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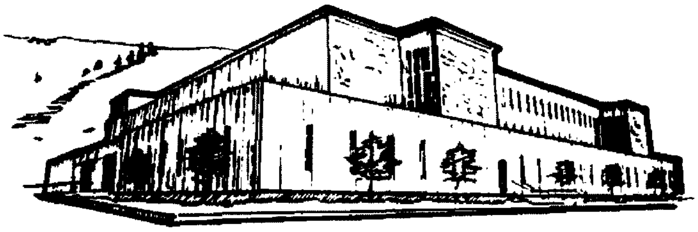

RELATIONSHIP BETWEEN SUPRASPINATUS STRENGTH AND THROWING VELOCITY AND ACCURACY OF MINOR LEAGUE PROFESSIONAL BASEBALL PLAYERS

By

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This study was conducted to establish whether a correlation existed between peak torque production of the supraspinatus muscle and throwing velocity or accuracy or both. Twenty-four minor league professional baseball players, consisting of 5 pitchers, 12 infielders, and 7 outfielders, were tested for supraspinatus strength and power using a Cybex II isokinetic dynamometer. Throwing velocity was measured with a radar gun. Throwing accuracy was measured with a rectangular target.

Results of statistical analyses performed on the data did not indicate a significant correlation between supraspinatus strength and throwing velocity or accuracy.

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INTRODUCTION

Context of the Study

Statement of the Problem

The supraspinatus muscle of the rotator cuff group is important in the function of the shoulder. Injuries to this muscle limit and, in severe cases, prohibit an individual's ability to participate in many activities. These limitations do not apply only to sports. People who routinely reach over their heads as part of their jobs, such as painters or carpenters, suddenly find that they no longer can work when they injure the supraspinatus. The simple joy of lifting a baby into the air may be denied them.

Sports requiring the use of overhead movements can cause injuries to the supraspinatus. Serving in tennis and overhead smashes in all racquet sports can cause problems. Swimming also causes quite a few injuries. Baseball, where all the players are required to throw a ball a great deal, produces many injuries to the supraspinatus. The position of highest susceptibility to supraspinatus injury is the pitcher, who constantly is required to throw at maximal or near maximal velocity and often throws over 100 pitches a game--not including the pregame warm up and preinning warm-up pitches. The rest of the players do not make as many throws during a game, but they do a great deal of throwing during practice.

Most injuries to the supraspinatus are of the overuse variety. These injuries usually cause the musculotendonous unit of the supraspinatus to weaken from lack of use during a healing phase. Pitchers usually are told to return to practice when they can pass a manual strength test with no pain. They no longer may have pain in the area, but do they have sufficient strength in the muscle to protect it from further injury?

Hypothetical Explanation of the Mechanics of Injury

The supraspinatus tendon is the most often injured portion of the rotator cuff. There is very little space for the tendon as it passes beneath the acromion-coracoid arch and inserts on the greater tubercle of the humerus. When the arm is elevated during the pitching motion, this space is further reduced. The humerus is internally rotated and elevated as a baseball is released. This causes the greater tubercle to come into close proximity to the acromion-coracoid arch. The supraspinatus tendon is between these two solid objects. If the humeral head is then allowed to slide forward, as the arm decelerates, the supraspinatus tendon will be impinged. Receptive impingement leads to an inflammatory response and thickening of the tendon. This causes a further reduction in the space available for the tendon to move. If this process is allowed to continue, the tendon can rupture and cause a partial or complete tear of the muscle.

A strong posterior cuff, infraspinatus and teres minor, is the best defense against this injury. A strong supraspinatus is also very important. The prevention of supraspinatus injury is much better than the rehabilitation of the injury.

Purpose of the Study

The purpose of this study was to determine correlations between the strength and power of the supraspinatus muscles of minor league professional baseball players and their throwing velocity and accuracy. A test examined in this study was designed to produce graphic quantitative measurements of the strength and power of the supraspinatus. The test results might be compared to a norm to determine a patient's readiness to return to participation. For baseball players, a good norm is the strength of healthy players who throw a baseball at approximately the same speed as a patient did before injury. This study attempted to determine if there is a correlation between the results of the test and the throwing velocity and accuracy of baseball players.

Research Subproblems and Hypotheses

Four subproblems, in relation to six hypotheses, were considered in this study: (a) determining subjects' maximum throwing velocity, (b) determining subjects' throwing accuracy, (c) determining subjects' maximum supraspinatus strength, and (d) determining subjects' maximum supraspinatus power. The six null hypotheses follow:

H_1. There will be no significant correlations between supraspinatus strength measured at 60° per sec and throwing velocity.

H_2. There will be no significant correlations between supraspinatus strength measured at 240° per sec and throwing velocity.

H_3. There will be no significant correlations between supraspinatus strength measured at 60° per sec and throwing accuracy.

H_4. There will be no significant correlations between supraspinatus strength measured at 240° per sec and throwing accuracy.

H_5. There will be no significant correlations between accuracy and throwing velocity.

H_6. There will be no significant correlations between supraspinatus strength measured at 60° per sec and supraspinatus strength measured at 240° per sec.

Theoretical Framework

Importance of the Study

Injuries to the supraspinatus are debilitating to baseball players. Manual testing of the supraspinatus does not yield quantitative results that can be compared to past and future tests. The Cybex II test could provide printed records of each test, and allow therapists or physicians to evaluate the progress of patients' rehabilitations. If the test scores correlate well with throwing velocity and accuracy, the test could be used to estimate how fast patients should be able to throw. The test also could be used as a screening device to identify people with muscular weakness of the supraspinatus which could put them at a higher risk of injury.

Assumptions

There were two assumptions.

1. The subject group was representative of the Class A Peninsula White Sox minor league professional baseball players of 1986-1987.

2. The subjects performed to the best of their abilities on all tests.

Delimitations of the Study

There were five study delimitations.

1. The study did not attempt to analyze the throwing motion of the subjects.

2. The study did not identify minimal strength requirements for injury prevention.

3. The study did not examine the relationship of the rest of the shoulder musculature to throwing velocity or accuracy.

4. The study was limited to males, ages 18-24, playing minor league professional baseball.

5. No subject could have a present or past injury which could inhibit his throwing ability.

Limitations of the Study

There were four study limitations.

1. The study did not test the strength of the supraspinatus in a natural throwing motion.

2. The supraspinatus cannot be truly isolated from all the other muscles involved with shoulder movement.

3. The subjects of this study were not randomly selected; they were volunteers.

4. The limited availability of the Cybex II dynamometer for testing and the team's travel schedule prevented a test-retest protocol to establish reliability.

Definitions of Terms

Accuracy. The ability to hit a target with a thrown baseball from a predetermined distance.

Angular velocity. The speed at which a lever arm rotates about a fixed axis.

Rotator cuff injury. An injury to any one or a combination of two or more of the four muscles that make up the rotator cuff of the shoulder. The injury can be anything from a mild strain to a complete tear of the muscle. The two most commonly injured muscles are the supraspinatus and infraspinatus. The other two muscles are the teres minor and subscapularus.

Strength. The maximal torque output, measured in ft lbs, that an individual can generate at an angular velocities of 60° and 240° per sec.

Supraspinatus strength. The peak torque measurement obtained from the shoulder strength test used in this study. The deltoid and supraspinatus muscles are responsible for the torque produced.

Velocity. The speed at which an individual throws a baseball at a specific target.

Organization of the Study

Chapter 2 reviews study-related literature regarding anatomy, injury prevention role, analysis of the throwing motion, and isokinetic testing. The study methodology is detailed in chapter 3. Chapter 4 focuses on the analyses of the data, and chapter 5 presents conclusions and makes recommendations for further research.

Chapter 2

REVIEW OF THE LITERATURE

A review of the literature covered four areas of investigation related to this study: (a) anatomy, (b) injury prevention role, (c) analysis of the throwing motion, and (d) isokinetic testing.

Anatomy

The shoulder arm complex, or the pectoral girdle, is attached to the axial skeleton only at the sternum. This allows the complex to be highly versatile in terms of movement, as well as unstable and relatively weak (Crouch, 1978). The complex is composed of three joints, the glenohumeral, the acromioclavicular, and the sternoclavicular. This study is concerned primarily with the glenohumeral joint.

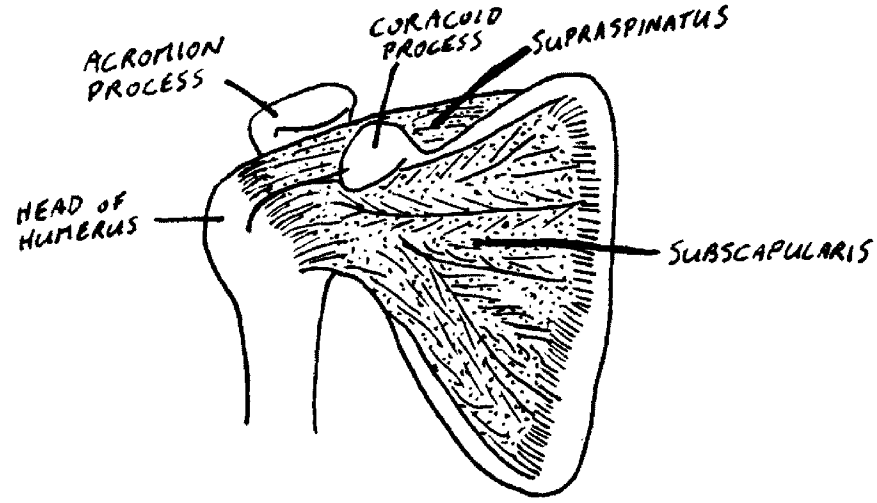
The glenohumeral, or shoulder joint, consists of the glenoid fossa of the scapula and head of the humerus. It is a ball-and-socket joint. The shoulder joint is the most mobile in the human body, and the most unstable. Motion is possible in all three planes and many movements are in a combination of these planes.

Dynamic stability of the shoulder joint is provided by the muscles of the rotator cuff (Distefano, 1977). The four muscles of the rotator cuff are, from anterior to posterior, the subscapularis, the supraspinatus, the infraspinatus, and the teres minor (Fig. 1). The subscapularis originates in the subscapular fossa and inserts on the lesser tuberosity of the humerus (Crouch, 1978).

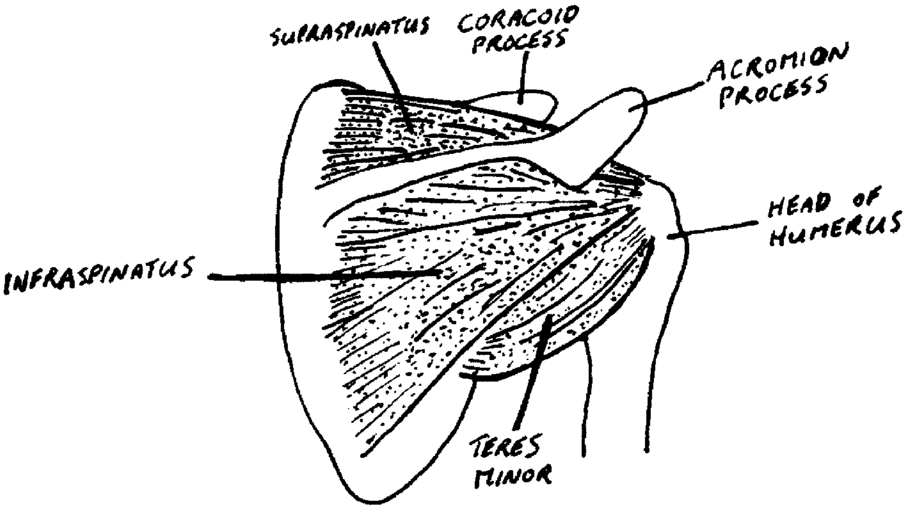
The supraspinatus originates in the supraspinatus fossa and inserts in the highest of three impressions of the greater tubercle of the humerus (Daniels & Worthingham, 1972). The supraspinatus is the starter muscle in shoulder abduction. The supraspinatus' insertion gives it a more efficient angle of pull than the deltoid when the arm is in adduction (Distefano, 1977).

The infraspinatus originates in the infraspinatus fossa and inserts in the second impression of the greater tubercle of the humerus. The teres minor originates on the upper two thirds of the axillary border of the scapula's dorsal surface and inserts on the lowest of three impressions of the greater tubercle of the humerus (Daniels & Worthingham, 1972). Both the infraspinatus and the teres minor externally rotate the humerus and assist in horizontal abduction.

The deltoid is not part of the rotator cuff; it crosses the shoulder joint and is involved to some extent



ANTERIOR ASPECT



POSTERIOR ASPECT

Figure 1. Muscles of the rotator cuff.

in most movements of the shoulder. The deltoid has three parts, and its anterior fibers originate from the lateral third of the anterior border and upper surface of the clavicle. Its middle fibers originate from the lateral border and upper surface of the acromion, and its posterior fibers originate from the posterior border of the spine of the scapula. All the fibers converge into a thick tendon which inserts into the deltoid tuberosity on the middle lateral surface of the humerus (Crouch, 1978).

According to Distefano (1977), stabilization is the main function of the rotator cuff muscles. They exert a compression force on the head of the humerus which keeps it in contact with the glenoid fossa. Perry's research, presented by Jobe and cited by Brunet, Haddad, and Porche (1982), showed that the supraspinatus cannot be isolated from the deltoid, but it can be isolated from the other muscles of the rotator cuff. Perry used electromyographic studies to show this (Brunet, Haddad, & Porche). The position for the supraspinatus isolation has the arm abducted 90°, horizontally adducted 30°, and internally rotated.

Injury Prevention Role

The use of the supraspinatus isolation test as a screening device to identify individuals who are at high risk to injury due to muscular weakness could be very helpful. Hage (1981) found that several studies indicated that many noncontact injuries are due to muscular weakness. Most injuries to baseball players' shoulders are of the noncontact variety. One thus may assume that, with an acceptable level of strength, at least some of these injuries may be prevented.

Polk (1968) sent questionnaires to professional and college baseball teams all over the United States to determine frequencies of injuries to baseball players. He found that shoulder injuries, caused primarily by throwing a baseball, made up 11.1% of the total injuries. Boscardin, Johnson, and Schneider (1989, p. 34) wrote, "The supraspinatus is very vulnerable to injury during throwing. Exercises to strengthen this muscle are essential components for a shoulder conditioning program."

General tests of shoulder strength may not identify the weakness of an individual muscle. Other muscles used in the movement may compensate for a weak muscle. Jobe and Moynes (1982) believed that rotator cuff muscles can become fatigued, injured, or atrophied individually, independent of the deltoid. They believed that the muscles must be considered separately during examination and rehabilitation. In their opinion, the supraspinatus muscle is the most frequently compromised in patients with rotator cuff pathology. Pappas, Zawacki, and McCarthy (1985a, p. 231) believed "the supraspinatus is frequently weak and atrophied in the throwing arm of the pitcher complaining of chronic shoulder discomfort."

Dan Watthen, head trainer and strength coach at Youngstown State University, found that "stronger players have fewer injuries" (Hage, 1981, p. 181). Bill Buhler, the L.A. Dodgers' athletic trainer, said, "There is . . . a correlation between conditioning and both injury occurrence and recovery time" (Moore, 1983, p. 170). Herman Schneider, the Chicago White Sox head trainer, "concentrates on strength and endurance, particularly in the pitchers. He is a firm believer in a correlation between fitness and injury avoidance" (Moore, p. 171).

Analysis of the Throwing Motion

Studies have analyzed muscular activity during phases of the throwing motion. Jobe, Tibone, Perry, and Moynes (1983) monitored the anterior, middle, and posterior fibers of the deltoid, and the four muscles of the rotator cuff, with a combination of dynamic EMG and high-speed film during the entire throwing motion. The researchers divided the throwing motion into four phases: wind up, cocking, acceleration, and follow through.

The wind up ends when the ball leaves the gloved hand. Jobe et al. (1983) found no consistent muscle activation pattern in this phase. The cocking phase ends with maximal external rotation of the humerus. The supraspinatus has the most intense involvement and, along with the deltoid, is activated first to elevate the arm. The teres minor and infraspinatus then increase their involvement during external rotation. The activity of the supraspinatus remains intense throughout this phase. Jobe et al. said that the subscapularis fires at the end of the cocking phase. This could be the initiation of the acceleration phases because the subscapularis is an internal rotator, not an external rotator.

The acceleration phase ends with the ball release. Jobe et al. (1983) found little activity during the acceleration phase, and that it took less than 1/10 sec to complete. This further indicates that the firing of the subscapularis is the initiation of the acceleration phase. Also in the acceleration phase, the arm is internally rotated and horizontally adducted.

According to Daniels and Worthingham (1972) the pectoralis major is a prime mover in horizontal adduction of the shoulder. Roy and Irvin (1983, p. 123) wrote, "The pectoralis major and latissimus dorsi act as powerful internal rotators of the throwing arm." Daniels and Worthingham (1972) indicated that the latissimus dorsi, teres major, and pectoralis major are prime movers, along with the subscapularis, in internal rotation. Of the above-mentioned muscles, Jobe et al. (1983) monitored only the subscapularis.

In a second study, Jobe, Moynes, Tibone, and Perry (1984) again electromyographically studied muscle function during the throwing motion of pitchers. The muscles monitored were the biceps, the lateral and long heads of the triceps, the pectoralis major, the latissimus dorsi, serratus anterior, and brachialis. They found a great deal of activity in this second set of muscles during the acceleration phase. The triceps, pectoralis major, latissimus dorsi, and serratus anterior were all at their peak of activity during this phase.

In another study, Glousman, Jobe, Tibone, Moynes, Antonelli, and Perry (1988) electromyographically examined the muscular activity of two groups of pitchers. All members of the first group had chronic anterior instability of the shoulder. All members of the second group were normal. The researchers found that the activity levels of the supraspinatus were greater for the first group in the late cocking and acceleration phases. Firing during the acceleration phase could be caused by use of the supraspinatus to improve the stability of the shoulder when the primary restraints are lax. As stated earlier, the supraspinatus does exert a compression force, drawing the humeral head toward the glenoid fossa.

The follow-through phase ends when all motion has stopped. All the muscles are firing at high intensity levels during this phase. The subscapularis continues to internally rotate the arm while the rest of the muscles decelerate the arm (Jobe et al., 1984). The supraspinatus activity is greater during the follow-through phase than at any other time during the pitching motion (Glousman et al., 1988). This indicates that the supraspinatus, along with the infraspinatus and teres minor, is responsible for much of the deceleration of the arm.

Penny and Welsh (1981) analyzed the throwing motion and found four phases.

1. The cock, which ends at maximal external rotation.
2. The drag, a change of direction, from external rotation to acceleration (internal rotation).
3. Acceleration, going from external to internal rotation of the shoulder.
4. Follow through.

Penny and Welsh (1981) believed that the subscapularis is subjected to a lot of stress during the drag phase because it is being used to change the direction of movement of the arm. They also believed that the posterior portion of the rotator cuff is stressed during the deceleration of the follow-through phase. If Penny and Welsh's phases had been used in Jobe et al.'s (1983) study, it is possible that the firing of the subscapularis would have been in the drag phase instead of the cocking phase.

Pappas, Zawacki, and Sullivan (1985b) used only three phases--cocking, acceleration, and follow through--to describe the throwing motion. They explained the cocking phase as "the period of time between the initiation of the wind up and the moment at which the shoulder is in maximum external rotation" (p. 217). They found that the cocking phase accounts for 80% of the time required for the entire pitching motion.

Gowan, Jobe, Tibone, Perry, and Moynes (1987) used intramuscular electromyography to monitor the muscle activity during the act of pitching a fastball. The supraspinatus was identified as a muscle which has greater activity during the early and late cocking stages, and less during the acceleration phase. Professionals and amateurs were tested in the study. The professionals had less supraspinatus activity than the amateurs during late cocking and acceleration. The selective use of specific muscles during the throwing motion can affect the velocity of a pitch.

Pitching velocity has been tested using a variety of methods. Sullivan (1970) used photocells and a light source with a target and microswitch. As a thrown ball passed between the photocells and the light source, a timer was started. When the ball hit the target, the microswitch stopped the timer. Velocity of the ball was calculated using the elapsed time and distance between the photocells and the target (17 ft). Each subject was given five throws.

Bartlett, Storey, and Simons (1989) measured throwing velocity with a Ray-Gun radar gun (Decatur Electronics, Inc., Decatur, IL 62521). Throwing speed was measured at a distance of 60 ft. Each subject was given three throws. The highest velocity was recorded as the subject's score.

Using a radar gun is a simpler method of measuring throwing velocity. The guns are readily available in professional baseball, are easy to operate, and are portable. A setup such as Sullivan's (1970) has a greater potential for something to go wrong. There are photocells, a light source, a microswitch, a timer, and all the electrical connections. The radar gun appears to be the better method of measuring throwing velocity.

Studies measuring throwing velocity reliability have found high correlations. Brose and Hanson (1967) reported a reliability coefficient of $\underline{r}$ = .92-.98, and Straub (1968) found a correlation of $\underline{r}$ = .97 for throwing velocity. Brose and Hanson noted that testing throwing velocity and accuracy with the same throw will cause subjects to reduce their velocity in an effort to improve their accuracy. Based on this observation, it is important to test throwing velocity and accuracy separately.

Throwing accuracy has been tested using square (Brose & Hanson, 1967), rectangular (Litwhiler & Hamm, 1973), and concentric targets (Straub, 1968). Distances from thrower to target has varied considerably. The reliability of accuracy testing was reported by Brose and Hanson to be $\underline{r} = .29-.69$. Straub reported the reliability of his accuracy testing to be $\underline{r} = .73$. The reliability of accuracy testing has not been found to be as consistent as throwing velocity testing. This could be due to an increased need for fine motor control in throwing accuracy.

Isokinetic Testing

The Cybex II is an isokinetic testing device. According to Elliott (1978, p. 2408), "The cybex device, by accommodating resistance against a lever moving at a set angular velocity (say 100° per sec), can measure dynamic strength at every point in the range of motion." Morris, Lussier, Bell, and Dooley (1983) found that

> isokinetic evaluations provide the researcher with a quantitative written record of the torques developed about a joint throughout the whole range of motion. Such values have been used to describe healthy populations as well as people with joint disabilities and such testing has become a standard method of testing various athletic populations for muscular strength, power and endurance. (p. 72)

Pedegana (1982) examined the relationship between upper extremity strength to throwing speed, using the Cybex II to do the strength testing. The tests used were flexion-extension, abduction-adduction, horizontal abduction-adduction, and internal and external rotation. Pedegana applied test speeds of 60° and 180° per sec.

Extension, flexion, and external rotation were found to have a significant relationship with throwing speed. Hooks (1959) also found that shoulder flexion strength correlated well with throwing. Although he measured strength with tensiometers, which is completely different from isokinetic testing, he found one of the same motions as Pedegana to be significantly related to throwing.

Alderink and Kuck (1986) tested high school and college-aged pitchers using a Cybex II and Upper Body Exercise and Testing Table (U.B.X.T.). They found that "the U.B.X.T. . . . has facilitated the testing of upper extremity strength because of an increased ability to stabilize the trunk" (p. 163). The researchers gave their subjects 10-15 warm-up repetitions before the tests at 90°, 120°, 210°, and 300° per sec.

Five maximal repetitions were performed at each test speed and verbal encouragement was given to maximize each subject's performance. The dual channel recorder's paper speed was set at 5 mm per sec and the damping control was set at 2 for all tests. The highest peak torque value of each set of five repetitions was measured and recorded as each subject's score. Alderink and Kuck (1986) found that the peak torque values decreased as the test speeds increased.

Perrin, Robertson, and Ray (1987) tested 15 college pitchers with a Cybex II at test speeds of 60° and 180°

per sec. Brown, Niehues, Harrah, Yavorsky, and Hirshman (1988) tested major league baseball players' internal and external shoulder rotators with a Cybex II at test speeds of 180°, 240°, and 300° per sec. They used five maximal repetitions at each test speed. Peak torque and average peak torque were measured for each test.

Ivey, Calhoun, Rusche, and Bierschenk (1985) tested members of the general population with a Cybex II at test speeds of 60° and 180° per sec. They used five maximal repetitions at 60° per sec and four maximal repetitions at 180° per sec. They tested shoulder internal-external rotation, flexion-extension, and abduction-adduction. In all tests, the torque output decreased as the test speed increased.

Bartlett et al. (1989) gave subjects five to seven warm-up repetitions on a Cybex II, at a test speed of 90° per sec. Subjects then were instructed to perform four maximal repetitions and the peak torque for each motion was recorded. Each subject was tested on four shoulder patterns.

A review of Cybex II shoulder testing literature has shown a wide variety of testing speeds and patterns. Three to five maximal repetitions was the standard number used to determine torque output. All of the studies measured peak torque and used the measurement in reporting the data.

There does not seem to be a learning period with isokinetic testing. Mawdsley and Knapik (cited in Westers, 1982, p. 43) observed, "Isokinetic testing apparently does not suffer from the same learning effects as isometric testing does although an initial 'trial' run is recommended to stabilize the test scores." The cybex manual (Cybex, 1983) also recommends 5-10 familiarization trials before beginning testing.

Sapega, Nicholas, Sokolow, and Saraniti (1982) studied torque overshoot in cybex testing. They found, using high-speed filming, that preset angular velocity was exceeded, caused by a delay in the engaging of the resistance mechanism. When the resistance mechanism did engage, it caused a deceleration and the resulting torque overshoot.

Sapega et al. (1982) reported,

> The initial torque spikes and secondary oscillations that often appear in cybex torque records do not represent intermittent surges of muscular contractile force, but rather the forces associated with the initial deceleration and subsequent velocity fluctuations of an initially overspeeding limb-lever system. The artificially high torque peaks produced have been termed "overshoot" and the troughs in between "undershoot." They are associated with the system deceleration and acceleration, respectively. (p. 371)

The researchers recommended maximizing the range of motion to increase the artifact-free portion of the curve, and examining data only from the artifact-free portion of the curve. The damping setting of the recorder should be cited with all data reported.

The reliability of the Cybex II has been well-documented. Unfortunately, most of the studies reviewed examined reliability with the knee flexion extension test. An upper extremity test in this present study involved greater stabilization problems. Inadequate stabilization can reduce the reliability of the test.

Johnson and Siegel (1978) tests Cybex II reliability using just the knee extension phase of the knee flexion extension test. That test is similar to the one used in this present study because both tests do not use reciprocal movement. Johnson and Siegel found correlation coefficients ranging from $\underline{r}$ = .93-.99.

Perrin (1986) studied the reliability of the Cybex II using two shoulder test patterns at angular velocities of 60° and 180° per sec. The test patterns used were shoulder flexion and extension, and shoulder internal and external rotation. Fifteen subjects were tested, then retested 1 week later. Perrin found reliability coefficients to be $\underline{r}$ = .91-.93 for shoulder tests at 60° per sec and $\underline{r}$ = .77-.93 for shoulder tests at 180° per sec. Perrin's results indicated that as the angular velocity of the test increases, the reliability of the test somewhat decreases.

The supraspinatus isolation test, using the Cybex II, has also been reported in the literature. Knoeppel (1985) reported,

> Additionally by turning the stool at an angle to the dynamometer and replacing the rotating handgrip with the neutral handgrip, isolation of the supraspinatus muscle can be obtained. Shoulder abduction with internal rotation (thumb turned down) is performed with the arm in approximately 30° of horizontal adduction. (p. 125)

Connelly Maddux, Kibler, and Uhl (1989) used a Cybex II and a U.B.X.T. to test subjects' shoulders with a test the researchers called a modified abduction adduction. They rotated the U.B.X.T. to position the arm in 30° of horizontal adduction and had the subjects' glenohumeral joint in full internal rotation. Connelly Maddux et al. said, "Electromyographic studies by Jobe and Moynes demonstrated that the dominant muscle of the rotator cuff contracting during MOD-AB/AD was the supraspinatus" (p. 265).

As previously noted, the deltoid is still involved in the movement. Howell, Imobersteg, Seger, and Marone (1986) found the supraspinatus and deltoid to be equally responsible for producing torque around the shoulder.

The following values, indicating the reliability of the Cybex II testing device, are derived from the Cybex II handbook (Cybex, 1983).

The torque measurement accuracy is:
For the 360 ft lbs scale + or - 4 ft lbs.
For the 180 ft lbs scale + or - 2.5 ft lbs.
For the 30 ft lbs scale + or - 1.5 ft lbs.

The torque measurement repeatability is:
For the 360 ft lbs scale + or - 2 ft lbs.
For the 180 ft lbs scale + or - 1 ft lbs.
For the 30 ft lbs scale + or - 2 ft lbs.

The position angle measurement accuracy is:
For the 300 scale + or - 3°.
For the 150 scale + or - 1.5°.

The position angle measurement repeatability is:
For the 300 scale + or - 2°.
For the 150 scale + or - 1°. (p. 81)

According to the Cybex II handbook, the most important variables affecting test accuracy are proper positioning and appropriate stabilization of the subject.

Chapter 3

METHODOLOGY

Design of the Study

Subjects

The 24 subjects in this study were volunteer members of the 1986 or 1987 Peninsula White Sox baseball team of the Class A Carolina league. In both 1986 and 1987, the entire team met as a group with this investigator where the purpose of the study and tests to be used were explained. After answering questions, the team members were asked if they would like to participate in the study. Random selection was not employed because of the limited number of possible subjects, and because the players were not required to participate in the study. If, in a random selection process, players not wishing to participate had been chosen, and players wanting to participate had not been chosen, the number of subjects could have been severely limited.

The volunteers then were individually interviewed by this investigator. The subjects were questioned about their recent medical histories. Specific attention was paid to past arm injuries. Any subject with a serious arm injury during the present season was excluded from the study. A serious arm injury was identified as one which prohibited a potential subject from throwing in a game for 2 weeks or more. The reasoning behind this limitation was that the subject's arm would have lost strength and conditioning--thereby adversely affecting his throwing velocity--had he not thrown for 2 or more weeks under game conditions. Too, throwing at maximum velocities for the testing could cause re-injury.

A copy of the medical questionnaire appears in Appendix A. In addition, each subject was given an informed consent form (a copy is in Appendix A) which he read, dated, and signed. No one had any questions concerning the consent form.

The sample population was believed to be representative of the Class A Peninsula White Sox minor league professional baseball players of 1986-1987. The players on these teams have generally played professional baseball for 1-4 years.

Equipment

The equipment used in this study tested three areas: (a) strength, (b) throwing velocity, and (c) throwing accuracy.

Strength. Strength tests were conducted with a Cybex II Isokinetic Dynamometer (Cybex Division, Lumex

Inc., Bayshore, NY 11706). The data were recorded with a Cybex Dual-Channel Recorder. This recorder graphically records the torque output in ft lbs and the range of motion in degrees.

Reliability of the Cybex II testing equipment was examined by Johnson and Sieger (1978) using the knee extension test. They found reliability coefficients of *r* = .93-.99. Perrin (1986) reported reliability coefficients of *r* = .91-.93 for shoulder testing at 60° per sec and *r* = .77-.88 for shoulder tests at 180° per sec. Reliability of shoulder testing at 240° per sec was not reported.

Kendall's W correlation coefficients corrected for ties were calculated from this present study's data. The three trials at 60° per sec produced a W of .95. The five trials at 240° per sec produced a W of .96. These results indicated the testing procedure was consistent within trials.

Reliability of the testing equipment established by the manufacturer was listed in the Cybex II handbook (Cybex, 1983).

The torque measurement accuracy is:
For the 180 ft lbs scale + or - 2.5 ft lbs.

The torque measurement repeatability is:
For the 180 ft lbs scale + or - 1 ft lbs.

The position angle measurement accuracy is:
For the 300 scale + or - 3°.

> The position angle measurement repeatability is:
> For the 300 scale + or - 2°. (p. 81)

Test validity was established by Perry, who used electromyographic studies to show that the supraspinatus could be isolated from the other three muscles of the rotator cuff (Brunet et al., 1982), although the deltoid is still active in the movement. The supraspinatus isolation position utilized was with the arm abducted 90°, horizontally adducted 30°, and internally rotated. The same positioning was used in this study except that an isokinetic rather than isometric test was used. The isokinetic test utilizes the same motion as the isotonic resistance exercise that Jobe and Moynes (1982) recommended for strengthening the supraspinatus. The same procedure, with less stabilization, was used by Knoeppel (1985) to strengthen (isokinetically) the supraspinatus and by Connelly Maddux et al. (1989), with stabilization, to test (isokinetically) supraspinatus strength.

The arm begins in complete adduction with the shoulder internally rotated, then is abducted to 90° to complete the test. The motion of the test should put more stress on the supraspinatus than the isometric test at 90° of abduction. According to Distefano (1977) the supraspinatus is the starter muscle in shoulder abduction. The supraspinatus' insertion gives it a more efficient angle of pull than the deltoid when the arm is in adduction (Distefano).

Throwing velocity. Velocity was measured with a Doppler Traffic Radar Gun (Decatur Electronics Inc., Decatur, IL 62521). The radar gun operates at 10.525 KMh_z. Calibration was checked daily with a tuning fork which oscillates at 2040 ± 5 Hertz at 70° F. The tuning fork causes a reading of 65 mph when the radar gun is correctly calibrated. The calibration of the radar gun did not require adjustment over the course of testing in this study.

Throwing accuracy. Throwing accuracy was measured by throwing at a target. The target was a screen that protected the first baseman from batted balls during batting practice. The 1-in. tubular metal frame of the screen was 8 ft high and 6 ft wide. The inside of the frame was covered with tightly strung heavy netting. Openings in the netting were 3/4-in. squares. The boundaries of the target were made of 1 1/2-in. white athletic tape, applied to the netting (see Fig. 1).

The target areas differed for the fielders and the pitchers. Pitchers were required to throw to a strike zone the approximate size of their 1-point target: 18 in. wide and 30 in. high. The bottom of the target was 18 in. above the ground. The pitchers' 2-point target, set in the middle of the 1-point target, was 8 in. wide and 12 in. high.

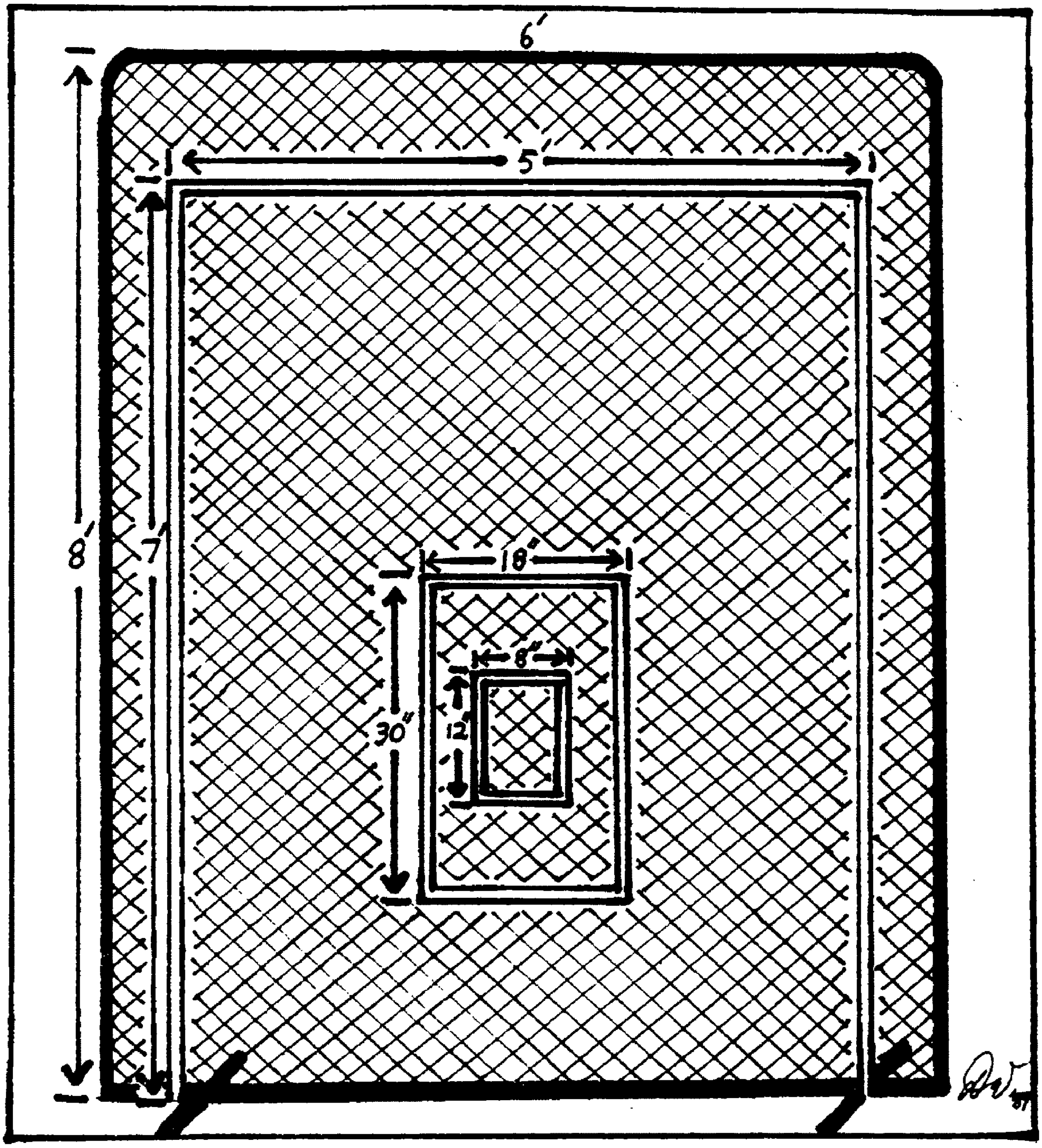


Figure 2. Throwing target.

The fielders' target was 7 ft high and 5 ft wide. The target was larger because fielders do not have to be as precise as do pitchers. Fielders are required to throw to other fielders; as long as a throw can be caught without forcing a receiving fielder to leave the base, it is accurate enough. The fielders' 2-point target was the pitchers' 1-point target because it resembled throwing at a fielder's body from knees to chest.

Procedure

Data collection. Each subject was seated on an Upper Body Exercise and Testing Table (U.B.X.T.). The footrest and stabilization handle were adjusted for each subject's comfort. The long arm of the shoulder testing accessory was adjusted to the subject's arm length (from distal point of acromion process to distal end of the metacarpals). The subject's upper torso movements were eliminated with pelvic and torso stabilization straps. The pelvic strap crossed the subject's iliac crests and wrapped around the bottom of the back of the U.B.X.T. The torso strap crossed the subject's pectorals, went under his arms, and around the back of the U.B.X.T. A complete protocol for Cybex II testing of the supraspinatus appears in Appendix B.

The instantaneous axis of shoulder rotation changes during the movement, due to rotary motion of the scapula. The compromise axis used was 1 in. medial to the acromion process when the arm was completely adducted. This is the axis suggested in the Cybex II handbook (Cybex, 1983, p. 36) for testing abduction-adduction. The supraspinatus isolation test is similar to the abduction-adduction test, hence the same compromise axis was used.

Each subject gripped the handle with his shoulder internally rotated and his thumb pointing down. He then abducted his arm to 90°. The Cybex II testing arm was locked in this position. While the subject continued to grip the handle, the angle of horizontal shoulder flexion was measured using a goniometer (see Fig. 2). The correct angle was 30°. Corrections were made by rotating the U.B.X.T.

While each subject was in 90° of abduction, the 0° baseline of the Cybex II Dual Channel Recorder was set to the fifth main division of the graph paper. This setting ensured that the positioned angle recorder would not go off the edge of the paper. The speed selector then was set to 60° per sec and a prepared text of instructions was read to the subject as the test proceeded. The text appears in Appendix B.

The Dual Channel Recorder's damping setting was 2 for all testing. This setting reduced possible torque overshoot. Sapega et al. (1982) found that introductory torque spikes that sometimes appear in the torque records

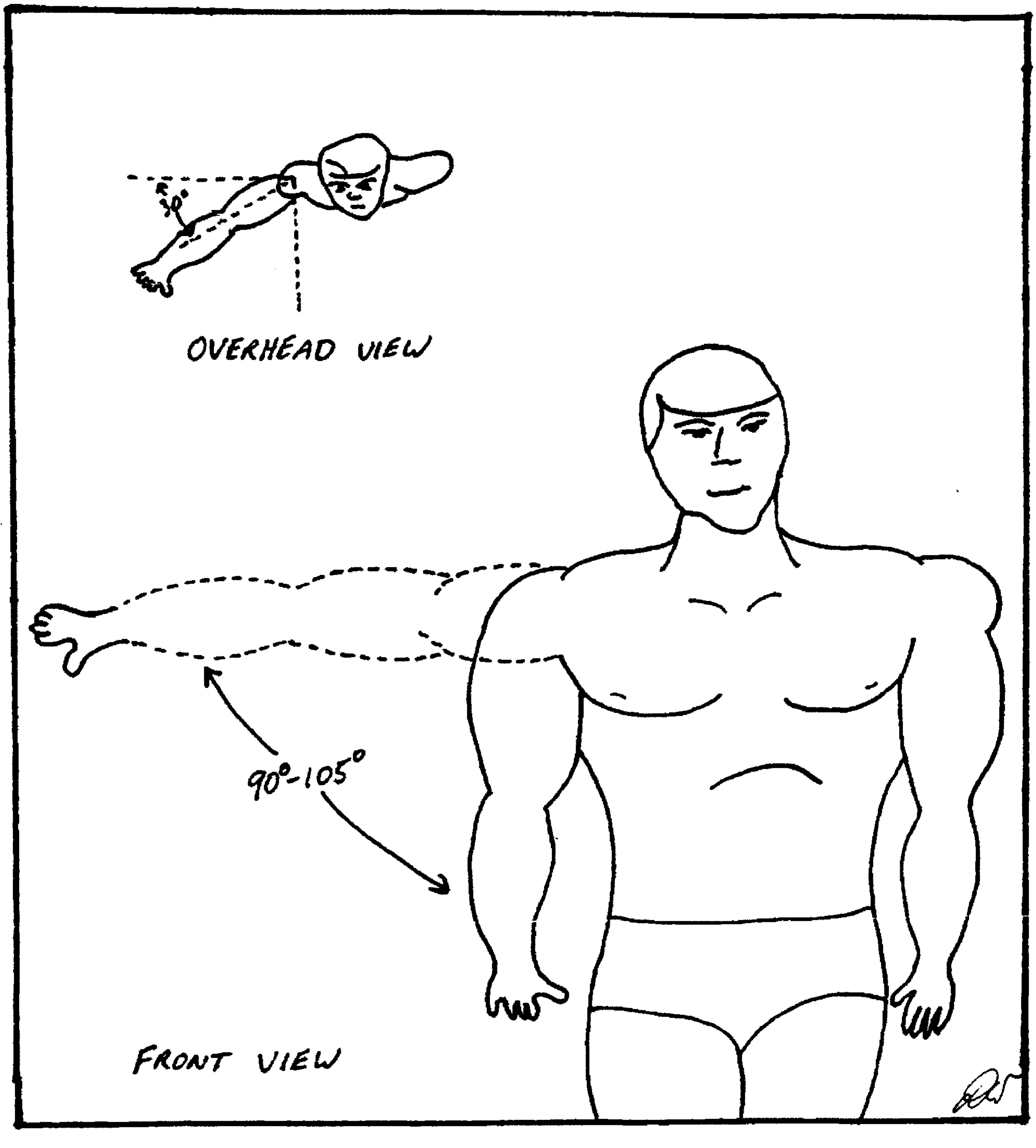


Figure 3. Measuring the angle of the horizontal shoulder adduction and the angle of shoulder abduction.

are caused by the beginning deceleration of an initially overspeeding limb lever system. The Cybex II handbook (Cybex, 1983) suggested the damping setting of 2. The paper speed of the Dual Channel Recorder was set at 5 mm per sec, as also suggested in the Cybex II handbook.

The 180 ft lbs torque range scale was used to record each subject's torque output during testing. This scale gives a value of 18 ft lbs to each of the 10 main divisions of the Dual Channel Recorder's graph paper. The 300° angle scale was used to record the subject's range of motion during the testing. This scale gives a value of 30° to each of the 10 divisions on the Dual Channel Recorder's graph paper.

These settings were found to be the most suitable during a pilot study conducted during January and February 1986 in Missoula, MT. When the 30 ft lbs scale was used, subjects produced too much torque to be recorded on the graph paper. No one produced 180 ft lbs of torque, so the 180 ft lbs scale was chosen for the research study. The 300° angle scale ensured that the entire range of motion remained on the graph paper. During the research study the calibration of the Dual Channel Recorder was checked before each testing session.

All subjects were allowed to warm up on the machine at the first test speed of 60° per sec until they said they were comfortable and ready to start the test. They also were given time to adjust to the second test speed of 240° per sec. The warm-up period before the first test consisted of 5-10 repetitions, most of which were submaximal. The adjustment period was fewer than 5 repetitions before the second test. These warm-up repetitions did not seem to fatigue the subjects, that is, no fatigue was reported by the subjects and none was reported in other studies.

Each subject performed three maximal repetitions with the dynamometer speed set at 60° per sec to determine the subject's supraspinatus strength. The speed setting of 60° per sec and the use of three repetitions is recommended in the Cybex II handbook (Cybex, 1983) for strength testing in all shoulder patterns. The highest peak torque value of the three repetitions was used as the strength score. The average of the three was not used because the Cybex II handbook stated, "Always make sure to take measurements from the best (highest peak) repetition for each muscle group" (p. 26). Alderink and Kuck (1986), Brown et al. (1988), and Bartlett et al. (1989) used the peak torque of the best repetition as the subjects' test score.

Each subject performed five maximal repetitions with the dynamometer speed set at 240° per sec to determine the subject's supraspinatus strength at 240° per sec. This speed setting is recommended in the Cybex II handbook

(Cybex, 1983, p. 13) for high speed strength testing the shoulder patterns of athletes. Five repetitions were employed because the Cybex II handbook noted that the highest peak torque usually occurs in the first five repetitions of the high speed strength test (p. 21). The highest peak torque value of the five repetitions was utilized as the strength at 240° per sec score. The average of the five repetitions was not used as the score because the Cybex II handbook advised using the best repetition (p. 26). Peak torque of the best repetition was also used as the subjects' test score by Alderink and Kuck (1986), Brown et al. (1988), and Bartlett et al. (1989).

Four to seven subjects were present during each testing session. The waiting subjects gave vocal encouragement to the subject being tested. This was consistent for all subjects.

Throwing velocity was measured at War Memorial Stadium, Hampton, Virginia. Weather conditions during testing were good both years. Winds were negligible and temperatures were in the high 80° F range. The position players threw from behind a marker 60 ft 6 in. from the foul line to a receiver at the foul line. The players were allowed a 2-step approach to throw. This made their throws more realistic because that is how they normally throw during a game.

This investigator stood behind the receiver with a radar gun to measure the velocity of each throw. Each subject was asked to throw four new baseballs to a receiver. The best of four throws was the velocity score. The average of the four throws was not used as the velocity score because this would not have been consistent with the determination of the strength scores; the strength scores were the best repetition of their respective tests.

The pitchers' velocity scores were derived during first-game appearances after the strength tests; the velocity of all pitches during a game are charted for the pitching coach. The velocity scores were measured with the radar gun positioned behind home plate in the third row of the seats. This position was necessary so as to not interfere with the game in progress. The fastest pitch thrown in each subject's first inning was recorded as the velocity score.

Throwing accuracy also was measured at War Memorial Stadium, Hampton, Virginia. The target previously described was set up at the foul line in the outfield. Markers were placed 90 ft and 120 ft away in the outfield. The infielders threw from 90 ft; this is the distance between the bases and an average infielder's throw. The outfielders threw from 120 ft; this is the average distance that outfielders throw to hit a cutoff man. All of the fielders were allowed a 2-step approach before throwing, as long as they stayed behind the marker, and all of the throws were overhand.

Each subject threw five new baseballs at the target. The subjects' scores were recorded by this investigator, who was standing behind the target. The lines of the target were counted as part of the target.

To simulate gamelike conditions, the subjects had to throw the ball with at least 80% of their maximum velocity or the throw did not count. Velocity was checked with the radar gun. This was not a problem because everyone threw fast enough. The pitchers followed the same procedure. They threw from a bullpen (practice) mound. The target was set up over the plate 60 ft 6 in. away.

The strength tests were conducted on 2 consecutive days; they could not all be done the same day because the Cybex II was available to this investigator for but a limited time each day. No subject reported any fatigue or muscle soreness when reporting to the ballpark after the testing. There was a recovery period of at least 4 hours between the strength tests and the throwing accuracy and velocity tests.

The position players' velocity and accuracy tests were done their second day of testing. The pitchers' accuracy tests also were done their second day of testing. The pitchers' throwing velocities all were measured within 3 days of their strength tests. The delay was necessary because this investigator had to wait for the subjects to pitch in a game. The pitching coach (and pitchers themselves) did not want the pitchers to throw as hard as they could when not in a game; there was a fear of injury. Nonetheless, all of the pitchers threw above 80% of their maximum velocity for the accuracy testing.

Chapter 4

RESULTS

Twenty-four subjects participated in this study. All the subjects were male, minor league, professional baseball players consisting of 5 pitchers, 12 infielders, and 7 outfielders. All the subjects played for the Peninsula White Sox baseball team of the Class A Carolina league. The subjects' ages ranged from 19-24 with a mean age of 20.9. The subjects' professional baseball experience ranged from 1-4 years with a mean of 2.2 years.

Analyses

Analysis of Throwing Velocity Data

Throwing velocity was measured in miles per hour using a Doppler Traffic Radar Gun. Each subjects' highest velocity of four throws was recorded as his velocity score. The results are shown in Table 1. The pitchers as a group had the highest mean velocity score at 86.2 mph. There was little difference between the infielders' and the outfielders' mean throwing velocities.

An $\underline{F}$ test indicated a significant difference among the three groups ($\underline{F}(2,21) = 8.371$, $\underline{p} \leq .05$). To identify which

Table 1

Throwing Velocity

Position	*n*	$\overline{X}$	*SD*	Range
Pitchers	5	86.2	1.3	87-94
Infielders	12	76.3	4.7	82-74
Outfielders	7	77.1	6.0	86-70
Totals	24	78.6	6.0	87-70

groups were significantly different from each other, Tukey's HSD test was used.

The only significant difference was between the pitchers and the infielders. The difference between the pitchers and the outfielders was high but not significant. The results of Tukey's HSD test indicated that the pitchers, on the average, threw with greater velocity than did the position players. This result was expected.

Pitchers become pitchers, in part, because they can throw hard. Baseball scouts all carry radar guns to help them evaluate pitching prospects. Chuck Hartenstien (1986), former major league pitching coach for the Milwaukee Brewers, remarked many times to this investigator, "There's no substitute for talent, and throwing hard is a talent." Although there is more to pitching than just throwing hard, velocity **is** a sought after quality in pitchers.

Analysis of Throwing Accuracy Test Data

Throwing accuracy was measured by having the subjects throw five baseballs at a target. The target had 1-point and 2-point zones. The total points for each subject's five throws were added and used as his throwing accuracy score. The results are shown in Table 2. The outfielders were the least accurate with a mean score of 3.1. The infielders' and the pitchers' mean scores were 5.5 and 5.2, respectively.

Table 2

Throwing Accuracy

Position	n	$\bar{X}$	SD	Range
Pitchers	5	5.2	1.5	7-3
Infielders	12	5.5	1.0	7-3
Outfielders	7	3.1	1.8	5-1
Totals	24	4.75	1.7	7-1

An F test indicated a significant difference among the three groups ($F(2,21) = 6.866$, $p > .05$). To identify which groups were significantly different from each other, Tukey's HSD test was used. None of the computed differences between means exceeded the critical HSD value. The greatest differences occurred between pitchers and outfielders and between outfielders and infielders.

The Tukey HSD failed to identify significant differences among any of the means tested. The greatest mean differences existed between outfielders and infielders, closely followed by pitchers and outfielders. Very little difference existed between pitchers and infielders.

The outfielders' mean accuracy score was more than 2 points less than the pitchers' and infielders' scores. The natural selection process of baseball tends to keep the more accurate throwers in the infield. To be successful, pitchers must control their pitches and infielders must throw accurately to the bases--which do not move.

Outfielders are supposed to catch as many balls on the fly as possible. When required to throw the ball quickly, outfielders throw to a cut-off or relay man who can move to catch the ball if the outfielder does not throw the ball directly to the cut-off or relay man. Outfielders are selected more for speed on foot and batting ability than for throwing accuracy.

Analysis of Supraspinatus Strength at 60° Per Sec Test Data

Supraspinatus strength at 60° per sec was measured in ft lbs of torque produced on a Cybex II dynamometer with an angular velocity of 60° per sec. The highest value of these maximal repetitions was used as each subject's score. The results of this test are shown in Table 3. The *F* test did not indicate a significant difference among the three groups at the .05 level ($F(2,21) = 1.599$, $p > .05$).

Table 3

Supraspinatus Strength at 60° Per Sec in Ft Lbs

Position	*n*	$\overline{X}$	*SD*	Range
Pitchers	5	52.6	9.7	60-36
Infielders	12	62.8	21.2	98-36
Outfielders	7	75.6	29.4	137-49
Totals	24	64.4	23.0	137-36

The outfielders had the highest mean score, the infielders had the next highest mean score, and the pitchers had the lowest mean score. Coleman (1982) found the same results when he tested major league baseball players. He tested shoulder flexion and extension with a Cybex II dynamometer set at 60° per sec. The outfielders produced the most torque and the pitchers produced the least torque. Although shoulder flexion and extension involves more of the shoulder musculature than the supraspinatus isolation test, both tests measure shoulder muscles involved in the throwing motion.

Coleman (1982) found that, although the position players lifted weights to help them with their hitting, the pitchers abstained from upper body weight training. Coleman believed that the lack of weight training was one reason for the pitchers' lower torque production. The difference in strength between the infielders and outfielders may be attributed to the greater lean body weight of the outfielders. The outfielders in Coleman's study were, on the average, 7.7 kgs heavier (lean body weight) than were the infielders. Because strength is a function of the cross sectional portion of the muscle (Lamb, 1978), larger muscles should produce greater torque.

Connelly Maddux et al. (1989) tested 21 males with the MOD-AB/AD test described in the review of literature. The researchers reported a mean peak torque value of 39 ft lbs at a test speed of 60° per sec. This is considerably less than the 64.4 foot lbs that the 24 athletes of this study produced at the same test speed. Connelly Maddux et al. did not test athletes who were constantly using their shoulders. This is the most probable reason for the large difference in peak torque means.

Analysis of Supraspinatus Strength at 240° Per Sec Test Data

Supraspinatus strength at 240° per sec was measured in ft lbs of torque produced on a Cybex II dynamometer with an angular velocity of 240° per sec. The highest value of five maximal repetitions was used as each subject's score. The results of this test are shown in Table 4. The *F* test did not indicate a significant difference among the three groups at the .05 level ($F(2,21) = 2.49$, $p > .05$).

Table 4

Supraspinatus Strength at 240° Per Sec in Ft Lbs

Position	*n*	$\overline{X}$	*SD*	Range
Pitchers	5	37.4	7.8	42-24
Infielders	12	47.3	17.6	77-27
Outfielders	7	58.0	16.8	92-42
Totals	24	48.4	16.93	92-24

The outfielders again had the highest mean score, and the pitchers had the lowest mean score. Brown et al. (1988) tested major league baseball players' internal and external shoulder rotators with a Cybex II dynamometer set at 180°, 240°, and 300° per sec. They found that the pitchers produced significantly more torque in internal rotation than did the position players; the researchers did not, however, differentiate between infielders and outfielders. The mean scores at 240° per sec were 40.5 ft lbs for the pitchers and 37.56 ft lbs for the position players. The external rotation test produced a mean score of 26.44 ft lbs for the position players and 24.95 ft lbs for the pitchers.

The pitchers' higher mean score for internal rotation may be attributed to the pitchers' significantly greater range of motion in external rotation. Brown et al. (1988) indicated that the greater range of motion could enable the pitchers to produce greater force because of the greater amount of elastic energy stored during the stretch phase. Luttgens and Wells (1982, p. 42) reported, "The work done by muscles shortening immediately after stretching was found to be greater than that done by those shortening from a resting state."

The test used in this study did not have the possibility of different lengths of muscular precontraction stretching. Each subject started the test with the arm completely adducted. The mean strength at 240° per sec scores were lower than the mean strength at 60° per sec scores in this study. This study supported the results in other studies.

Brown et al. (1988) found that the torque outputs decreased as the angular velocity increased. Ivey et al. (1985) also noted that torgue values decreased when angular velocity was increased. They tested general population subjects at speeds of 60° and 180° per sec. Researchers Alderink and Kuck (1986) tested high school- and college-aged baseball pitchers with a Cybex II dynamometer set at angular velocities of 90°, 120°, 210°, and 300° per sec. They also found that peak torque values decreased as angular velocity increased. Luttgens and Wells (1982) said, "As the speed of a muscular contraction increases, the force it is able to exert decreases" (p. 42).

Correlations

Results of the data analyses are displayed in Table 5. The Pearson coefficient of correlation was used to determine the correlation coefficients. For the values of the testing to be considered statistically significant, the *r* value had to be greater than the relevant tabled value (Minium & Clarke, 1982).

Scatterplots were done for each of the six correlations. Nothing unusual was found in the scatterplots. Using the .05 significance level, five correlations were found to be statistically significant. All the *r* values for strength at 60° per sec:strength at 240° per sec were significant. This was expected.

Actually, this investigator had expected the correlation values for strength at 60° and 240° per sec

Table 5

Summary of Correlation Coefficients

Variances	Position Pitchers (n = 5) r .05 = .755	 Infielders (n = 12) r .05 = .532	 Outfielders (n = 7) r .05 = .666	Total (N = 24) r .05 = .388
Strength:velocity	0.3041	-0.0826	0.6790*	0.0408
Strengh:accuracy	0.2673	0.1134	0.3562	-0.0155
Strength:power	0.8809*	0.8388*	0.9364*	-0.8840*
Power:velocity	-0.0098	-0.1064	0.5969	-0.0940
Power:accuracy	-0.1167	-0.1347	0.4697	-0.1377
Velocity:accuracy	0.1034	0.3793	0.0916	0.1160

*Significant at .05.

to be higher. The supraspinatus and deltoid were the muscles tested in both tests. The movement pattern was the same. The only difference was the angular velocity.

The lower-than-expected correlation value may be explained by research done with the recruitment of muscle fiber types. Brooks and Fahey (1984) reported that

> fiber recruitment is usually determined not by the speed of a movement but by the force necessary to perform the movement. For instance, slow twitch fibers may be exclusively recruited while lifting a light weight rapidly, but all muscle fibers will be recruited when lifting a heavy weight slowly. (p. 354)

Subjects with different ratios of fast-to-slow twitch muscle fibers could perform differently with each test speed. A wide range of ratios have been reported, from 13%-60% slow twitch and 40%-87% fast twitch (Lamb, 1978). While one subject may have a high percentage of fast twitch fibers, a second may have a high percentage of slow twitch fibers. The first subject should, theoretically, produce more torque than the second subject at 60° per sec, and the second subject should produce more torque than the first subject at 240° per sec. With 24 subjects, 24 different ratios of fast twitch to slow twitch fibers were possible. These different ratios could affect the correlation between the strength tests.

Alderink and Kuck (1986), Brown et al. (1988), and Ivey et al. (1985), reported decreases in peak torque as the angular velocity increased. None of the authors reported correlation coefficients. Nonetheless, an examination of the published means yielded that the decreases in torque appeared to be fairly linear as angular velocity increased.

The only other $\underline{r}$ value that indicated a statistically significant relationship was the coefficient of the outfielders' strength at 60° per sec and throwing velocity. The outfielders also had the highest mean strength scores of the three groups. Whether the relationship is a coincidence is, at present, unknown. Electromyographic analyses of the shoulder musculature of pitchers during the throwing motion has shown moderate or low activity of the supraspinatus during the acceleration phase (Gowan et al., 1987; Glousman et al., 1988; Jobe et al., 1983). This evidence indicated that the significant relationship of strength and throwing velocity in this study could, indeed, be a coincidence.

The outfielders' r value for strength at 240° per sec and throwing velocity, although not statistically significant, did show a strong relationship. This was to be expected because of the high four values for all the strength at 60° and 240° per sec correlations and because the outfielders' strength at 60° per sec and throwing velocity correlation was statistically significant. The different ratios of fast-to-slow twitch muscle fibers between the outfielders, discussed earlier, is a possible explanation for the strength at 240° and throwing velocity not being statistically significant.

The relationships between strength at 60° per sec and accuracy, strength at 240° per sec and accuracy, and throwing velocity and accuracy were statistically nonsignificant. There is a lack of literature involved in the examination of strength measurements and throwing accuracy. The results of this part of the study will have to be taken at face value.

The results of the throwing velocity and accuracy relationship agree with other results found in the literature. Straub (1968) did not find a significant relationship between subjects' maximal throwing velocities and their accuracy. Brose and Hanson (1967) reported similar results. They also noted that their reliability coefficients for accuracy testing were low: .29-.69. The poor reliability of accuracy testing could be a problem with this part of the study. Strength of the supraspinatus muscle of the rotator cuff has been shown, within the limitations of this study, not to have a statistically significant relationship to throwing velocity or accuracy.

Chapter 5

CONCLUSIONS, DISCUSSION, AND RECOMMENDATIONS

Conclusions

Within the limits of this study, the following conclusions may be drawn.

H_1, there will be no significant correlations between supraspinatus strength at 60° per sec and throwing velocity, was accepted by the sample group as a whole. The outfielders' subgroup did, however, reject the null hypothesis.

H_2, there will be no significant correlations between supraspinatus strength at 240° per sec and throwing velocity, was accepted by the group as a whole and individually by the subgroups:

H_3, there will be no significant correlations between supraspinatus strength at 60° per sec and throwing accuracy, was accepted by all groups of subjects.

H_4, there will be no direct positive correlations between supraspinatus strength at 240° per sec and throwing accuracy, was accepted by all groups of subjects.

H_5, there will be no significant correlations between accuracy and throwing velocity, was accepted by all groups of subjects.

H_6, there will be no significant correlations between supraspinatus strength at 60° per sec and supraspinatus strength at 240° per sec, was rejected by all groups of this study.

Discussion

The acceptance of H_1 agreed with the results of the electromyographic studies of Gowan et al. (1987) and Jobe et al. (1983). Both studies found the supraspinatus to be relatively inactive during the acceleration phase of the throwing motion. Glousman et al. (1988) did find higher supraspinatus activity in subjects with chronic anterior instability during the acceleration phase. That finding gives support to the belief that the supraspinatus functions as a glenohumeral joint stabilizaer.

For H_2, the result again agreed with the findings of Gowan et al. (1987) and Jobe et al. (1983). The testing of torque outputs at higher angular velocities has been shown to be important. Wilk (1990) believed that high speed isokinetic testing is the only way to test the shoulder musculature in relation to throwing. The higher test speeds will give investigators a more accurate picture of how the muscle performs during athletic events.

No other studies dealing with the H_3 and H_4 questions were located in the literature. The acceptance of H_5 agreed with the findings of Straub (1968). He observed that high velocity throwers were not more accurate than low velocity throwers. The rejection of H_6 substantiated the findings of Alderink and Kuck (1986, Brown et al. (1988), Ivey et al. (1985), and Perrin et al. (1987).

This study has shown that the strength and power of the suprapsinatus muscle of the rotator cuff is not highly correlated to throwing velocity or accuracy. One exception was a group of seven outfielders whose supraspinatus strength at 60° per sec produced a statistically significant r value with their throwing velocity. This may have been due to chance; the small sample size of seven outfielders (n = 7) could have been a possible source of error.

This investigator, with eight years of experience as an athletic trainer in minor league professional baseball, has witnessed many cases where players' ability to throw was severely restricted because of supraspinatus weakness or injury. Although the supraspinatus has been shown not to be a prime mover in the acceleration phase of the throwing motion, this investigator believes the supraspinatus is important to the dynamic stability of the shoulder in the throwing motion. Suzuki (1981, p. 68) said, "There is no doubt that the supraspinatus muscle play[s] the most important role in joint stability." Pappas et al. (1985a, p. 230) stated, "A proper functioning supraspinatus is a prerequisite for proper depression and stabilization of the humeral head within the glenoid during the phases of throwing."

Recommendations

On the basis of the results of this study, four recommendations are presented for further research.

1. A similar study should be undertaken using new isokinetic testing equipment now available. Since the testing for this study was completed, several companies have produced isokinetic dynamometers that measure torque output eccentrically and concentrically at angular velocities of up to 450° per sec. The new study should measure torque output of the supraspinatus eccentrically and concentrically at angular velocities in the <u>functional range</u> of 300°-450° per sec (Wilks, 1990). The study could attempt to (a) correlate torque values with throwing velocity and accuracy or (b) gather torque output values to establish normative data.

2. The supraspinatus test designed for this study could be used to examine the bilateral differences of supraspinatus power in specific populations of those using predominantly one arm, for example, baseball or tennis players.

3. A study should be done that (a) isokinetically tests other muscles or muscle groups of the shoulder area,

and (b) determines their correlations to throwing velocity and accuracy.

4. A study examining the effects of the shoulder muscles' passive recoil on throwing would be of great interest.

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APPENDICES

APPENDIX A

Medical Questionnaire
Informed Consent

MEDICAL QUESTIONNAIRE*

Arm History

1. Which arm do you throw with? Left___ Right___

2. Have you ever had any shoulder surgery? Yes___ No___

   If yes, how long ago?________________________________

3. Have you ever had any elbow surgery? Yes___ No___

   If yes, how long ago?________________________________

4. Have you had any arm or shoulder injuries that have stopped you from throwing this season? Yes___ No___

   If yes, when was the injury and for how long did the injury keep you from playing in a game?________________

   ____

   ____

5. Do you have an arm injury now? Yes___ No___

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*Each potential subject was asked the questions verbally.

INFORMED CONSENT

Potential Subject:

Please read the following carefully and ask any questions that you might have. When you understand the testing procedure, please complete the bottom section. Thank you.

You will have the muscular strength and power of the supraspinatus muscle of your throwing shoulder tested, using a Cybex II isokinetic dynamometer.

Your throwing velocity and accuracy will also be tested. Throwing velocity will be tested by having you throw a baseball to a catcher from a distance of 60 ft 6 in. (Only the pitchers will throw from the pitcher's mound.) You will throw four baseballs and the speed will be measured with a radar gun. Throwing accuracy will be measured by having you throw five baseballs at a target. Pitchers will throw from a distance of 60 ft 6 in. at a target 18 in. wide and 1 1/2 ft high. The bottom of the target will be 18 in. off the ground. Infielders will throw from 90 ft at a target 7 ft high and 5 ft wide. Outfielders will throw at the same target as the infielders--but from 120 ft.

You will not be identified in the results or anywhere else in this study. You will be able to see your results if you wish. You are free to withdraw from this study at any time without bias. There should be no danger of injury due to the testing.

You should be aware that in the event physical injury results from biomedical or behavior research, the human subject should individually seek appropriate medical treatment and shall be entitled to reimbursement or compensation consistent with the self-insurance program for comprehensive general liability established by the Department of Administration under authority of MCA title 2, chapter 9, or by satisfaction of the claim or judgment by the means provided by MCA, section 2-9-315. In event of a claim for such physical injury, further information may be obtained from the university legal counsel.

I, the subject, am aware of the conditions and methods of this study, and I am willing to participate in it. I also understand that the Chicago White Sox are not connected with this study in any way.

Print your name in full: ______________________________

Date: ________________ Signature: ______________________________

APPENDIX B

Protocol for Cybex II Testing of the Supraspinatus Instruction Text

PROTOCOL FOR CYBEX II TESTING OF THE SUPRASPINATUS

Dynamometer head tilted back 40°.

U.B.X.T. backrest to highest position.

U.B.X.T. seat to middle position.

Footrest height for subject comfort.

Universal adapter (J) with abduction-adduction stabilization handle (N) in receiving tube #4.

Pelvic and torso stabilization straps.

Offset input adapter (K) with shoulder testing accessory (C).

Shoulder extension-flexion handgrip (P) installed so the handle is perpendicular to the long arm of shoulder testing accessory (C).

Install safety cushion (G) in receiving tube #3.

Abduction should be limited to approximately, but not less than, 90° by installing table extension pad (H) in receiving tube #1. The pad should block the shoulder accessory tube and not the subject's hand.

The U.B.X.T. must be rotated 30° toward the shoulder being tested so as to isolate the supraspinatus.

Set the 0° baseline at the fifth major division, with the subject in 90° of abduction.

Set input direction cw for right, ccw for left.

Start the test in complete adduction.

The subject's arm should be internally rotated so that his thumb is pointing down when he grips the handgrip.

INSTRUCTION TEXT

The following instructions were read to the subjects after they had been positioned for the test.

* * *

I will now turn on the machine and set the speed.

You can move your arm up and down now.

I am only interested in how hard you can push the bar up. So bring it down fairly easy, OK? Concentrate on driving it up.

Is the movement smooth? Does your arm feel stretched or shortened at any point in the range of motion? (If the subject answered, "Yes," adjustments were made to correct the problem.)

Use this as a warm up period and get used to the machine.

Notice that no matter how hard you push, the speed of the movement stays the same.

Are you ready to start?

When I say, "Go," I want you to perform three reps, pushing up as hard as you can on each one, OK?

Ready, set, go!

OK, good. Now I'm gong to increase the speed of the machine.

Try a few practice reps. It's a lot faster now.

Are you ready?

When I say, "Go," I want you to perform five reps, rushing up as hard as you can on each one, OK?

Ready, set, go!

All right. Thanks. That's it for this test.