance. A lack of research implementing these two devices in a training program suggests the need to quantify the effect they may have on throwing velocity.

The purpose of this study was to determine the effects of three different training programs on throwing velocity, internal rotator (IR) peak torque and external rotation (ER) range of motion (ROM) of the throwing arm on Division II baseball players.

Materials and Methods

Twenty-three Division II Varsity baseball players (mean age, 19.5 ± 1.1 yrs; height, 182 ± 6.6 cm; weight, 83.5 ± 10 kg) were recruited from the St. Cloud State University baseball team. Before beginning the study, a written and oral explanation of all procedures was given to each subject. Each subject then read and signed an informed consent form and a physical activity readiness questionnaire. If there were no contraindications and the athlete had met the four week active throwing period requirement, he was selected as a subject. The athletes had just finished fall baseball practice and were entering a winter training program. Athletes were assigned randomly to one of three training groups: traditional (T), traditional plus Throwing Cord (TC), or traditional plus arm ergometer (AE).

Throwing cords (Acceleration Products Inc., Fargo, ND) made of elastic tubing with neoprene Velcro sleeves were used to provide resistance to the throwing arm in the TC group. The "Freestyle" AE (Ergometrx Inc., Minneapolis, MN) and the computerized program provided with the AE was used to apply resistance during AE training.

All ROM measurements were taken using a passive-assisted approach. Shoulder ER ROM was measured with a goniometer (Therapeutic Equipment Corp., Clifton, NJ). One of two testers took all measurements to minimize inter-tester error. Measurement of shoulder ER ROM was determined according to Esch and Lepley (1974) (6). The goniometer axis was placed on the center of the elbow with the shoulder abducted 90°, the elbow flexed to 90°, and the palm facing the ground. The anterior-posterior plane served as a reference for determining ROM. Zero degrees was on the anterior side and 180° on the posterior side.

Isokinetic strength evaluation of the IRs of the throwing arm took place at Orthopaedic Sports Center in St. Cloud, MN. Internal rotator strength was determined using a Biodex (Biodex Corp., Shirley, NY) isokinetic dynamometer. The dynamometer was calibrated according to the established protocol by Biodex. To facilitate warm-up and familiarization with the dynamometer, each subject performed five submaximal and one maximal repetition at the test speed of 180°/sec (3). The testing position was the modified neutral testing position described by Davies (4), with the subject standing, the shoulder at 0° abduction and the elbow at 90° flexion. This position was chosen to promote a full effort at the designated test speed. A test speed of 180°/sec was selected as recommended by Brown (3). Brown found highest peak torque's at 180°/sec when isokinetically testing the internal and ERs of 41 professional baseball players. Subjects completed three maximal trials of five repetitions in accordance with procedures by Arrigo (2), which showed IR and ER peak torque is attained between the second and fourth repetition. A 60 second rest period was given between each set. The peak torque achieved during the three trials was recorded for both pre and post testing. Care was taken to avoid selecting the "overshoot" torque which typically appears as an initial spike in the subject's torque output (13).

After a minimum rest period of 24 hours and maximum of two days following the IR strength testing and ER ROM testing, each subject performed a throwing velocity test. Each subject warmed-up to his own satisfaction before beginning the trials as if preparing to play or pitch a game. All subjects threw from a level surface to a target positioned 18.5 meters (appr. 60" 6') away. In order for the trial to be recorded, the throw had to hit in the area characterized as the strike zone (76 cm wide x 91.5 cm high). A maximum of 20 attempts was allowed to hit the strike zone 10 times. A JUGS radar gun (Jugs Gun Corp., Tualatin, OR) was held by the tester behind the target to determine the peak velocity of the ball. The ball velocity of each throw in the strike zone (up to 10) was recorded.

Subjects were encouraged to begin all training sessions with stretching exercises for both the upper and lower body, and a minimum of 50 throws. Additional warm-up was allowed until the athlete felt he was ready to train. The T group trained according to the traditional training program provided by the coach. This program consisted of variations in throwing intensity (expressed as a percentage of maximum velocity), time and distance. Both the TC and AE supplemented training groups trained two times per week for five weeks with the appropriate device. On training days when the TC or AE were not used, the TC and AE groups used the traditional throwing program. All subjects were instructed to follow the team weight training program.

For the first two weeks of the training period, all groups threw five times per week. The final three weeks consisted of four throwing sessions per week. To minimize arm soreness and facilitate recovery of the shoulder muscles as resistance was increased with the TCs and AE the number of throwing sessions per week was decreased to four.

Subjects in the TC supplemented group performed their throwing motion for six sets of 10 repetitions with the TC attached to the arm. The TCs were attached to the arm when the shoulder was abducted 90° and the elbow flexed to 90°. The attachment sites were one-half inch proximal to the radial and ulnar styloids on the forearm and midway between the olecranon process and the acromion on the upper arm. In both instances, the elastic tubing was on the posterior or dorsal side of the arm. At the completion of the deceleration phase, subjects using the TC began a three second count to slowly return the arm to the starting position.

Preliminary research by Frappier has shown increases in throwing velocity after six weeks of training with the TC.[2] However, in order to implement the training program between fall and spring baseball, only a five week training period was available.

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[2] Interview with John Frappier, MS, Exercise Physiologist, June, 1996.

Subjects in the AE supplemented group also went through six sets of 10 repetitions of their throwing motion with the arm attached to the AE. The athlete stood with the throwing arm closest to the front of the AE and wrist strap around the throwing arm wrist (Figure 1). As the athlete began his motion he strided away from the AE pulling on the wrist strap until he completed his motion. No ball was released when using the AE or the TCs. Both the TC and AE groups had a 1-2 minute rest period between sets to facilitate recovery of the shoulder musculature.

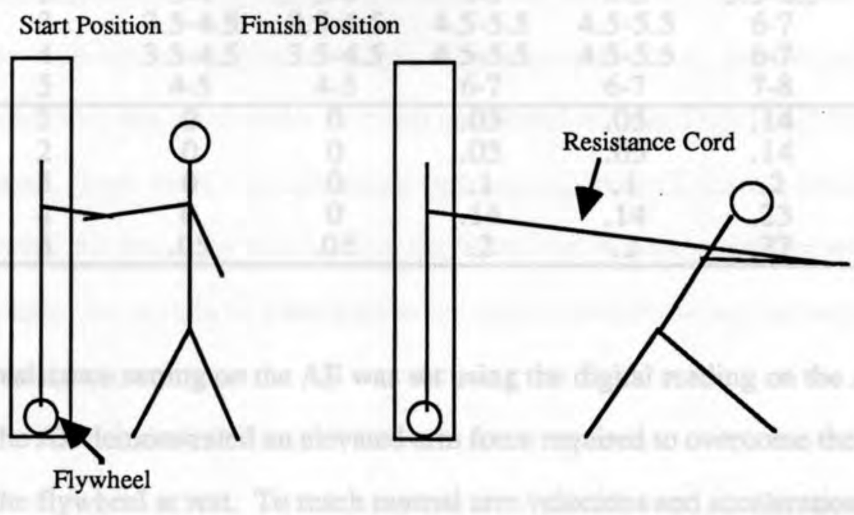

Figure 1. Start and finish positions while using the arm ergometer.

Resistance applied for the TC and AE supplemented training groups is listed in Table 1. Resistance was added progressively from sets 1-6 for each session. The amount of resistance applied by the TC is determined by the amount of stretch of the cord. A load cell (Transducer Techniques model MLP-200, Temecula, CA) was used to determine the amount of resistance applied at distances of stretch ranging from 15-122 cm. The load cell was calibrated using various increments of weight and a regression equation obtained.

Voltage readings were converted to kilograms of resistance. Horizontal displacement during the throwing motion was determined during pilot testing to be the subject's stride length plus 5 cm (± 2 cm). This was used to establish the correct starting point to obtain the desired resistance applied by the TC.

Table 1

Resistance Applied During Each Training Session With The Throwing Cord and Arm Ergometer

				Resistance	(Kg/set)		
Group	Week	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6
	1	3-4	3-4	4-5	4-5	5.5-6.5	5.5-6.5
	2	3-4	3-4	4-5	4-5	5.5-6.5	5.5-6.5
TC	3	3.5-4.5	3.5-4.5	4.5-5.5	4.5-5.5	6-7	6-7
	4	3.5-4.5	3.5-4.5	4.5-5.5	4.5-5.5	6-7	6-7
	5	4-5	4-5	6-7	6-7	7-8	7-8
	1	0	0	.05	.05	.14	.14
	2	0	0	.05	.05	.14	.14
AE	3	0	0	.1	.1	.2	.2
	4	0	0	.14	.14	.23	.23
	5	.05	.05	.2	.2	.27	.27

The resistance setting on the AE was set using the digital reading on the AE. Pilot testing with the AE demonstrated an elevated arm force required to overcome the moment of inertia of the flywheel at rest. To reach normal arm velocities and accelerations encountered during throwing, an electric motor was used to drive the flywheel via a "V" belt attached to the flywheel shaft. With the flywheel spinning, the moment of inertia was decreased at the beginning of the acceleration phase and allowed the subjects to more closely simulate normal acceleration of the arm. At peak arm accelerations the flywheel revolution was not fast enough and the subject had to overcome the added resistance. Even with the motor spinning the flywheel, the high arm velocities caused a large horizontal extensor torque on the shoulder. To prevent any injury from this torque, subjects were instructed to accelerate the arm normally until they felt the resistance being applied then maintain arm velocity and complete the throwing motion.

After completing resisted throws with the TC or AE, each subject threw a baseball an additional 40 times to a target unresisted. The unresisted throws were an accuracy practice and cool down period. All sessions were supervised by the researcher and/or his associates to ensure uniformity of training.

To estimate the amount of work done during each training session with the AE and TC, a subject was filmed while performing the throwing motion with both the TC and AE. A load cell was connected to the AE or TC to record the resistance offered by each device. The force data were time normalized to 60 Hz using a common event and interpolated. Distance moved from one point to the next was calculated with the Peak5 3-D Motion Analysis System. Total work was calculated by summing work (Σ force x distance) performed during the throwing motion. For the unresisted throwing motion, work was calculated by using the weight of a baseball as the force to overcome and an average distance moved during a stride.

An ANOVA showed differences between groups prior to training so an ANCOVA using the pre training data as the covariate was used to analyze data. Training group (T, TC or AE) was the independent variable, with dependent variables being IR peak torque, shoulder ER ROM and average ball velocity. Post-test ball velocity values were correlated with IR peak torque and ER ROM both individually and combined.

Results

Twenty-three of the 25 volunteer subjects completed the five week program. Two athletes who did not finish the study dropped out do to conflicting responsibilities, not injury. Of the 23 who completed the study, 19 attended ≥85% of the training sessions. All subjects attended ≥70% of the training sessions. Table 2 shows the results from pre and post-testing for average ball velocity, ER ROM and IR peak torque, as well as team averages for each.

Table 2

Pre and Post Training Values For Each Subject and Team Averages

Group	Code #	Aver. Ball Vel-Pre m.p.h.	Aver. Ball Vel-Post m.p.h.	Ext. Rot. ROM-Pre degrees	Ext. Rot. ROM-Post degrees	Pre - IR Peak Torque N•m	Post - IR Peak Torque N•m
TC	1	74.20	74.10	105	117	74.6	70.5
TC	2	73.80	68.90	100	131	65.1	69.1
TC	9	65.86	67.40	103	140	55.6	71.9
TC	10	74.00	74.20	114	127	74.6	88.1
TC	12	68.60	67.50	90	114	55.6	63.7
TC	13	75.10	73.50	142	136	82.7	66.4
TC	15	74.80	73.90	140	156	54.2	61.0
TC	22	73.10	71.70	148	131	78.6	86.8
TC	23	64.13	65.38	92	92	67.8	71.9
TRAD	8	72.60	71.70	135	130	66.4	78.6
TRAD	5	75.50	74.50	123	130	84.1	77.3
TRAD	6	74.11	73.70	119	108	78.6	84.1
TRAD	11	72.80	74.80	126	135	74.6	78.6
TRAD	18	73.22	72.90	122	128	78.6	82.7
TRAD	20	76.30	80.50	119	130	70.5	89.5
TRAD	24	75.56	76.80	121	133	71.9	81.3
AE	3	69.44	69	115	123	74.6	74.6
AE	4	72.70	69.70	150	143	71.9	71.9
AE	7	75.40	73.80	134	137	65.1	69.1
AE	14	67.80	66.90	140	125	58.3	51.5
AE	17	73.60	74.00	120	124	75.9	71.9
AE	21	69.80	71.90	115	119	51.5	55.6
AE	25	64.25	64.78	114	119	58.3	73.2
Team		**72.03**	**71.81**	**121**	**127**	**69.1**	**73.2**

Figure 2 shows the average ball velocity values for each of the three training groups before and after the five week training period. The ANCOVA statistical analysis, using pre-training velocity values as the covariate showed no significant difference within or between groups. Absolute change in average velocity within each group was <1 mph.

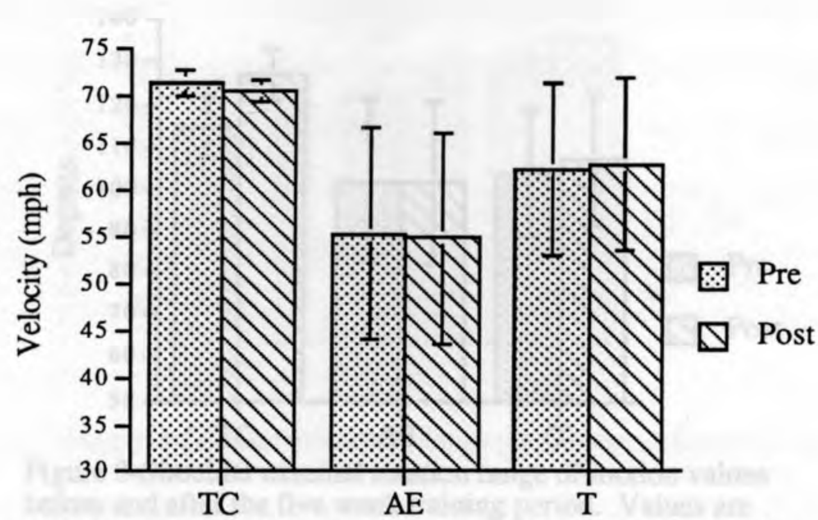

Figure 2-Average ball velocity values before and after the five week training period. Values are means +/-SEM.

Average ER ROM values are shown in Figure 3. No significant differences were found within or between groups probably due to large variability in ROM between subjects. Absolute change in mean ER ROM for the TC, AE, and T groups was 12°, +.3°, and 4°, respectively. Post-training ER ROM and ball velocity values showed a weak correlation ($p = .10$, $r=.35$, $R^2=.12$, SEM= ±3.7). Pre to post-training team average showed a 6° increase in ER ROM. Average ER ROM for pitchers was 130° both pre and post-training while position players improved from 115° to 125°. No significant difference was found between pitchers and position players despite the large mean increase of the position players.

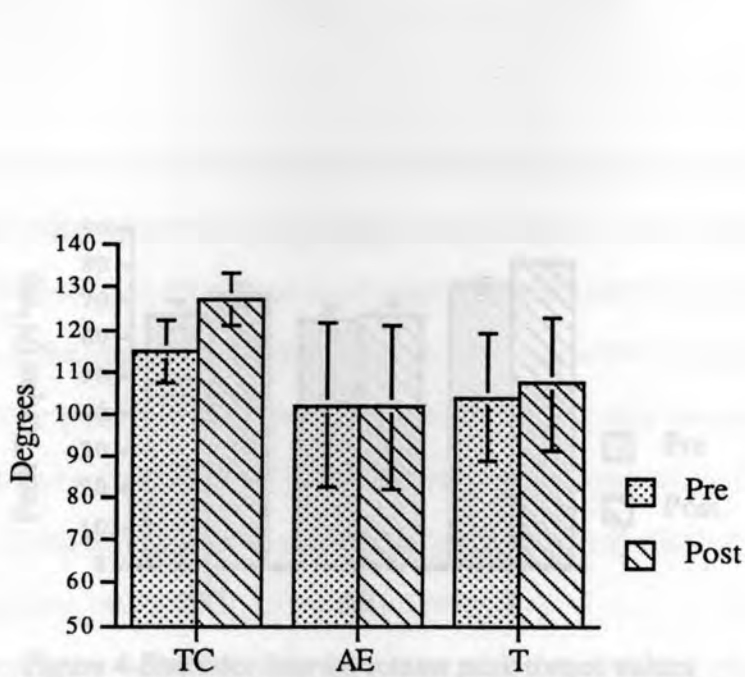

Figure 3-Shoulder external rotation range of motion values before and after the five week training period. Values are means +/-SEM.

Figure 4 illustrates the average IR peak torque values for both pre and post-training test results. Although average peak torque values increased for all three groups, there were no significant differences detected within or between groups. Absolute changes in average IR peak torque ranged from 5.4 N•m for the T group to 1.2 N•m for the AE group. A moderate correlation (p= .02, r=.47, R^2=.22, SEM= ±3.4) between IR peak torque and throwing speed was found. The team averages for IR peak torque pre and post-training were 69 and 73 N•m, respectively.

Work estimates for each of the three training groups showed large differences between groups. The AE group did the most work averaging 12,750 N•m of work for each training session over five weeks, with a minimum of 12,400 N•m and maximum of 13,500 N•m. For the TC group, 3,525 N•m of work was the minimum, 4,400 N•m the maximum, and the average workload per session over the five week training period was 3,700 N•m. The T group averaging a throw every five seconds for 15 minutes, did approximately 6000 N•m of work per session. In a 10 minute throwing session the amount of work performed was 4000 N•m.

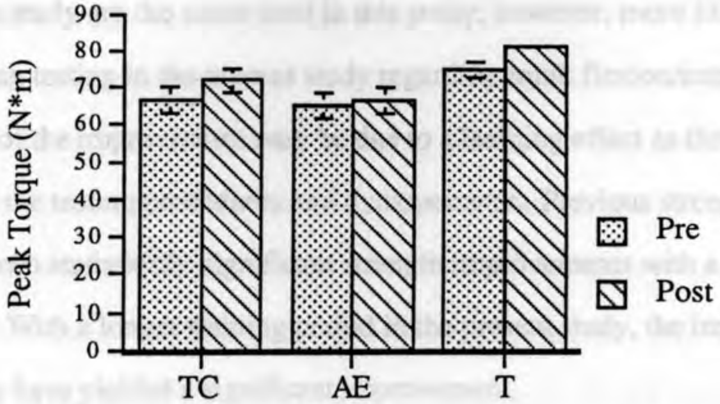

Figure 4-Shoulder internal rotator peak torque values before and after the five week training period. Values are means +/-SEM.

Discussion

The results of this study demonstrate that while IR peak torque and ER ROM have been correlated with throwing velocity in previous studies, small improvements in these parameters did not elicit gains in throwing velocity.

An increase in IR peak torque was seen in all groups. Due to a small average absolute change and large variability between subjects within a group, this difference was not statistically significant. A study by Pawloski (9) showed IR peak torque measured at 240°/sec is significantly correlated with throwing velocity. Perrin (10) compared bilateral relationships of several isokinetic measures of the shoulder musculature of pitchers and found the greatest bilateral difference was between the shoulder internal rotator muscle group. Mean values recorded in this study (69 N•m pre-test and 73 N•m post-test) are somewhat higher than mean peak torque values recorded by Brown (3) who tested 41 professional baseball players, and Alderink (1) who tested 26 baseball pitchers whose mean age was 18 yrs. Brown recorded a mean IR peak torque value of 57 N•m at a test speed of 180°/sec and Alderink 45 N•m at a test speed of 240°/sec. Alderink's methods of testing, however, were quite different from the methods used in this study. The methods used in Brown's study are the same used in this study; however, more liberty may have been given during testing in the present study regarding trunk flexion/extension and rotation. Some of the improvement may be due to a learning effect as the subjects got acquainted with the testing procedures and dynamometer. Previous strength training studies have shown statistically significant strength improvements with a 8-12 week training period. With a longer training period in the present study, the improvements in IR peak torque may have yielded a significant improvement.

It is interesting to note that while the TC group had the largest average increase in ER ROM, it had no relationship to average ball velocity. This seems to contradict the length-tension relationship described by Winter (15) which says a muscle that is stretched is able to generate more muscle force. Wang (14) found faster ball velocity at release was related to greater ER of the shoulder at the beginning of the acceleration phase. In the present study, pitchers had a greater average ER ROM than position player's; however, the average ROM value did not increase as it did for position players from pre to post-testing. The higher ER ROM average for pitchers found in this study is consistent with a previous study showing pitchers to average 9° more ER ROM in the throwing arm than position players (3). Despite the greater average ER ROM for pitchers, the pitchers averaged only 2.5 (pre-training) and 1.5 (post-training) mph greater throwing velocity than the position players.

To minimize the number of variables that may have influenced any changes in throwing velocity, specific exercises for the ERs of the shoulder were not included after each session with the TC or AE. Strengthening the ERs will help stabilize the shoulder for the high eccentric forces which occur during the deceleration phase of throwing. The ER muscles have been found to be approximately two-thirds as strong as the IR muscles (4).

Training and rehabilitation programs should strive to increase this ratio to support the shoulder joint and decrease the potential for injury (4).

The importance of isotonic training should not be dismissed. Although typical isotonic training is much slower than the throwing motion and may incorporate more slow twitch muscle fibers, the actual contribution of slow and fast twitch muscle fibers to accelerating the arm is not known and their involvement may be very beneficial. Selective recruitment of slow or fast twitch fibers has not been substantiated (12). Slow twitch muscle fibers can reach peak force within .1 s. Even though the arm acceleration phase occurs in approximately .05 s, slow twitch muscle fibers may be very instrumental in the accelerating the arm, while helping delay fatigue of the fast twitch fibers (11). Sale and MacDougall (12) suggest that evidence indicates strength training should be as specific as possible but also recognize that supplemental training at a low velocity may be necessary to cause maximal adaptation within the muscles.

Workloads between the three groups varied drastically yet differences in throwing velocity, ER ROM, and IR peak torque were not significantly different. Improvement was not consistent with increasing workloads. The AE group did approximately three times more work than the TC and T group. The large difference in amount of work with no effect on results suggests the importance of other influences on the throwing motion.

Not releasing a ball to a target may have hindered the TC and AE groups. This may have caused an alteration in the throwing motion. The muscles involved may have been called upon differently or mechanics changed to overcome the added resistance while not having to release a ball to a target. Prior research by Frappier[3] using the TC, involved the release of a ball and has shown increases in throwing velocity between 1-4 mph with an average increase of 2 mph The importance of releasing a ball when training may be

[3] Interview with John Frappier, MS, Exercise Physiologist, June, 1996.

partially explained by the transfer of momentum theory. The transfer of momentum theory states that as a proximal segment is slowed the distal segment is speeded up (14). Wang (14) showed that the forearm is slowed prior to release of a baseball therefore speeding up the hand due to the transfer of momentum theory. Not releasing a ball during training may not have trained the muscles involved in this component of the throwing motion, and could have had an influence on the non-significant findings of this study.

Additional limitations to this study that may have affected the findings include: 1) a five week training period may not have been long enough to allow for neural or physiologic changes in the musculature being trained, 2) the small group size (TC, AE, T) and large variability between subjects both within and between groups, 3) the lack of control over outside activities and inability to positively control the amount and intensity of throwing on traditional training days, and 4) and the current training status of the subjects being at a high level at the start of the study. Matching the subjects by strength for the TC and AE groups may also have allowed for more individualized programs to ensure all athletes were working at a level that would stimulate changes in the muscles being trained.

Recommendations

This study tested the effectiveness of three training programs on throwing velocity. None of the three methods was found to be superior to one another. The theorized success of the TC and AE on improving throwing velocity is based on the principles of specificity and overload. Both the TC and modified AE provided resistance to the throwing arm while striving to maintain the normal throwing motion and therefore meet the criteria for the specificity and overload principles. The moderate correlation found between ER ROM, IR peak torque, and ball velocity suggest these two variables together may have an effect on ball velocity; however, individual correlations between ER ROM and IR peak torque with ball velocity, indicate little practical value in predicting ball velocity due to the large SEM.

To truly determine the effectiveness of these devices for supplementing a traditional throwing program, further studies with more control over the traditional throwing, weight training, outside activities, and a longer training period supplemented with the TC and AE needs to be conducted.

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APPENDIX B

Informed Consent Form

You are invited to participate in a study designed to increase throwing velocity for baseball. We hope to determine if both the arm ergometer and Throwing Cords can be used to supplement traditional throwing programs to increase throwing velocity and which (the AE or TC) elicits the greatest improvement. You were selected for this study because you are currently training for baseball.

If you decide to participate, the researcher and his associates will explain all test procedures and training protocols with you. Pre and post testing will consist of strength testing performed on an isokinetic dynamometer, shoulder range of motion measurement and throwing velocity testing. Training will consist of two groups supplementing the traditional throwing program with either the AE or TC and one group doing only the traditional throwing program. Throwing sessions with the AE and TC will consist of six sets of 10 repititions with resistance and 40 throws with a regulation ball at the end of the training session.

Training sessions with the AE and TC will be done two times per week for six weeks plus two to three days of the traditional program. The traditional training group will follow the designated protocol. The testing and training sessions should take no longer than 45 minutes. You may experience soreness and stiffness as a result of overloading your muscles. Since you are an active baseball thrower, the risk of injury is very slight. If you feel discomfort during training inform the researcher and discontinue the exercise.

Any information that is obtained in connection with the study and can be identified with you will be coded and stored in a locked cabinet. All information will remain confidential and be disclosed only with your permission. Your decision to participate or not will not prejudice your future relations with SCSU. If you decide to participate, you are free to discontinue participation at any time without prejudice. If you have any additional questions, please contact Dean Stulz at 320-255-2373 or 320-654-6209. He will be happy to answer any questions you may have.

Your signature indicates that you have read the information provided and have decided to participate. You may withdraw at any time without prejudice after signing this form should you choose to discontinue participation in this study.

________________________ ________________

Signature Date

APPENDIX C

Physical Activity Readiness Questionnaire

1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?

2. Do you feel pain in your chest when you do physical activity?

3. In the past month, have you had chest pain when you were not doing physical activity?

4. Do you lose your balance beccause of dizziness or do you ever lose consciousness?

5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

6. Is your doctor currently prescribing drugs (for example, water pills) for your high blood pressure or heart condition?

7. Do you know of <u>any other reason</u> why you should not do physical activity?

If a person answers yes to any question, vigorous exercise or exercise testing should be postponed. Medical clearance may be necessary.

Referenced from <u>ACSM's Guidelines for Exercise Testing and Prescription, Fifth Edition</u>.

*Please pay particular attention to question #5 regarding the elbow and shoulder.

APPENDIX D

Pre and Post-Test Results for Average Velocity, ER ROM, and IR Peak Torque

Group	Code #	Aver. Ball Vel-Pre m.p.h.	Aver. Ball Vel-Post m.p.h.	Ext. Rot. ROM-Pre degrees	Ext. Rot. ROM-Post degrees	Pre - IR Peak Torque N·m	Post - IR Peak Torque N·m
TC	1	74.20	74.10	105	117	74.6	70.5
TC	2	73.80	68.90	100	131	65.1	69.1
TC	9	65.86	67.40	103	140	55.6	71.9
TC	10	74.00	74.20	114	127	74.6	88.1
TC	12	68.60	67.50	90	114	55.6	63.7
TC	13	75.10	73.50	142	136	82.7	66.4
TC	15	74.80	73.90	140	156	54.2	61.0
TC	22	73.10	71.70	148	131	78.6	86.8
TC	23	64.13	65.38	92	92	67.8	71.9
TRAD	8	72.60	71.70	135	130	66.4	78.6
TRAD	5	75.50	74.50	123	130	84.1	77.3
TRAD	6	74.11	73.70	119	108	78.6	84.1
TRAD	11	72.80	74.80	126	135	74.6	78.6
TRAD	18	73.22	72.90	122	128	78.6	82.7
TRAD	20	76.30	80.50	119	130	70.5	89.5
TRAD	24	75.56	76.80	121	133	71.9	81.3
AE	3	69.44	69	115	123	74.6	74.6
AE	4	72.70	69.70	150	143	71.9	71.9
AE	7	75.40	73.80	134	137	65.1	69.1
AE	14	67.80	66.90	140	125	58.3	51.5
AE	17	73.60	74.00	120	124	75.9	71.9
AE	21	69.80	71.90	115	119	51.5	55.6
AE	25	64.25	64.78	114	119	58.3	73.2
Team		**72.03**	**71.81**	**121**	**127**	**69.1**	**73.2**

APPENDIX E

Traditional Throwing Programs For Position Players and Pitchers

POSITION PLAYER PROGRAM

WEEK #	THROWING PROGRAM	RUNNING PROGRAM
1	4-6 day of catch 30 yards maximum distance 15 minutes maximum 40% maximum velocity	First workout day - 10 minute run Other days - 8 sprints fo 60 yards
2	5 days of catch (20 minutes total) STEP 1 - 30 yards maximum distance - 10 minutes STEP 2 - 40 yards maximum distance - 10 minutes, 70% maximum velocity	First workout day - 10 minute run Other days - 10 sprints of 60 yards
3	3 days (Example: Mon., Wed., Fri.) 20 minutes total time STEP 1 - 20 yards maximum distance - 10 minutes, 70% maximum velocity STEP 2 - 30-40 yards maximum distance - 10 minutes, 90-100% velocity maximum	First workout day - 15 minute run Other days - 10 sprints of 60 yards
4	3 days (Example: Mon., Wed., Fri.) 20 minutes total time STEP 1 - 20 yards maximum distance 10 minutes, 70% maximum velocity STEP 2 - 40-50 yds. maximum distance - 10 minutes, 100% velocity	First workout day - 15 minute run Other days - 12 sprints of 60 yards
5	3 days (Example: Mon., Wed., Fri.) 20 minutes total time STEP 1 - 30 yards maximum distance - 10 minutes, 70% maximum velocity STEP 2 - 40 yards - 10 minutes, 100% velocity	First workout day - 15 minute run Other days - 12 sprints of 60 yards

PITCHER PROGRAM

WEEK #	THROWING PROGRAM	RUNNING PROGRAM
1	4-6 day of catch 30 yards maximum distance 15 minutes maximum 40% maximum velocity	First workout day - 10 minute run Other days - 8 sprints fo 40 yards
2	5 days fo catch (20 minutes total) STEP 1 - 30 yards maximum distance - 10 minutes STEP 2 - 40 yards maximum distance - 10 minutes, 70% maximum velocity	First workout day - 10 minute run Other days - 10 sprints of 40 yards
3	3 days (Example: Mon., Wed., Fri.) 20 minutes total time STEP 1 - 20 yards maximum distance - 10 minutes, 70% maximum velocity STEP 2 - 30-40 yards maximum distance - 10 minutes, 90-100% velocity maximum	First workout day - 15 minute run Other days - 10 sprints of 40 yards
4	3 days (Example: Mon., Wed., Fri.) 20 minutes total time STEP 1 - 20 yards maximum distance 10 minutes, 70% maximum velocity STEP 2 - 40-50 yds. maximum distance - 10 minutes, 100% velocity	First workout day - 15 minute run Other days - 12 sprints of 40 yards
5	3 days (Example: Mon., Wed., Fri.) 20 minutes total time STEP 1 - Play catch to loosen up - 10 minutes STEP 2 - ON MOUND - Fastballs Only! - 10 minutes, 50-75% maximum velocity	First workout day - 15 minute run Other days - 12 sprints of 40 yards

APPENDIX F

Weight Training Program

Huskies Baseball Strength Program 1997 - Off Season Workout

Instructions:

1. Perform one set of each exercise.
2. Take no more than 2-3 minutes to perform each exercise.
3. Lift forty percent of the maximum weight you can lift during each exercise.
4. Rest periods between exercises should be no more than one minute.
5. After you have reached the maximum number of repetitions for an exercise, increase the weight by ten percent.
6. Alternate lower body exercises and upper body exercises.

Area	Exercise	Number of Repetitions
Hip/Back	Reverse/Side Sit-up	15-20
Quads	Leg Extensions	30-50
Quads/Buttocks	Leg Press	30
Hamstrings	Leg Curl	30-50
Shoulders	Bench Press/Lat. Pull	30-50
Shoulder/Arms	Chin-ups	30-50
Pectoral/Shoulder/Arms	Dips	30-50
Biceps	Biceps Curls	30-40
Triceps	Triceps Curls	30-40
Wrist/Forearm	Wrist Curls	40-60

APPENDIX G

Resistance Applied for Each TC and AE Training Session.

Group	Week	Set 1	Set 2	Resistance Set 3	(Kg/set) Set 4	Set 5	Set 6
	1	3-4	3-4	4-5	4-5	5.5-6.5	5.5-6.5
	2	3-4	3-4	4-5	4-5	5.5-6.5	5.5-6.5
TC	3	3.5-4.5	3.5-4.5	4.5-5.5	4.5-5.5	6-7	6-7
	4	3.5-4.5	3.5-4.5	4.5-5.5	4.5-5.5	6-7	6-7
	5	4-5	4-5	6-7	6-7	7-8	7-8
	1	0	0	.05	.05	.14	.14
	2	0	0	.05	.05	.14	.14
AE	3	0	0	.1	.1	.2	.2
	4	0	0	.14	.14	.23	.23
	5	.05	.05	.2	.2	.27	.27