EFFECT OF TWO STRENGTH TRAINING PROGRAMS ON THROWING VELOCITY

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ABSTRACT

The purpose of this study was to examine the effects of two strength training programs on throwing velocity, range of motion and strength of the rotator muscles of the glenohumeral joint.

Thirty-four male subjects (ages 18-28 yrs. old) participated in a repeated measures experimental design study with subjects randomly assigned to one of three groups (Weight, Tubing, Control). Subjects were pretested for external and internal rotation range of motion, concentric and eccentric external and internal rotation peak torque, and maximum throwing velocity. One group of subjects then completed an eight week exercise program using weights (weight group) while another group completed an exercise program using surgical tubing (tubing group). The third group served as the control group and did not exercise. At the end of eight weeks, all subjects were post-tested on the same variables under the identical conditions of the pretest.

Statistical analysis included computation of analysis of variance with repeated measures and Pearson Product Moment Correlation matrices on all variables for the pretest, posttest, and change (difference between pre and posttest) values.

The results indicated that both the weight and tubing protocols produced a significant ($p<.01$) increase in external and internal rotation range of motion. The tubing group had a significant ($p<.05$) increase in throwing velocity while the control group had a significant ($p<.05$) decrease in throwing velocity. No group had any significant changes in any of the strength variables. The correlation matrix revealed that the only significant relationship on the change values was between concentric internal torque and throwing velocity ($r=.46$, $p<.01$).

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ACCEPTANCE OF DISSERTATION

The dissertation, EFFECT OF TWO STRENGTH TRAINING PROGRAMS ON THROWING VELOCITY, by Byron S. Shenk is accepted in partial fulfillment of the requirements for the degree, Doctor of Education.

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> "By this the love of God was manifested in our case, that God has sent His only begotten Son into the world so that we might live through Him. In this is love, not that we have loved God, but that He loved us and sent His Son to be the propitiation for our sins."

DEDICATION

This dissertation is dedicated to my mother and dad who by their lives provided me an example of God-like love and to my three sons, Eric, Todd, and Troy, whose never ending love and support of their dad inspires me to strive to be a godly man.

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Chapter One

INTRODUCTION

In the sport of baseball, pitching is considered the single most important factor to the success of any team. Baseball experts (Allen 1982, Alston and Weiskopf 1978, Reiff 1971, Sullivan 1970) estimate that the probability of any team being a consistent winner depends 65 to 85 percent on the quality of a team's pitching. This is true at all levels of play, from youth leagues up through the major leagues and the World Series each fall. The importance of pitching can be illustrated with the fact that in youth leagues, the boy or girl who can throw the ball the fastest traditionally is the pitcher.

Throwing is a vital skill to every defensive player in baseball (Croce 1987) with speed, distance, and/or accuracy being the requisite ingredients for successful throwing and pitching. In pitching, velocity is usually considered to be the single most important requirement to success at higher levels of play (Allen 1982, Alston and Weiskopf 1978, Reiff 1971), even though other factors such as control and movement of the ball on all types of pitches are also high priorities. Some baseball experts (Allen 1982, Alston and Weiskopf 1978) rate velocity as the most important 'raw' quality to look for in a pitcher as they believe it is the one fundamental requirement for successful pitching that cannot be taught.

If throwing velocity can be enhanced, not only the pitcher, but every member of a baseball team potentially can become a better player. Athletes, coaches, athletic trainers, and sports medicine specialists are among those who are constantly seeking ways and means to increase throwing velocity.

Factors Influencing Throwing Velocity

There is an ongoing and unresolved debate as to which physiologic factors, outside of biomechanical considerations, can most influence throwing velocity. One theory which has been proposed is that degrees of external rotation of the humerus is the one physical characteristic which correlates significantly with throwing velocity (Atwater 1979). According to this theory, the nearer an individual approaches their absolute physiologic limit of external shoulder rotation the more likely they will be able to achieve their potential maximum velocity. Experienced major league pitchers attain over 160 degrees external rotation with the arm abducted at 90 degrees while in the act of pitching (Pappas et al. 1985). Other investigators (Tullos and King 1973) also believe that increasing degrees of external rotation improves the efficiency of the internal rotator muscles, and thus enables the pitcher to deliver the ball with greater velocity.

Another proposed theory relates to strength of the shoulder rotator muscles. Several researchers (Brown et al. 1988, DeRenne 1985, Pawlowski and Perrin 1987, Thompson and Martin 1965) found a positive relationship between strength of the external and internal rotator muscles of the shoulder joint and velocity of a thrown ball. In a recent study of professional baseball pitchers and position players it was shown that both the degrees of rotation and strength (isokinetic peak torque) of the shoulder joint external and internal rotator muscles were significantly greater in the dominant than nondominant arm of all the players (Brown et al. 1888). Additionally, the pitchers had significantly greater bilateral strength of the shoulder rotator muscles, and greater dominant arm external rotation and forearm pronation than the position players. However, there was no significant difference in the amount of pronation between the dominant and nondominant arms of pitchers.

A few studies have shown other results. McCraw (1975) found the correlation between strength and speed to be from -0.03 to 0.09. Richardson (1976) found a positive relationship (r=.36) between grip strength and velocity. A more recent study (Pedegana et al. 1982) examined fourteen upper extremity strength measures and throwing velocity and found two movements, wrist extension and elbow extension, appeared to have more direct relationships with velocity than did the others.

Little or no experimental work has been reported that examined the effect of increasing shoulder joint external rotation on throwing velocity. Sandstead (1968) found that external shoulder rotation correlated significantly with throwing velocity. However, no studies have examined the effect that increasing the range of motion in the shoulder joint has on throwing velocity.

Many studies have investigated the relationship between strength of the shoulder musculature and throwing velocity and the subsequent effect of increased strength on throwing velocity (Brose and Harrison 1967, DeRenne 1985, DeRenne 1987, Elias 1964, Hooks 1959, Litwhiler 1973, Logan 1966, Prospecue 1975, Sullivan 1970, Swangard 1965, Thompson and Martin 1965, Van Huss 1962). Each of these studies established a cause and effect relationship between enhanced strength of the shoulder musculature and increases in throwing velocity. However, the best method for increasing throwing velocity has yet to be identified. A variety of methods have been used to apply resistance to the throwing muscles. Increases in throwing velocity have been found after weight training (Hooks 1959, Sullivan 1970, Swangard 1965, Thompson and

Martin 1965), after training with a rope friction resistive device (Logan 1966), and after throwing overweight balls (Brose and Harrison 1967, DeRenne 1987, Elias 1964, Litwhiler 1973, Prospecue 1975, Sullivan 1970, Van Huss 1962).

Factors Related To Injury Prevention

Not only is a high level of strength considered important to successful pitching but adequate strength and flexibility are recognized as two important factors in injury prevention (Blackburn 1987, Croce 1987, Grant and Ritch 1988, Jobe et al. 1984, McCue et al. 1985, Pappas et al. 1985, Sain and Andrews 1985). Each of the above writers emphasized that these two components must be given direct attention in the fitness and conditioning programs designed for maximal performance and injury prevention.

Strength of the rotator cuff muscles (subscapularis, supraspinatus, infraspinatus, teres minor) is especially important in the prevention of injuries in pitchers. A major function of the rotator cuff muscles is to counter the high compressive joint forces created within the glenohumeral joint and to keep the humerus properly aligned within the glenoid cavity during the acceleration and deceleration phases of throwing (Basmajian 1967, Blackburn 1987, Gowan et al. 1987, Hughston 1985, Jobe et al. 1984, McCue 1985, McLeod 1985, Kessell 1986, Kulund 1989, Pappas et al. 1985).

Both weight training and surgical tubing are commonly employed in the rehabilitation of throwing injuries (Blackburn 1987, Croce 1988, Grant and Ritch 1988, Jobe et al. 1986, Kulund 1989, McCue et al. 1985, Pappas et al. 1985). However, only two of the above writers (Grant and Ritch 1988, Kulund 1989) report that they commonly use tubing in other than a rehabilitation setting. If tubing strength training can be shown to effectively increase velocity and/or strength in the throwing musculature without hindering range of motion (or if it enhances range of motion), it can aid baseball players through injury prevention, rehabilitation, and enhancement of performance. Tubing has the advantages of convenience (can easily be carried and used by the player), utility (can be used in warm-up, as an aid to stretching, in rehabilitation, and strength training), and specificity (isolation and exercise of the rotator cuff muscles is readily achieved) (Behm 1988, Grant and Ritch 1988, Kulund 1989).

Statement Of The Problem

The purpose of this study was to examine the effects of an established weight training regimen and a surgical tubing strength training regimen on throwing velocity, range of motion, and on the concentric and eccentric strength of the external and internal rotator muscles of the shoulder joint.

Definitions

1. Throwing velocity. The time rate at which a player is able to throw a baseball in a linear direction measured in units of miles per hour.

2. Shoulder joint. The ball and socket joint created by the junction between the glenoid labrum of the scapula and the head of the humerus.

3. External rotators of the shoulder joint. The muscles which insert onto the proximal humerus which when contracted synchronously serve primarily to position the shoulder for the delivery of the pitch by abducting, horizontally extending, and externally rotating the humerus, and to decelerate the arm in the follow-through phase of the pitch. Muscles commonly considered in this group include the supraspinatus, infraspinatus, teres minor, and deltoid.

4. Internal rotators of the shoulder joint. The muscles which insert onto the proximal humerus which when contracted synchronously serve primarily to accelerate the humerus forward in space by horizontally flexing and internally rotating the humerus. Muscles commonly considered in this group include the pectoralis

major, subscapularis, and latissimus dorsi.

5. Concentric strength of the shoulder rotators. The peak torque generated by concentric (to move toward a common center, i.e., to shorten) muscle contractions of the external and internal rotators of the shoulder joint.

6. Eccentric strength of the shoulder rotators. The peak torque generated by eccentric (to move away from a common center, i.e., to lengthen) muscle contractions of the external and internal rotators of the shoulder joint.

7. Weight training program. A systematically planned progressive resistive exercise program employing barbells and dumbbells and designed to stimulate concentric and eccentric muscle force development capacity.

8. Surgical Tubing training program. A systematically planned progressive resistive exercise program employing surgical tubing (stretch tubing) and designed to stimulate concentric and eccentric muscle force development capacity.

Research Hypotheses

It was hypothesized that each of the strength training programs (weight training and surgical tubing training) would increase throwing velocity, range of motion, and the concentric and eccentric strength of the external and internal rotators of the shoulder joint. It was further hypothesized that the increase in velocity from the surgical tubing strength training program would be significantly greater than the increase in velocity obtained from the weight training strength program.

Delimitations

This study was limited to thirty-four University of Virginia volunteer male subjects, eighteen years old or older, who had previously participated in some form of organized baseball or softball (e.g., high school, youth leagues, American Legion, college, or semi-professional) but who were not currently participating in any organized baseball or softball and who were free of any injury to the throwing arm. The study was limited to the effects of a weight training strength program and a surgical tubing strength training program on throwing velocity, shoulder joint range of motion, and the concentric and eccentric strength of the shoulder rotator muscles.

Limitations

The overhand throw is a highly skilled motion used by both pitchers and field players. Not all of the subjects used in the study were experienced pitchers, therefore some subjects may not have been completely comfortable throwing for speed off the pitching mound. The subjects also had a variety of past athletic experiences in the throwing sports of baseball, softball, and football, so various levels of competency existed within the groups.

Limitations existed in that the investigator was not able to have complete control of the sleep, diet, rest, fatigue, and psychological and environmental factors which may have had an effect upon the performance of the subjects. Likewise, the investigator was unable to objectively determine the degree of effort the subjects applied during training and testing.

Velocity measurements in this study were limited by the recorded accuracy, to the nearest one-tenth mile per hour, of the K-15 radar gun (Doppler Corp., Chanute, Kansas). Strength measurements in this study were limited to the accuracy of the force transducer of the Kinetic Communicator (Kin Com) dynamometer (Chattex Corp, Chattanooga, TN).

Chapter Two

REVIEW OF THE LITERATURE

The review of the literature is divided into six sections. The first is a brief review of the basic biomechanics of the throwing motion and the muscles involved in throwing. The next three sections address strength training, specificity of training, and specificity of exercise. The final two sections deal with the instrumentation used to collect velocity and strength data.

Biomechanics Of Throwing

The overhand throw, as used in baseball pitching, is a complex motion that involves the entire body in a coordinated manner. Despite this fact, the shoulder usually receives the most detailed attention in an analysis of the total performance. This is primarily due to the complexity of shoulder girdle anatomy and movements, and that the act of throwing per se creates a greater incidence of injuries to the shoulder than to any other body area or part (Basmajian 1967, Jobe et al. 1984, McCue et al. 1985, McLeod 1985). The importance of the lower extremities and trunk in throwing should not be overlooked or minimized when discussing the total performance. A classic work in biomechanical analysis of the overhand throw (Toyoshima et al. 1974) established that 46.9% of the velocity of the overhand throw could be attributed to the step and body rotation. The remaining 53.1% is due to arm action.

In executing the overhand throw, the throwing limb functions within a system of segmental links. This link system is considered to be an open kinetic chain. It is considered an open system because the last most distal segment is not fixed but is free to move in space. It is a kinetic system because internal muscle torques act between the individual links in the system. In general, the more proximal (base) segments are slower moving compared to the distal (free end) segments (i.e., knee or hip compared to the hand) (Cooper et al. 1982, Kreighbaum and Barthels 1985, Lehmkuhl and Smith 1983). This has some important implications for the timing of movement patterns in throwing. Likewise, it is imperative that the strength training program for the throwing athlete be designed to enhance these movement patterns.

During the throwing act (excluding the stance when the pitcher is communicating signals with the catcher), there is no measurable time frame wherein significant action takes place with the feet in a bilateral static position (i.e., feet apart on a straight line with weight evenly distributed between the two limbs as in an "at ease" standing position). Neither is there a time in a normal throwing act where the throw is executed while the body weight is supported by other than the feet (i.e., such as in a sitting or supine lying position). Yet many of the traditional strength training moves are performed in these positions (i.e., standing barbell press, seated behind the neck press, bench press, squat).

The actual throwing motion focuses more around the shoulder than the arm. The shoulder serves a functional purpose for the hand in most activities involving the upper limb. Kessell (1986), in describing the shoulder, places emphasis on the thought that the main function of the shoulder, regardless of the activity an individual is engaged in, is to place the hand in the proper position to execute desired movements.

In the most fundamental sense the term 'throw' or 'throwing' can be used to characterize movements used to "pull" along an object that is allowed to lag back behind the proximal segments that are moving forward. Likewise the term 'throw' refers to the characteristics of the general movement pattern of a throw and not to the throw itself (Kreighbaum and Barthels 1985, Lehmkuhl and Smith 1983).

Five Phases Of Throwing

The act of throwing is typically described as occurring through five phases and includes the stance, wind-up, cocking, acceleration of the arm, and the follow-through phases (Jobe et al. 1983, McCue et al. 1985, McLeod 1985). Exertion of forces in the proper direction, proper time, proper sequence, and over the greatest practical range while maintaining ground contact until release are all essential biomechanical principles to the throwing act (Cooper et al. 1982, Kreighbaum and Barthels 1985, McCue et al. 1985, McLeod 1985). The execution of motion in each of the five phases of throwing involves the incorporation of one or more of the above biomechanical principles in a coordinated manner. Following is a review of the five phases of throwing.

1) The Initial Stance.

The stance is a time when the body's center of gravity falls within the base of support as the pitcher stands relaxed facing the catcher while receiving signals. It is characterized by the feet and legs being nearly static while the hands may be cupped together in front of the body, waist high. The trunk may be slightly flexed at the waist, and the shoulders internally rotated as the pitcher and catcher communicate signals. It is an important time in that the pitcher uses this phase (time) to prepare physically and mentally for the powerful explosive effort to follow (Jobe et al. 1983, McCue et al. 1985, McLeod 1985). It is a time of little or no physical stress on the body with minimal muscle activity of any of the throwing muscles (Gowan et al. 1987, Jobe et al. 1983).

2) The Wind-up.

The wind-up is that time that movement begins in the stance until the moment that the ball is removed from the glove. The wind-up establishes a rhythm for movements that are to follow, is used to conceal the ball and distract the batter, and places the body in a position so all segments can properly contribute to the projection of the ball.

Some significant actions during this time involve the initial step back, the push-off, rotation of the hips, trunk, and shoulders away from the direction of the throw with the pivot on the ipsilateral leg. By flexing and drawing across the body the contralateral leg, and shifting the center of gravity over the supporting foot, dynamic balance is maintained. With the use of high speed photography (Pappas et al. 1985), three events have been identified which occur simultaneously as the contralateral leg pushes off and leaves the ground. These are the arms flex forward with the ball concealed in the glove, the ipsilateral leg and the trunk rotate approximately 90°, and the contralateral hip and knee flex.

Following these simultaneous events, the weight is then shifted from the contralateral or striding leg to the ipsilateral or pivot leg. The striding leg is swung forward across the front of the body as the ball is removed from the glove following the weight shift. With the removal of the ball from the glove, the wind-up phase is ended. Key factors during this phase are dynamic balance and establishing a smooth rhythm (Gowan et al. 1987, Jobe et al. 1983, Pappas et al. 1985, Sain and Andrews 1985). This is also a time of low stress on the body and low to moderate activity in the muscles used in throwing (Gowan et al. 1987, Jobe et al. 1983).

3) The Cocking Phase.

The cocking phase is a period of shoulder abduction and external rotation. It begins as the ball is released by the gloved hand and ends when maximum external rotation at the shoulder is obtained. Contact of the forward foot divides this stage into early and late phases. The knee of the pivot leg flexes slightly, lowering the center of gravity. The throwing shoulder is brought into a position of abduction, extension, and internal rotation as the ball is removed from the glove. The elbow varies among pitchers at this moment and may be completely extended or flexed to approximately 90°. The wrist is flexed during this sequence and it is the only time the wrist flexes during the pitching sequence (Gowan et al. 1987, Jobe et al. 1983, Pappas et al. 1985).

High speed photography (Pappas et al. 1985) has shown the entire cocking stage lasts approximately 1.5 seconds and accounts for nearly 80% of the time required to complete the entire pitching sequence. The cocking mechanisms serve to increase the distance through which force may be applied to the ball.

In this phase the upper body and arm become like a coiled spring being pulled back ready to unleash. The weight is shifted forward and the body lowered as the contralateral leg continues forward across the body. The pivot leg vigorously extends, driving the body forward into the final phase of the stride. Simultaneously, the hips and pelvis begin to rotate forward, followed by a segmental rotation of the trunk progressing from the pelvis to the shoulders. The contralateral foot is planted at the end of its forward stride slightly to the left of an imaginary line running from the pitching mound to home plate (for a right-handed pitcher). This allows the pelvis and trunk maximum rotation prior to delivery (Jobe et al. 1983, Pappas et al. 1985)

The chest is thrust forward during this time. The shoulder is abducted 90° and maximal external rotation of 160° or more takes place in the humerus. The elbow is flexed 90° and the entire anterior capsule and internal rotators of the shoulder and anterior chest are placed under a strong stretch. Even though the ball does not move forward during this time, the chest and shoulder advance forward during the late stages of this phase, placing an even greater extrinsic loading to the pitching arm. All anterior muscles of the chest and shoulder joint are eccentrically loaded through these actions (Gowan et al. 1987, Jobe et al. 1983, McCue et al. 1985, Pappas et al. 1985).

During the cocking phase there is considerable and intense muscle activity that takes place in a sequential activation pattern. First the deltoid (anterior, middle, and posterior heads) contracts concentrically to abduct the humerus to 90° and hold it there. This is followed by the supraspinatus, infraspinatus, and teres minor muscles contracting to bring the arm into external rotation. Lastly the subscapularis fires, supposedly to decelerate the shoulder's external rotation (Gowan et al. 1987, Jobe et al. 1983, Pappas et al. 1985).

Other muscles of the shoulder girdle have either eccentric or concentric activity of varying intensity during this time. Some of these include the rhomboids, trapezius, pectoralis major, latissimus dorsi, biceps, triceps, and serratus anterior. Of course, the major trunk and leg muscles are active during this time (Gowan et al. 1987, Jobe et al. 1983, Pappas et al. 1985). This is a time of high stress to the upper body.

4) The Acceleration Phase.

The acceleration phase begins with the throwing shoulder and humerus in maximum external rotation and ends with ball release. The acceleration phase is very short, always less than one-tenth of a second (Jobe et al. 1984) in length. Just prior to acceleration the anterior muscles of the shoulder are at maximum stretch, eccentrically contracted, when suddenly each must concentrically contract to propel the arm forward (Gowan et al. 1987, Jobe et al. 1984, Pappas et al. 1985).

It is at this point in the throwing act that one sees with clarity the concept of a system of segmental links functioning within the body. Ariel (1985), Kreighbaum and Barthels (1985), and Lehmkuhl and Smith (1983) have each described the importance of movement patterns wherein the slower joints begin their movement as the faster more distal joints complete their backswing. In this open kinetic chain system no appreciable pause between the backswing and forward swing of these faster-moving joints is necessary. Also at this point one sees a demonstration of the concept, noted earlier in this discussion, that in the most fundamental sense the term throw or throwing can be used to characterize movements used to "pull" along an object that is allowed to lag back behind the proximal segments that are moving forward.

At this point the hips have already internally rotated and moved forward. Simultaneously, the trunk is flexing forward and the shoulder has begun internal rotation and forward movement while the arm still lags back behind (in maximum external rotation and horizontal abduction). This increases the distance over which the forearm and hand can be accelerated in the propulsive phase. Thus, the anterior musculature and capsule of the shoulder are put on extreme stretch as the backward moving and externally rotating limb is suddenly pulled forcefully forward by the shoulder combined with powerful concentric contractions of the internal rotator muscles initiating internal rotation of the arm. This combined backward to forward movement and eccentric to concentric contraction stretches the tendons and connective tissue in the anterior muscles, making the forward movement more forceful (Kreighbaum and Barthels 1985, Lehmkuhl and Smith 1983).

The high degree of stretch and high forces on the shoulder complex are due to a combination of muscle contractions and change in direction executed at very rapid rates of speed. Pappas et al. (1985) reported the average time for the acceleration phase in major league pitchers was 50 ms (1/20 of a second) with peak angular velocities of shoulder internal rotation reaching as high as 9,198 deg/second with an average of 6,180 deg/second. Peak accelerations approaching 600,000 deg/sec/sec were measured. The muscles involved in the cocking phase are also involved in the acceleration phase, however, often with the reverse function in the acceleration phase from the cocking phase (e.g., concentric to eccentric or eccentric to concentric and or to stabilizer).

Four actions occur sequentially which lead to ball release. First, the shoulder is powerfully derotated from maximal external rotation (up to 160° or more) to the point of ball release where the shoulder is in 40° to 60° of external rotation. Then, as the shoulder derotates the elbow goes from approximately 90° flexion to approximately 120° of flexion and then rapidly extends to a position of about 25° flexion at ball release. From here the wrist goes from extension to a position of extension in the neutral position at release (the wrist does not snap forward into acute flexion). Finally radioulnar pronation occurs a few milli-seconds prior to release (Atwater 1979, Jobe et al. 1984, Pappas et al. 1985).

5) The Follow-Through.

The follow-through phase begins at ball release and continues until the motion of throwing has ceased. The major purpose of the follow-through is to safely and comfortably decelerate the throwing arm (Jobe et al. 1984, McLeod 1985, Pappas et al. 1985). Studies have shown that the follow-through phase lasts 350 ms, which is 18% of the pitching sequence (Jobe et al. 1984, Pappas et al. 1985). Peak elbow extension velocities (accelerations) reach about 500,000 deg/sec/sec just prior to ball release (Pappas et al. 1985). This is a period of extremely high stress to the rotator cuff muscles responsible for deceleration and to the biceps brachii muscle, also a decelerator.

The remaining actions/functions of the follow-through activity has the shoulder moving across the body and the elbow going into extension and forearm pronation. The final phase of deceleration occurs passively with the body merely catching up with the arm as the athlete comes to a position of balance with both feet in contact with the ground in preparation for play that follows (Gowan et al. 1987, Jobe et al. 1984, Pappas et al. 1985, Sain and Andrews 1985).

<u>Strength Training</u>

Strength is considered one of the most primary components of successful performance in athletic and sport activities (Costello 1988, Croce 1987, Prins 1978). For many years efforts to improve sport and athletic performance have involved trial and error and scientific research in the areas of nutrition, psychological aspects, biomechanical analysis, scientific advancements in equipment, training conditions and environments, and training methods. No one aspect of improving performance has received more attention than the area of strength improvement. It would be advantageous to be able to develop methods of building strength for each specific sport which would eventually result in improved performance for that particular sport.

The sport of baseball was relatively slow to accept the concept of using progressive resistive exercises to improve performance. Progressive resistive exercises as now known had their inception in therapeutically oriented rehabilitation hospitals and clinic. During World War II the urgent need for hospital beds and speedier recovery for the wounded was directly responsible for a chain of events that led to this type of exercise at Gardiner General Hospital, Chicago, Illinois, in the spring of 1944 (DeLorme 1951).

<u>Early strength research</u>. A large number of investigations were conducted to study the effects of systematic or heavy weight training on power, strength, endurance, and speed of muscle contraction in the 1940's and 1950's (Capen 1950, Chui 1950, Clarke and Henry 1960, Houtz et al. 1946 , Masley et al. 1952, Whitley and Smith

1965, Wilkens 1952). These early investigations studied the effect of weight training on a variety of physical qualities such as speed of arm movement and coordination (Clarke and Henry 1960, Masley et al. 1952, Whitley and Smith 1965, Wilkens 1952), power and circulatory-respiratory endurance which were measured with a battery of test items such as standing long jump, jump and reach, shot putting, etc. (Capen 1950, Chui 1950), and strength, which was the primary focus of each these early studies.

Strength training for baseball. One of the first, if not the first, investigations of weight training for baseball involving a professional in the field of physical education and baseball, appeared in 1958 when coach Hòoks of Wake Forest College shared with several fellow coaches a weight training program he had implemented for his baseball prospects (Elias 1964). Many investigations followed in the 1960's on the effect of various 'overload methods' and weight training on velocity of throwing. In the last decade fewer studies have been reported, but some research has continued on the effect of strength training and velocity of throwing (DeRenne 1985). Today, progressive resistive exercises and strength training are universally accepted for all aspects of baseball training and conditioning (Croce 1987).

Methods of strength development. Three primary methods of building strength are currently recognized and include isometric, isotonic, and isokinetic training (Atha 1981, Clarke 1973, Prins 1978). Some research has shown that the isokinetic method may be superior to the other two forms of strength building when the purpose of the program is to enhance fast and powerful muscle contractions (Astrand and Rodahl 1986, Chu and Smith 1971, Pipes and Wilmore 1975, Rosentswieg and Hinson 1972). This superiority may be related largely to the physiological and biological principle of 'specificity of training' which will be examined later in the discussion. However, no one method has proven superior for strength development in general (Astrand and Rodahl 1986, Atha 1981, Clarke 1973).

Categories of strength. Several categories of strength are recognized by many strength and conditioning experts. These categories include absolute strength, general strength, special strength, and specific strength (Behm 1988, Costello 1988, Croce 1987, Gambetta 1988, Gambetta 1987, Korchemny 1988). These categories exist in both the concentric and eccentric contraction modes. One of these strength specialists (Gambetta 1987, Gambetta 1988) sees absolute strength as the absolute or maximum contractile generating capacity of a muscle and its primary function is the overcoming of inertia. It can also be called maximum strength. It is essential for sports requiring acceleration and quick stops and starts. He defines general strength as a good core level of muscular strength for joint stabilization, coordinated movements in a manner that minimizes stress on the rest of the musculoskeletal system: bone, tendon, ligament, and cartilage as well as utilizing the normal elasticity of the muscle to absorb shock. He sees special and specific strength as very important in order to apply the general (maximum) strength to the sport. Lastly, he sees eccentric strength as necessary for stopping quickly and changing direction.

The concept of optimum strength rather than maximum strength is of primary importance in athletics (Costello 1988, Croce 1987, Gambetta 1988, Gambetta 1987, Korchemny 1988). Optimum refers to the ability to use and express the strength that has been developed for maximal or improved performance. Not all athletes can utilize their maximum strength efficiently when performing specific sport skills (e.g., some very strong people do not run very fast or some very heavily muscled athletes do not throw very well) (Korchemny 1988). All four (Costello 1988, Croce 1987, Gambetta 1988, Korchemny 1988) see excess work on absolute or maximal strength development as potentially detrimental to specific sport performance. For example, if excessive hypertrophy results this adds additional mass to the athlete's body which must be moved (increased inertia), demanding more strength to perform at the same level.

It is possible through poor program design (excess work on bulk and pure or absolute strength) that hypertrophied muscle can diminish the muscles' elastic properties with a resultant decrease in mobility and range of motion. It is also possible that excessive hypertrophied muscle on one aspect of the agonist/ antagonist function can result in a decrease of contraction speed in the opposite less hypertrophied mass as it works to overcome the larger mass. It is possible in a desire to gain absolute strength to spend excess time on this element at the expense of sport-specific type strength training needs.

Physiological considerations in strength training. There is always the questions, why, how, and how much does a muscle increase in strength. Muscular strength, the maximum force or tension generated by a muscle, can be improved up to a physiologic limit by working the muscle close to its force-generating capacity (DeLorme 1948, Goldberg et al. 1975, MacDougall et al. 1984). There is agreement among physiologists that strength development is the result of physiological adaptations resulting from imposed demands to the biologic systems (Astrand and Rodahl 1986, Logan and McKinney 1977). Possessing an understanding of the basic components which elicit adaptations in the muscular unit enables training efforts to be focused directly on the need of individual athletes. Exercise physiologists give us an understanding of these basic components. Strength improvements are governed by the intensity of the overload and not by the specific method. The intensity and duration of tension are the most important factors eliciting strength increases (Astrand and Rodahl 1986, Atha 1981, Clarke 1973, MacDougall et al. 1980).

Strength development has both a neural and muscular component as elucidated in the following quotes. "The improvements in a muscle's force production capacity with resistance training are related to a blend of favorable adaptations that occur both in the muscle itself as well as in the neural organization and excitability for a particular movement" (McArdle et al. 1986). "Muscles are strengthened by increasing their size and by enhancing the recruitment and firing rate of their motor units. It appears that both of these processes are involved in the adaptive response to resistive exercise" (Brooks and Fahey 1985). Both of these, as well as other experts (Astrand and Rodahl, Atha 1981, MacDougall et al. 1984), agree that there is a limit to the neural contribution to muscular strength increases.

As cited earlier in this discussion, isokinetics has been recognized as the potentially superior method to develop strength in the form of fast and powerful muscular contractions. This may be largely due to the fact that the intensity and duration of tension, which is considered to be the most important factors in eliciting strength increases, as noted earlier in the discussion, can be most effectively applied to the neuromuscular unit through isokinetic exercise techniques or machines. Isokinetic training with variable speed control, will allow the load to vary as the force applied at the various joint angles varies, while allowing limb speeds to be reached that are closer to the actual speeds of performance (than with isometric or isotonic training methods). Isokinetic strength training can incorporate the concept of constant speed while maintaining maximum resistance throughout the range of motion (Prins 1978). Thus, higher intensity and duration applied throughout the full range of motion may elicit the adaptation more effectively with isokinetic training as a greater number of motor neurons may be recruited (Coyle et al. 1981, Lesmes et al. 1978, Piper and Wilmore 1975, Prins 1978).

Strength needs in baseball. In the sport of baseball, the fundamental skills of hitting, throwing, and running (base running, running to field balls as well as lateral speed and agility) all benefit from high strength levels (Croce 1987, Gambetta 1988, Gambetta 1987). However, both of these writers agree that the key issue is the interplay between the general, special, and specific strength requirements of the various skills. Therefore, the key emphasis in strength training must be on special and specific strength. This is especially so considering the rapid acceleration and deceleration of joint action that occurs in a very rapid time sequence in throwing; a period of time that is much too short for maximal strength to be generated (Gambetta 1988).

The relationship of strength and injury prevention.

Many strength specialists (Behm 1988, Costello 1988, Croce 1987, Gambetta 1988, Gambetta 1987, Korchemny 1988) emphasize that adequate strength levels play an important role in injury prevention. They see joint integrity, proper strength and proper strength ratios of prime movers and antagonistic muscles, and stabilizing muscles as keys to injury prevention. Croce (1987) and Gambetta (1988) see excessive hypertrophy as a potential problem for increasing injury to the baseball pitcher through impingement syndrome or reduced range of motion. Both believe that if bulk precludes flexibility then one gets diminished returns from strength gains. All three believe a balance in the training program must be the goal. Blackburn (1987) stated that "flexibility is of paramount importance in the prevention of throwing injuries".

Some specific throwing muscle injuries that occur either due to imbalance or inadequate strength levels include the impingement syndrome of the shoulder because of weak infraspinatus and teres minor muscles, biceps tendonitis due to poor eccentric strength of the biceps group necessary to counteract the acceleration and deceleration forces in throwing, and elbow tendonitis which can be caused by overdevelopment of the triceps (Gambetta 1988). Croce (1987) writes, "the primary reason for this reduction in injuries is that players who condition themselves for both strength and flexibility are building a balance between muscle bulk and muscle leanness."

In conclusion, it becomes apparent that for the baseball pitcher, the objective of the strength training program is to develop strength that is specific to the act of throwing, both in terms of performance and injury prevention. The emphasis of the strength training program for the pitcher should not be high levels of absolute strength. Rather, the main emphasis should be for relative strength as expressed as a percentage of body weight. The concept is to get as strong as possible and at the same time maintain body weight as low as possible while keeping flexibility and muscle elasticity at high levels (Costello 1988, Gambetta 1988, Korchemny 1988).

Specificity Of Training

The major objective in training is to elicit biologic adaptations in order to improve performance in a specific activity. In considering human physiologic adaptations one must recognize and cooperate with certain principles that operate with respect to biologic systems of the body. Subsequently, all training must be based on these principles so as to obtain optimal results.

The most fundamental principle to be observed in physical training is the principle of 'specificity of training' (Astrand and Rodahl 1986, Logan and McKinney 1970, McCafferty and Horvath 1977). Specificity refers to adaptations in the metabolic and physiologic systems depending on the type of demand or overload imposed on that particular system (Coyle et al. 1981, Gollnick et al. 1981, Logan and McKinney 1970, McCafferty and Horvath 1977). Adaptation implies change, that is to increase (e.g., growth in muscle hypertrophy, increase in anaerobic or aerobic capacity etc.) or decrease (e.g., reversibility or decrease in muscle hypertrophy, anaerobic or aerobic capacity, etc.). Adaptation can occur only in the presence of stress and the physiological systems will respond to appropriate stimuli (Gollnick et al. 1981, Logan and McKinney 1970, McCafferty and Horvath 1977).

The following quote succinctly summarizes adaptation results from the specificity principle.

> "Repeated stresses on physical systems frequently lead to adaptations resulting in an increase in functional capacity. However, not all stresses are appropriate to enhance the functioning of physiological systems. Physical training is beneficial only as long as it forces the body to adapt to the stress of physical effort. If the stress is not sufficient to overload the body, then no adaptation occurs. If a stress is so great that it cannot be tolerated, then injury or overtraining results. The greatest improvements in performance will occur when the appropriate exercise stresses are introduced into the individual's training program" (Brooks and Fahey 1985).

These adaptations occur at the subcellar level (McCafferty and Horvath 1977) and involve histochemical changes (Prins 1978, Thorstensson 1976) and involve both neural and muscular changes or responses (Astrand and Rodahl 1986, Clarke 1960, Gollnick et al. 1981, MacDougall et al. 1984, MacDougall et al. 1980).

Muscles hypertrophy (increase in size) when they are forced to contract at close to their maximum tensions. Hypertrophy is the major mechanism involved in enlarging muscle. Muscle fibers increase in size by increasing the number and size of their myofibrils. Myofibrils within the cell thicken and increase in number and additional sarcomeres are formed with protein synthesis. This probably occurs as a result of increased amino acid transport into the cells caused by the tension which aids their incorporation into the contractile protein (Goldberg et al. 1975, Gollnick et al. 1981, MacDougall et al. 1984, MacDougall et al. 1981, Saltin and Rowell 1980).

Hypertrophy is directly related to the process of synthesis of cellular protein of the contractile elements and reduced protein breakdown. Increased muscle weight reflects an increase in water content as well as muscle protein, especially sarcoplasmic protein. Thus, a specific type of training appears to induce specific adaptations on the level of protein synthesis (Goldberg et al. 1975, MacDougall et al. 1980, McCafferty and Horvath 1977).

A number of biochemical alterations accompany hypertrophy in strength training. In high-intensity resistance type training there is an increase in muscle glycogen, CP, ATP, ADP, creatine, phosphorylase, phosphofructokinase (PFK), and enzyme activity especially in the Krebs cycle (Astrand and Rodahl 1986, Goldberg et al. 1975, Gollnick et al. 1981, McCafferty and Horvath 1977, Saltin and Rowell 1980). Therefore, stressing a particular system or body part does little to affect other body parts or systems. For example, if one wishes to develop muscular strength in the upper extremities, an aerobic fitness program of running or bicycling would not effectively achieve this goal as both the specific systems (anaerobic) and muscles (arms) would not be subjected to appropriate stimuli to cause adaptation in functional capacity. Thus, training the specific muscles involved in the desired performance is of great importance to specificity of training (Brooks and Fahey 1987, McArdle et al. 1986).

For the most part, the purpose of training will determine the type of training. The following aptly sums up the training response.

> "In most cases as long as a threshold tension is developed, increases in strength will occur. But the type of strength developed is the important consideration in sport and exercise. For example, endurance running up steep hills will develop a certain amount of muscular strength, but the muscular adaptations that result from this type of training will differ from those produced from high-resistance, low-repetition squats. The distance runner tends to develop sarcoplasmic protein (oxidative enzymes, mitochondrial mass, etc.), whereas the weight lifter tends to develop contractile protein. The nature of the adaptive response must always be considered when designing the training program. Several factors determine the rate and type of strength that results from a resistance training program, including overload, specificity, and reversibility" (Brooks and Fahey 1985).

Specificity of training also applies to energy systems within the body as well as fiber types (Froese and Houston 1985, Hickson and Rosenkotter 1980, McCafferty and Horvath 1977, Saltin and Rowell 1980). This has particular implications when one designs the training program so that objectives in the program are not in conflict. As an example, if one is attempting to develop absolute strength and incorporates considerable aerobic work at the same time, the strength gains will suffer. Hickson and Rosenkotter (1980) showed that pure strength gains were up to 20% less when aerobic and strength training programs were engaged in simultaneously when compared to the strength gains made when engaged in strength training only. However, these two areas (energy systems and fiber types) are outside the scope of this discussion but are nonetheless subject to the specificity of training principle.

Specificity Of Exercise

With the acceptance of isokinetic devices for conditioning, strength training, and rehabilitation of athletes, a new dimension became available to exercise physiologist and sports medicine professionals. This new dimension was the development of dynamometers with which to quantify various aspects of muscular work. It has been established or reported by various researchers that the amount of work done is not as important as the rate at which it is done, when power is the variable on which extension of the limits of performance depends (e.g., development of maximum power) (Froese and Houston 1985, Coyle et al. 1981, Moffroid and Whipple 1970, Moffroid and Kusiak 1975, Sagedahl 1986).

Isokinetics allowed the study and development of new understandings in the areas of specificity of speed as related to power development/improvements in exercise and training (Carr et al. 1981, Coyle et al. 1981, Knapik and Ramos 1980, Lesmes et al. 1978, Moffroid and Whipple 1970, Moffroid and Kusiak 1975, Pipes and Wilmore 1975), and new understandings of the force-velocity relationship and/or force-velocity and muscle fiber type relationships in human muscle (Caiozzo et al. 1981, Froese and Houston 1985, Perrine and Edgerton 1978, Thorstensson et al. 1976). Other research conducted in rehabilitation settings has examined speed specific exercise and overflow effects (Sherman et al. 1981, Timm 1987). Some of the significant findings concerning speed of exercise have been 1) an athlete's peak power output occurs with higher velocities (Caiozzo et al. 1981, Coyle et al. 1981, Knapik and Ramos 1980, Moffroid and Whipple 1970, Sagedahl 1986), and 2) an athlete's peak torque output decreases with higher velocities (Caiozzo et al. 1981, Coyle et al. 1981, Moffroid and Whipple 1970, Knapik and Ramos 1980, Thorstensson et al. 1976).

A third point regarding findings and speed of exercise has some conflict in interpretation of results. Some researchers (Caiozzo 1980, Carr et al. 1981, Sherman et al. 1981) found improvements in peak torque only at training speed. Others (Caiozzo et al. 1981, Coyle et al. 1981, Lesmes et al. 1978, Moffroid and Whipple 1970) found improvements at the training speed and speeds below the training speed. Timm (1987) recently found a physiological overflow to 120° above and below the specific isokinetic exercise speed. The differences of the findings in these investigations may be traced to variations in research designs, exercise prescriptions, muscles involved, and testing procedures.

There is generally strong agreement that when training athletes for performance and improvement of performance, speed-specific training is best. That is, in a slow-velocity event, which demands maximal muscular tension, the best training is that which most nearly mimics the performance action, the velocity rate, and develops high tension. In a high-velocity event, which demands maximal muscular power, the best training is that which most nearly mimics the performance action, the velocity rate, and develops high power levels (Coyle et al. 1981, Lesmes et al. 1978, Moffroid and Whipple 1970, Pipes and Wilmore 1975).

Action specificity.

A neglected area in many training programs is action specificity (e.g., training action that mimics the performance action at velocities near to the velocity of the performance) (Behm 1988, Gambetta 1988, Logan and McKinney 1970). This concept is supported by metabolic and muscle fiber type specificity (Froese and Houston 1985, McCafferty and Horvath 1977), Prins 1978, Thorstensson 1976). Psycho-motor learning theories also lend some support to this concept in that evidence suggests it is more beneficial to learn a task as a whole movement than to divide it into components parts (Brigs and Walters 1958).

Since most weight training exercise programs or isokinetic training exercise programs attempt to isolate individual muscles, or become so general that they stress all the muscles in a region, action specificity is largely ignored (Behm 1988, Logan 1977). Many weight training exercises are performed in static positions with feet in line and set (squat, over-head press, dumbbell presses), or on the back (bench press, flys), or in a prone position (bent over row, prone lateral raises), or seated (behind the neck presses, seated presses, leg press). None of these positions lend themselves to mimicking sport-specific actions very well. Most isokinetic exercises are done with the hand holding onto a fixed lever or the shins fixed to a lever, moving through a fixed range of motion while in either a sitting, seated, or fixed standing position. Again, these positions and or actions do not mimic sport-specific actions very well.

In addition, this type of training may produce inappropriate hypertrophy of some muscles which may interfere with efficiency of movement in sports performance (Behm 1988, Costello 1988, Gambetta 1988, Korchemny 1988). Action specific training may reduce the number of exercises and time required to stimulate the desired muscles.

Previous research studies on the effect of weight training on throwing velocity.

Several investigators have reported results of research conducted on the effect of weight training on throwing velocity. Swangard (1965) found a significant increase in throwing velocity after an eight week weight training program for college varsity players. The program included wrist curls and extensions, ulnar and radial deviations, biceps curls, supine lateral raises, pullovers, shoulder shrugs, standing press, and squats. However, the gain of the weight training group was not significantly greater than the gains of an isometrically trained group and a control group (varsity baseball players in daily practice and play) in this study. All three groups were varsity team members in season practice and play.

Thompson and Martin (1965) used a four week weight training program consisting of just four exercises to supplement regular baseball practice for an experimental group while a control group participated only in regular baseball practice. The four weight exercises were the barbell pullover, bench press, alternate dumbbell press, and clean and press. They found that the experimental group experienced a significant increases in throwing velocity whereas the control group did not.

Sullivan (1970) conducted research using three weight training exercises (wrist curls, supine lateral rise, and bent-arm pullover) and resistive simulative throwing (simulative throwing against a rope through a wall pulley) involving eight conditions. The conditions included weight training with and without progression (progression of the resistive overload), weight training with and without progression combined with throwing practice and no throwing practice, simulative training resistance with and without progression in combination with throwing and no throwing practice, and simulative training with no resistance combined with and without throwing practice. Grip strength, wrist flexion strength, arm rotation strength (external rotation of the arm in a supine position with the elbow at the side), and throwing velocity were each pretested and posttested. He found that the weight training was more effective for increasing throwing velocity, wrist flexion strength, and arm rotation strength than was the simulative resistive training. He also found that progression or non-progression of resistance had no significant effect on throwing velocity.

Hooks (1962) tested 30 freshmen baseball players on skills of hitting and throwing and strength of the muscles acting on the wrist, elbow, and shoulder joints. After participation in a body building program using weights for six weeks, during which time the baseball skills were not practiced, they were retested. The results revealed significant improvements in strength measures, hitting, and throwing for distance. However, velocity of throwing was not measured in this study.

Research using surgical tubing for strength training for baseball.

No research studies were found in the literature where specific testing was done on the effect of strength training with surgical tubing on throwing velocity. However, one study was found that bears mention at this point because of the similarity it bears to tube training. Logan (1966) conducted an experiment using simulative pitching wherein the subjects pulled on a rope which ran through a device called the "Exer-Genie". The resistance could be set from zero pounds up to "no movement possible". He choose a resistance level of 2.5 pounds for this study and had the subjects train five days per week in simulative pitching. This light resistance was chosen, after conducting a pilot study, to ensure specificity of motion (e.g., that the subjects would not alter normal body mechanics or muscular patterns from normal pitching). He found a significant increase in throwing velocity following six weeks of training.

Grant and Ritch (1988) did report that they used surgical tubing with nineteen college baseball players for an eight week period as part of the preseason conditioning program. No other strength training was engaged in during this time by the nineteen players. Through isokinetic testing at speeds of 60°, 180°, and 300°, they reported these players demonstrated a combined mean improvement of 25% in strength and endurance of the dominant throwing arm compared to the non-tube exercised non-dominant arm. In addition, they stated that of the players trained with surgical tubing not one sustained a soft-tissue injury or dislocation of the shoulder joint during that year's baseball season.

Surgical tubing gives the ability to mimic the total body actions, not just the shoulder actions, of the actual throwing motion. Tubing allows the trunk to rotate and flex while the legs step and push and the arms and upper torso are externally rotating, flexing, etc., giving a total body action against resistance. Tubing also allows execution of the action at speeds which more nearly approach actual performance than does the use of weights or isokinetic machines. Tubing, as does weight training, also allows for the development of eccentric muscle forces (Behm 1988).

Isokinetics reportedly have the potential to be superior to isometric and isotonic methods for development of explosive strength (Chu and Smith 1971, Pipes and Wilmore 1975, Rosentwieg and Hinson 1972). However, that superiority was shown only in concentric work performance. Eccentric muscle strength is necessary for quickly stopping and changing directions (Gambetta 1988) and is considered of vital importance to injury prevention, especially in the pitching/throwing act (Blackburn 1987, Croce 1987, Gambetta 1988, Jobe et al.1984, McCue et al. 1985, Pappas et al. 1985). Most isokinetic training methods to this point in time have not been able to train the eccentric component or to develop eccentric force (Pipe and Wilmore 1975). This is a serious deficiency of isokinetic strength training which makes its use for the athlete less than desirable. Future developments in the scientific and technological arenas may make eccentric training devices available to the typical athlete but to date such is not the case. At this time tubing provides the most efficient method of mimicking the action specific and speed specific components of sports performance.

Reliability of Velocity Measurement

Measurements of throwing velocity in early studies involved the use of electro-mechanical devices involving micro switches, photoelectric cells and circuit wiring (Elias 1964, Logan et al. 1966, Richardson 1977, Sullivan 1970) or some type of reaction timer (Swangard 1965, Thompson and Martin 1965). Often the velocity was not recorded in miles per hour but in units of seconds or parts of seconds.

The use of Police traffic control Radar Gun units to measure velocity in baseball studies has been the method of choice for many years (Richardson 1976). Radar units operate on a set Hertz or frequency. This frequency is calibrated at the factory and can be checked with the appropriate instrument (tuning fork) by any local police department which uses radar units for traffic control. Should re-calibration of the unit be needed it is usually returned to the factory (Richardson 1976). Measurement is in units of mile per hour to the nearest one-tenth mile per hour.

Reliability of Isokinetic Measurement

Isokinetic exercise equipment, with its constant speed control, permits the load to vary, depending on the force applied at various joint angles. Theoretically, isokinetic-type training makes it possible to activate the largest number of motor units and consistently overload muscles to achieve their maximum tension-developing or force capacity at every part in the range of motion (accommodating resistance) (Moffroid and Whipple 1970, Prins 1978). Isokinetic dynamometers have been interfaced with micro-computers to give precise measurements of peak torque (PT), torque acceleration energy (TAE), average power (AP), and total work (TW) at a variety of speeds, as measured in degrees per second (McArdle et al. 1986, Perrin 1986).

The Kinetic Communicator (Kin-Com) (Chattex Corp., Chattanooga, TN) was the isokinetic equipment used in this study. The Kin-Com permits testing of concentric and eccentric muscle contractions in the isokinetic mode from zero to 210 degrees per second.

The majority of studies on validity and reliability of isokinetic measurements have been done on other types of isokinetic dynamometers (Barbee and Landis 1984, Hart et al. 1981, Johnson and Seigal 1978, Perrin 1986). The coefficient of reliability ranged from r=.75 to r=.99 for peak torque, for power, for total work, and for torque acceleration energy. Variations occur due to speed differences (reliability coefficients are higher at lower speeds) and joints being tested (lower joints such as the knee are more readily stabilized and the majority of testing seems to be on the lower joints). Perrin

(1986) found reliability coefficients in the internal and external shoulder rotators to range from r=.74 to r=.93 while the knee extension coefficients ranged from r=.84 to r=.93 (measured at 60°/sec and 180°/sec).

Farrell and Richards (1986) reported on the mechanical reliability of the Kin-Com. They found that it provided valid measurements of lever arm speed, lever arm position, and force as the force transducer sits on the lever arm. This length can be measured to the nearest centimeter. However, test-retest reliability of specific test protocol(s) was not found in their report. Hageman et al. (1989) reported reliability coefficients from a low of r=.83 for the shoulder external rotators during eccentric contractions in 45° abduction at 180°/sec to a high of r=.93 for the shoulder internal rotators during concentric contractions in a mid-flexion position at 60°/sec for the Kin-Com.

Variation of testing positions for measurement of eccentric and concentric strength of the shoulder rotator muscles using the Kin-Com have been reported. Brown et al. (1988) used a standing position with the arm abducted at both 45° and 90°. Ellenbecker et al. (1988) tested eccentric shoulder strength in internal and external rotation in the seated position with the arm abducted to 90°. However, neither group reported a test-retest reliability coefficient.

Chapter Three

Methodology

Subjects

Thirty-four male volunteers from the student body of the University of Virginia served as subjects for this study. All subjects were over 18 years of age, free from any injury to the throwing arm or shoulder, and had previously played organized baseball or softball. However, none of the subjects participated in organized baseball or softball during the study.

Subjects were verbally informed and given a written detailed description of the experiment prior to signing a "consent to participate form" which had been approved by the University of Virginia Human Investigations Committee (Appendix B). Pre-test data collection was conducted over a two day period for each subject. The first day involved collection of personal data of name, age, height, weight and the bilateral assessment of range of motion and concentric and eccentric strength of the external and internal rotator muscles of the shoulder joint. Each subject's throwing velocity was obtained on test day two. A minimum of two days rest was allowed between assessment of strength and measurement of throwing velocity. In addition, on the second test day the subjects were randomly assigned to one of the two experimental groups or a control group for the duration of the experimental study. The two-day test protocol was identical for collection of post-test data.

Measurement of Concentric and Eccentric Strength

Bilateral external and internal shoulder rotator muscle group peak torque was measured at 150 degrees per second with the Kinetic Communicator (Kin- Com) dynamometer. Each subject was in an upright sitting position with the legs extended straight out in front and the feet resting on a chair. Subjects were secured to the Kin-Com test chair by straps at the hips and chest. The axis of the shoulder joint (glenohumeral joint) was aligned with the center of the axis of the Kin-Com force lever arm with the subject's arm abducted to 90°at the shoulder. With the elbow flexed to 90°, each subjects' hand was strapped to the force transducer shaft in a pronated position according to the manufacturer's recommended protocol (Kin-Com, Chattex Corp., Chattanooga, TN).

To serve as a warm-up and to get acquainted with the operation of the Kin Com machine each subject completed five practice trials concentrically and eccentrically, beginning at approximately fifty-percent of maximum effort and working up to two-thirds effort. Following a brief rest each subject was then asked to give three maximum efforts, both concentrically and eccentrically. There was a brief pause between each effort of approximately 15 seconds to record the just completed effort before the change was made from concentric to eccentric or eccentric to concentric trials. The mean for the peak torque of the three trials was recorded by the computer. This mean was used as the 'peak torque' value for this investigation. When the three maximum efforts on the left side were completed the subject rested approximately four minutes while the Kin- Com was set up to test the right side. The exact test procedure was then repeated with the right shoulder rotator muscle group. The Kin-Com unit was calibrated prior to the pretest and posttest sessions according to the manufacturer's recommendations.

Measurement of Shoulder Range of Motion

Standard goniometric procedures (Norkin and White 1988) were used to measure degrees of external and internal rotation of the arm at the shoulder joint using a two Arm, plastic goniometer (TEC, Cliffton, New Jersey). This measurement was recorded bilaterally and taken prior to any warm-up or throwing activity.

The subject was supine on a table with the arm being tested in 90° of shoulder abduction with the elbow flexed at 90°. The forearm was positioned perpendicular to the supporting surface and in 0° of supination and pronation so that the palm of the hand faced the feet. The full length of the humerus rested on the supporting surface with the elbow free, extending beyond the edge of the supporting surface. A pad was placed under the humerus so that the humerus was level with the acromion process.

The center of the fulcrum of the goniometer was placed over the olecranon process. The proximal arm (stationary arm) of the goniometer was aligned so that it was perpendicular to the floor. This arm of the goniometer also contained a bubble level so as to ensure that this arm was perpendicular at all times during the measurement procedure. The distal arm (movable arm) was aligned with the ulnar styloid process and the olecranon process as reference points. These points were first marked with ink so as to keep the goniometer arm in place throughout the measurement process. The examiner provided stabilization at the distal end of the humerus to keep the shoulder in 90° of abduction in the beginning of the range of motion (ROM).

The examiner moved the forearm through external range of motion to the physiologic end-feel point. The end of the range of motion in external rotation was attained when additional motion caused the scapula to press against the posterior rib cage and or the humeral head began to push forward/upward in the pectoral region. Once the end of the range of motion was found the investigator read the goniometer to the nearest degree. The same techniques were duplicated when measuring internal rotation. In all cases the left arm values were recorded first and then the right arm values.

Measurement of Throwing Velocity

Throwing velocity was measured in the University of Virginia's indoor practice arena (The Cage) so as to standardize atmospheric conditions for all subjects. Subjects threw off a portable pitching mound to a fixed target 60 feet 6 inches away. Velocity was measured by a hand held K-15 radar gun (Doppler Corp., Chanute, Kansas) which was set four feet behind and slightly to the right of the target for right-handed pitchers and four feet behind and slightly to the left of the target for left-handed pitchers. The radar gun was completely rebuilt and calibrated by the factory prior to the first testing sessions. The Charlottesville City Police Department then calibrated the radar gun after the first test session and again before and after the second test sessions. The accuracy of the radar gun for the three calibrations was established as being within one-tenth mile per hour each time.

Each subject warmed up until such time as he was ready to be tested for the three maximal effort throws. Each subject was instructed to throw from the set position and to attempt to achieve maximum velocity on each of the three attempts. There was no verbal encouragement or motivational efforts given to the subject once he was on the mound and ready to throw. The velocity of each individual throw was recorded but not disclosed to the subject until after the third throw was completed. The highest recorded velocity of the three throws was the value used for all statistical analyses.

Weight Strength Training Program

A modified version of the regular University of Virginia baseball pitchers workout program was utilized for this investigation. The modification was that no exercise was performed for more than three sets. Each subject worked out three days per week. Each subject was given assistance in selection of the proper workout resistance. The basic guideline was to use a weight that allowed one to perform the required number of repetitions and sets with good form but with the final few repetitions in each set demanding a very strong effort to complete. Subjects were encouraged to work with a partner to serve as spotters for one another and to encourage optimal effort. Table 1 presents a detailed outline of the week by week weight training program that was employed for this investigation.

Surgical Tubing Strength Training Program

Equipment. Each subject in the tubing group trained with a six foot length of surgical tubing, three-thirty-seconds thickness (Best Priced Company, New York). Both ends of the tube had a permanent four inch loop secured with adhesive tape. When exercising, one end of the tubing was attached to a secure support and the other end grasped by the pitching hand.

Protocol. The surgical tubing exercise training became progressive resistance training through either of two manipulations. One manipulation was to increase the tension with which the exercises were performed. This was accomplished by moving farther away from the point of attachment before performing the exercise, thereby increasing the stretch on the tubing which increased the resistance provided by the tubing. For safety reasons the tubing was not to be stretched more than about 70% of its resting length (Behm 1988).

The second manipulation was through the number of sets and repetitions the exercise was performed. During the first two weeks all tubing exercises were performed for three sets of ten repetitions. During weeks three

Table 1. Baseball Weight Training Program By Weeks

WEEKS 1 and 2

Exercise	Set 1 WTxREP	Set 2 WTxREP	Set 3 WTxREP
Monday			
Squat or Hip Sled	10	10	8
Incline Bench Press	10	10	
Curls (YOUR CHOICE)	10	10	
Front DB Raise	12	12	
Triceps Pushdown	10	10	
T-Bench Int/Ext Rotation	12	12	
Bent Arm Pull Over	10	10	10
Bench Crunch 3 x 25			
Trunk Twist 1 x 30			
Wednesday			
Leg Extension	10	10	10
Leg Curl	10	10	10
Lunges	10	10	
Shrugs	15	15	
Lat Puldwn-BHND Neck	10	10	
Bentover Row	10	10	
Bent Arm Pull Over	12	12	
Bench Crunch 2 x 25			
T-Bench Int/Ext Rotation	12	12	
Trunk Twists 1 x 30			
Friday			
Squat or Hip Sled	10	10	10
Incline Bench Press	10	10	
Lat Puldwn-BHND Neck	10	10	
Curls (YOUR CHOICE)	10	10	
Front DB Raise	12	12	
Triceps Kickback	10	10	
T-Bench Int/Ext Rotation	12	12	
Bench Crunch 3 x 25			
Trunk Twist 1 x 30			

Table 1 Continued

WEEKS 3 and 4

Exercise WTxREP	Set 1 WTxREP	Set 2 WTxREP	Set 3 WTxREP
Monday			
Squat or Hip Sled	10	10	10
Incline Bench Press	10	10	
Curls (YOUR CHOICE)	10	10	
Front DB Raise	10	10	
Upright Row	10	10	
T-Bench Int/Ext Rotation	10	10	
DB Standing Press	10	10	
Bent Arm Pull Over	10	10	10
Bench Crunch 2 x 30			
Trunk Twist (1 x 25 warm-up)			
Wednesday			
Upright Row	10	10	
Triceps Pushdown	10	10	
Bench Press	10	10	
Lunges	10	10	
Shrugs	10	10	
Lat Puldwn-BHND Neck	10	10	
Bentover Row or Low Row	10	10	
Bent Arm Pull Over	10	10	10
T-Bench Int/Ext Rotation	10	10	
Ladder Crunch 2 x 30			
Trunk Twists (1 x 25 warm-up)			
Friday			
Squat or Hip Sled	10	10	10
Incline Bench Press	10	10	
Lat Puldwn- to chest	10	10	
Curls (YOUR CHOICE)	10	10	
Front DB Raise	10	10	
Bent Arm Pull Over	10	10	10
T-Bench Int/Ext Rotation	10	10	
Dead Lift	10	10	
Bench Crunch 2 x 30			
Trunk Twist (1 x 25 warm-up)			

Table 1 Continued

WEEKS 5 and 6			
Exercise WTxREP	Set 1 WTxREP	Set 2 WTxREP	Set 3 WTxREP
Monday			
Squat or Hip Sled	10	10	8
Incline Bench Press	10	10	
Curls (YOUR CHOICE)	10	10	
Triceps Pushdown	10	10	
Upright Row	10	10	
T-Bench Int/Ext Rotation	10	10	
Bent Arm Pull Over	10	10	8
DIAG ABD EXT ROT	10	10	
Ladder Crunch 2 x 30			
Trunk Twist (1 x 25 warm-up)			
Wednesday			
DIAG ABD EXT ROT	10	10	
Triceps Kickback	10	10	
Bench Press	10	10	
Lunges	10	10	
CURLS (Your Choice)	10	10	
Lat Puldwn-BHND Neck	10	10	
Bent Arm Pull Over	10	10	8
Power Clean	8	8	8
T-Bench Int/Ext Rotation	10	10	
Bench Crunch 2 x 30			
Trunk Twists (1 x 25 warm-up)			
Friday			
Squat or Hip Sled	10	10	8
Incline Bench Press	10	10	
Lat Puldwn- to chest	10	10	
Curls (YOUR CHOICE)	10	10	
Lateral Raise	10	10	
Bent Arm Pull Over	10	10	8
Bench Int/Ext Rotation	10	10	
Power Clean	8	8	8
Ladder Crunch 2 x 30			
Trunk Twist (1 x 25 warm-up)			

Table 1 Continued

WEEKS 7 and 8

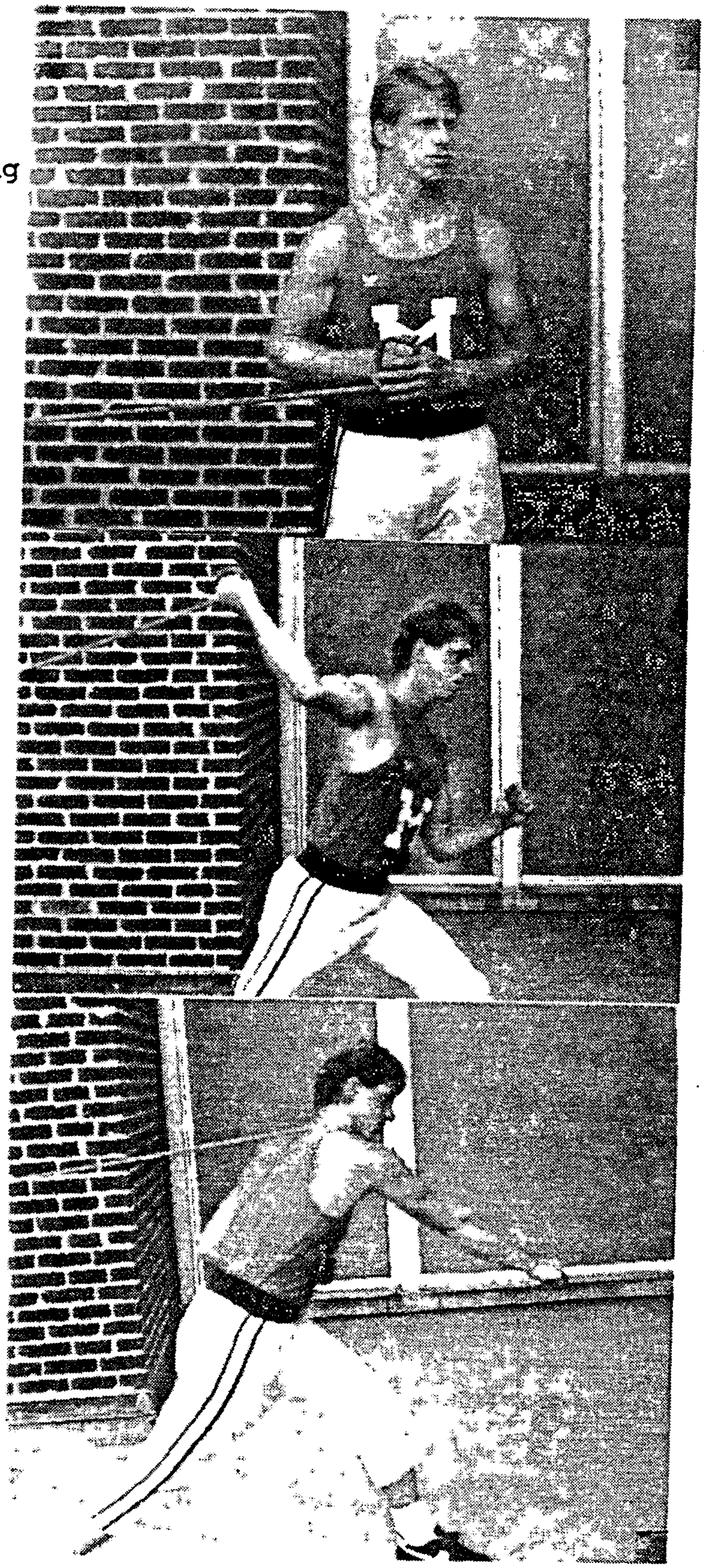
Exercise WTxREP	Set 1 WTxREP	Set 2 WTxREP	Set 3 WTxREP
Monday			
Trunk Twist (warm-up) 1x30)			
Squat or Hip Sled	10	8	8
Bench Press	10	10	
Curls (YOUR CHOICE)	10	10	
Triceps Kickback	10	10	
Lunges	10	10	
T-Bench Int/Ext Rotation	10	10	
Bent Arm Pull Over	10	8	8
DIAG ABD EXT ROT	10	10	
Bench Crunch w/ Twist 2 x 30			
Wednesday			
Trunk Twist (1x25 warm-up)			
DIAG ABD EXT ROT	10	10	
Triceps Pushdown	10	10	
Incline Bench Press	10	10	
Squat or Leg Press	10	8	8
CURLS (Your Choice)	10	10	
Seated Low Row	10	10	
Bent Arm Pull Over	10	8	8
Power Clean	8	8	8
T-Bench Int/Ext Rotation	10	10	
Bench Crunch w/ Twist 2 x 30			
Friday			
Trunk Twists (1x25 warm-up)			
Squat or Hip Sled	10	8	8
Incline Bench Press	10	10	
Lat Puldwn- to chest	10	10	
Curls (YOUR CHOICE)	10	10	
DIAG ABD EXT ROT	10	10	
Bent Arm Pull Over	10	10	8
T-Bench Int/Ext Rotation	10	10	
Lunges	10	10	
Bench Crunch w/ Twist 2 x 30			

and four the exercises were performed for three sets of twelve repetitions. During weeks five and six the exercises were performed for four sets of ten repetitions During weeks seven and eight the exercises were performed for four sets of twelve repetitions.

Exercise 1. Mimic Pitching: Each subject stood with his back to the fixture where the tubing was attached. The tubing was held in the pitching hand at the waist with the opposite hand touching the tubing hand as in the set position in baseball pitching. In this stance the tube was stretched 30-36 inches. The subjects then executed as nearly as possible a complete pitching motion, going through the wind-up, cocking, acceleration and follow-through phases of pitching with the arm/upper body. At the same time every effort was made to execute lower body actions compatible with the normal pitching motion with emphasis on rotation of the hips, step of the lead leg, and push off with the support foot. Three or four sets of ten to twelve repetitions were completed. Figure 1 illustrates this exercise technique.

Exercise 2. Reverse Pitching: Each subject stood facing the fixture to which the tubing was attached with the other end of the tube grasped firmly in the pitching hand. The feet were in a comfortable stride position with the left foot nearer to the attachment point for the right-handed pitcher (right foot advanced for the left-

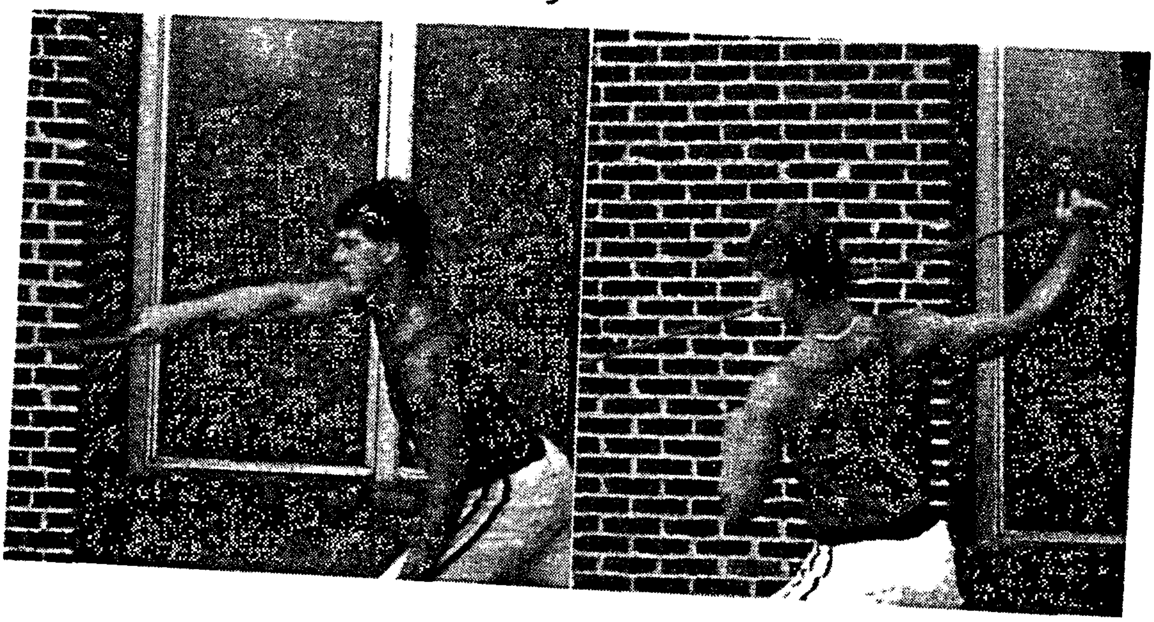
Figure 1.
Mimic Pitching



handed pitcher). The subjects stood away from the point of attachment at a distance so that with the arm holding the tubing completely extended toward the attachment point the tubing was just taut (not stretched more than 12-18 inches). The subjects then executed in reverse order the wind-up and cocking motion of a normal pitch as rapidly as possible pulling against the tubing with the posterior muscles and external rotators of the shoulder girdle. The subjects then allowed the stretched tube to pull the hand/arm back to the starting position with a slow three to five count, trying to feel an eccentric muscle mode. There was some rotation of the hips and trunk but at no time were the feet moved during this exercise. Three or four sets of ten to twelve repetitions were completed. Figure 2 illustrates this exercise technique.

Exercise 3. Standing Supraspinatus (Empty Can): Each subject stood with the tubing securely in hand and the opposite end under the foot of the throwing side, controlling tension by the placement of the tube under the foot (i.e., the shorter the distance between the hand holding the tube and foot the greater the resistance). With the thumb turned down and touching the thigh (approximately where the seam on a pair of slacks would be) the hand was lifted upward to eye level at about 30° of horizontal flexion (to the 2 o'clock position). The

Figure 2. Reverse Pitching



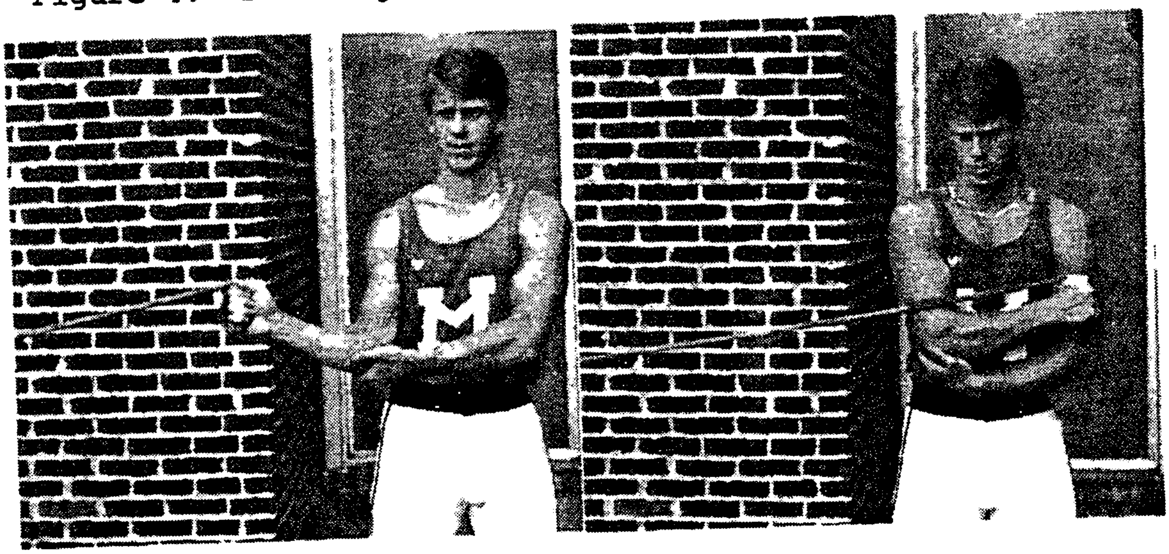
subjects slowly returned to the starting position with a three to five count. This exercise was completed for three or four sets of ten to twelve repetitions. Figure 3 depicts this exercise technique.

Exercise 4. Standing Internal Rotation: Each subject stood with the arm to the side and elbow bent at 90°. The tubing was held securely in hand with the opposite end secured approximately 36 inches above the floor. The subjects stood with the body parallel to the taut tubing and with the hand externally rotated as far as possible (the hand holding the tubing was externally rotated as far as possible away from the body). The subjects pulled against the tubing, internally rotating the forearm across the body while keeping the bent elbow at the side. The elbow remained flexed at 90° throughout the exercise. The subjects returned to the starting position with a slow three to five count. Three or four sets of ten to twelve repetitions were completed. Figure 4 illustrates this exercise technique.

Exercise 5. Standing External Rotation: Each subject stood with the arm to the side and elbow bent at 90°. The tubing was held securely in the hand with the opposite end secured approximately 36 inches above the floor. The subjects stood with the body parallel to the taut tubing with the hand internally rotated as far as possible (the hand holding the tubing was across the

Figure 3. Standing Supraspinatus (Empty Can)

Figure 4. Standing Internal Rotation



front of the body). The subjects pulled against the tubing, externally rotating the forearm out away from the body as far as possible while keeping the bent elbow at the side. The elbow remained flexed at 90° throughout the exercise. The subjects returned to the starting position with a slow three to five count. Three or four sets of ten to twelve repetitions were completed. Figure 5 illustrates this exercise technique.

Exercise 6. Standing Extension: For this exercise the tubing was attached at or near floor level. Each subject stood facing the attachment spot holding the tubing securely in the hand at a distance so that the tubing was taut. With the arm extended at the side and slightly in front of the body, the hand was turned out away from the body as far as possible (externally rotated) and then pulled straight back against the tubing to an end point keeping the arm/hand as nearly in line with the shoulder joint as possible with the thumb turned up. The hand was returned to starting position with a slow three to five count. Three or four sets of ten to twelve repetitions were completed. Figure 6 illustrates this exercise technique.

Pre-Exercise Warm-up Routine

Warm-up activities for the weight group consisted of five to eight minutes of activity. These activities

Figure 5. Standing External Rotation

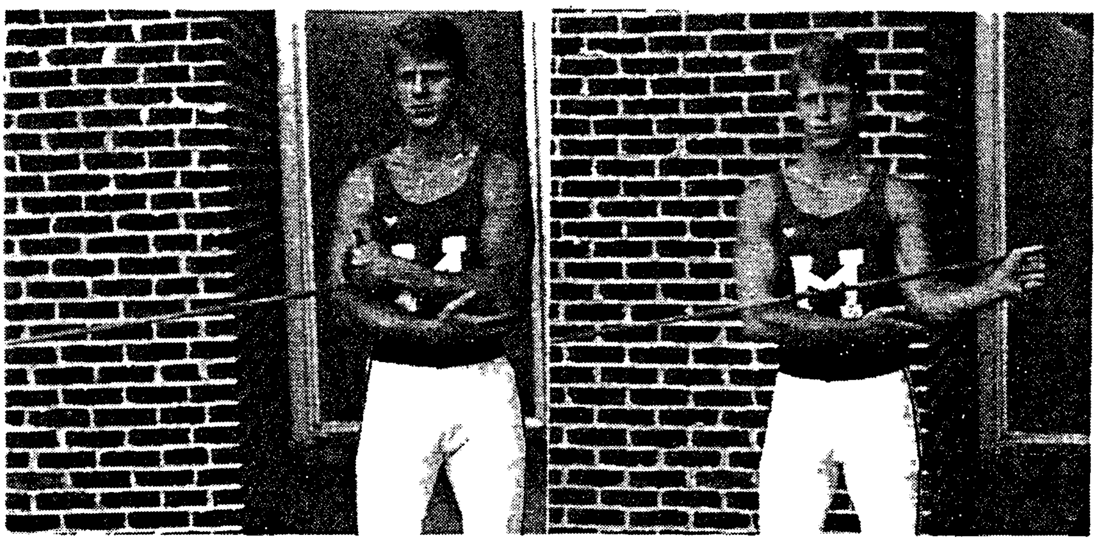
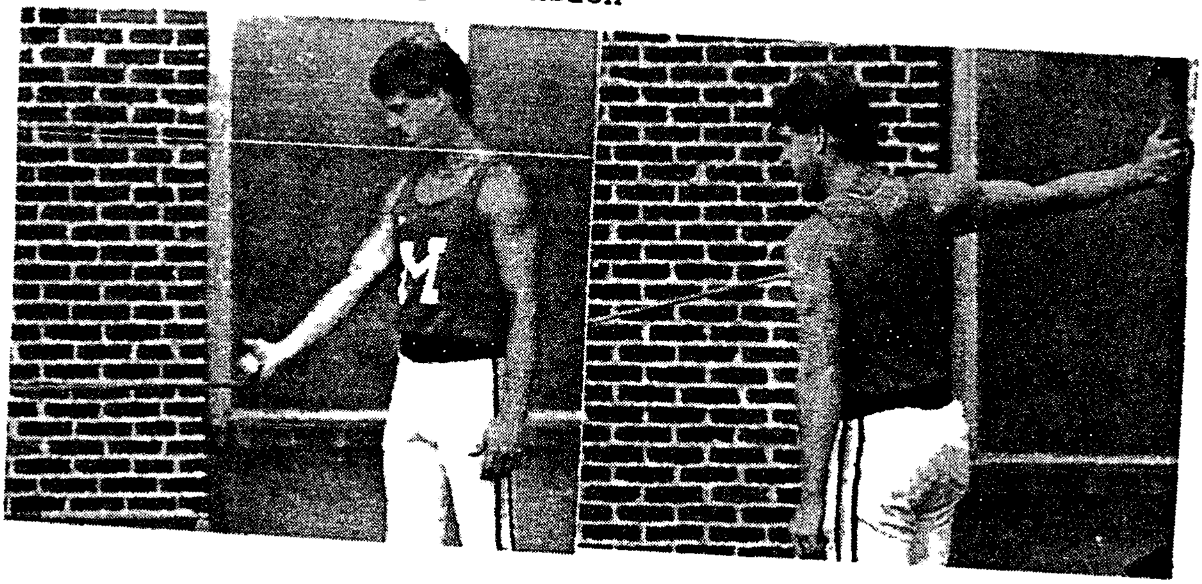


Figure 6. Standing Extension



included jumping jacks, alternate toe touches, sitting hamstring stretches, thigh adductor stretches, and trunk twists with a broom stick held across the shoulders. Specific stretching of the external and internal rotator muscles of the shoulder was avoided in all warm-up sessions. The tubing group did no warm-up activities of any kind since the resistance of the tube was low and the first few repetitions served as warm-up.

Statistical Analysis

Seven separate two-way analysis of variance (ANOVA) with one repeated measures design were computed for degrees of external and internal rotation, concentric external and internal peak torque, eccentric external and internal peak torque, and throwing velocity for pretest and posttest measures for each group. Tukey (Keppel 1982) HSD post-hoc analyses were performed to identify significant sources of variance and to identify differences in treatment effects. Finally, to determine the relationship between range of motion measures, strength measures, and throwing velocity, Pearson Product Moment correlation matrices were generated for the pretest, posttest, and change values.

CHAPTER FOUR

RESULTS

The purpose of this study was to examine the effects of two exercise programs on throwing velocity, strength, and range of motion of the rotator muscles of the shoulder joint. The range of motion measures included degrees of external and internal rotation of the shoulder joint. The strength measures included concentric and eccentric peak torque of the external and internal rotator muscles. Reliability of the strength and range of motion assessment procedures was determined by retesting eight control subjects a minimum of seven and a maximum of twenty-one days following the pretest. Table 2 presents these reliability coefficients. Appendix D presents the reliability raw data scores.

Treatment of the data included calculation of means and standard deviations for degrees of external and internal rotation, external and internal muscle group concentric and eccentric peak torque, and throwing velocity. Tables 3 - 5 present these pretest and posttest means and standard deviations. The raw data for these variables are found in Appendices F - H.

Table 2. Test-Retest Reliability Coefficients For Goniometric and Strength Measures

Test	Correlation
Degrees External Rotation	$.89^{+}$
Degrees Internal Rotation	$.93^{+}$
Concentric External Torque	$.95^{+}$
Eccentric External Torque	$.97^{+}$
Concentric Internal Torque	$.99^{+}$
Eccentric Internal Torque	$.95^{+}$

$^{+}p<.01$

Table 3. Pre and Post-Test Values Range of Motion Values (Degrees) For Shoulder Joint External and Internal Rotation (Mean ±SD)

GROUP	PRETEST Mean	S.D.	POSTTEST Mean	S.D.
CONTROL				
External Rotation	97.36	±4.72	98.73	±4.96
Internal Rotation	68.82	±8.04	70.09	±7.91
WEIGHT				
External Rotation	98.00	±8.37	103.09	±7.61
Internal Rotation	67.63	±8.81	72.09	±9.53
TUBING				
External Rotation	102.25	±6.10	104.42	±5.98
Internal Rotation	69.00	±7.00	72.83	±7.33

Table 4. Pre and Post-Test Strength Values (Newton Meters) For Concentric and Eccentric Peak Torque Of The Shoulder Rotators (Mean ±SD)

GROUP	PRETEST Mean	S.D.	POSTTEST Mean	S.D
CONTROL				
Concentric External Torque	32.55	±6.23	31.91	±5.50
Eccentric External Torque	39.00	±7.06	37.46	±5.82
Concentric Internal Torque	29.91	±7.91	27.81	±8.26
Eccentric Internal Torque	44.00	±10.56	41.00	±7.54
WEIGHT				
Concentric External Torque	40.09	±9.19	41.36	±9.14
Eccentric External Torque	48.82	±10.77	51.09	±12.29
Concentric Internal Torque	38.36	±10.41	37.18	±10.25
Eccentric Internal Torque	58.46	±17.45	57.09	±12.90
TUBING				
Concentric External Torque	34.33	±5.79	34.50	±5.74
Eccentric External Torque	44.17	±10.03	43.75	±9.34
Concentric Internal Torque	32.58	±8.18	30.67	±6.80
Eccentric Internal Torque	45.42	±11.97	47.33	±9.28

Table 5. Pre and Post-Test Values (Miles Per Hour) For Throwing Velocity (Mean ±SD)

GROUP	PRETEST Mean	S.D.	POSTTEST Mean	S.D.
CONTROL	67.90	±6.70	66.76	±7.31
WEIGHT	70.46	±6.56	70.86	±7.72
TUBING	67.86	±8.80	69.72	±7.37

Seven separate two-way analysis of variance (ANOVA) with one repeated measures design were computed for degrees of external and internal rotation, concentric external and internal peak torque, eccentric external and internal peak torque, and throwing velocity for pretest and posttest measures for each group. Table 6 presents the analysis of variance results generated for each dependent variable by group, by pretest and posttest (time), and by group x time (interaction).

Tukey (Keppel 982) HSD post-hoc analyses were performed to identify significant sources of variance and to identify differences in treatment effects. Appendices I - K present the post-hoc results.

Finally, to determine the relationship between range of motion measures, strength measures, and throwing velocity, Pearson Product Moment correlation matrices were generated for the pretest, posttest, and change values. Tables 7 - 9 present these correlation matrices.

Reliability

Reliability for peak torque measures obtained with the Kin-Com (Kinetic Communicator, Chattanooga, TN) dynamometer, and range of motion measures obtained with the goniometer were determined from test-retest data collected from eight subjects from the control group. The test-retest data collection sessions were separated

Table 6. Analysis of Variance Calculated F Ratios

VARIABLE	F ratio For Between-Groups (A)	F ratio For Repeated factor (B)	F ratio For Groups x time (AxB)
EXROT	2.04	30.48+	4.73*
INROT	.10	38.09+	3.56*
COEXT	4.77*	.16	.67
ECEXT	4.57*	.02	2.28
COINT	3.56*	2.64	.07
ECINT	5.85+	.72	1.67
VEL	.58	.81	4.42*

EXROT (Degrees External Rotation), INROT (Degrees Internal Rotation), COEXT (Concentric External Rotation Torque), ECEXT (Eccentric External Rotation Torque), COINT (Concentric Internal Rotation Torque), ECINT (Eccentric Internal Rotation Torque), VEL (Throwing Velocity)
*$p<.05$
+$p<.01$

Table 7. Pearson Product Moment Correlation Coefficients For Pretest Range Of Motion, Strength, And Throwing Velocity Values

	EXROT	INROT	COEXT	ECEXT	COINT	ECINT	VEL
EXROT	1.00	.16	.36*	.41*	.17	.25	.38*
INROT		1.00	-.27	-.24	-.07	-.08	-.40*
COEXT			1.00	.85+	.69+	.84+	.52+
ECEXT				1.00	.63+	.79+	.47+
COINT					1.00	.79+	.56+
ECINT						1.00	.52+
VEL							1.00

EXROT (Degrees External Rotation), INROT (Degrees Internal Rotation), COEXT (Concentric External Torque), ECEXT (Eccentric External Torque), COINT (Concentric Internal Torque), ECINT (Eccentric Internal Torque), VEL (Throwing Velocity)
*$p<.05$
+$p<.01$

Table 8. Pearson Product Moment Correlation Coefficients For Posttest Range Of Motion, Strength, And Throwing Velocity Values

	EXROT	INROT	COEXT	ECEXT	COINT	ECINT	VEL
EXROT	1.00	.09	.48+	.47+	.21	.38*	.52+
INROT		1.00	-.10	-.05	-.03	.08	-.12
COEXT			1.00	.90+	.77+	.83+	.55+
ECEXT				1.00	.73+	.82+	.60+
COINT					1.00	.87+	.42*
ECINT						1.00	.55+
VEL							1.00

EXROT (Degrees External Rotation), INROT (Degrees Internal Rotation), COEXT (Concentric External Torque), ECEXT (Eccentric External Torque), COINT (Concentric Internal Torque), ECINT (Eccentric Internal Torque), VEL (Throwing Velocity)
*$p<.05$
+$p<.01$

Table 9. Pearson Product Moment Correlation Coefficients For Change Between Pretest And Posttest Range Of Motion, Strength, And Throwing Velocity Values

	EXROT	INROT	COEXT	ECEXT	COINT	ECINT	VEL
EXROT	1.00	.45+	.20	.31	-.09	-.02	-.03
INROT		1.00	.17	.10	-.1 9	-.04	.11
COEXT			1.00	.56+	.41*	.53+	.13
ECEXT				1.00	.07	.38*	-.05
COINT					1.00	.49+	.46+
ECINT						1.00	.08
VEL							1.00

EXROT (Degrees External Rotation), INROT (Degrees Internal Rotation, COEXT (Concentric External Torque), ECEXT (Eccentric External Torque), COINT (Concentric Internal Torque), ECINT (Eccentric Internal Torque), VEL (Throwing Velocity)
*$p<.05$
+$p<.01$

by at least one and not more than three weeks time. The coefficient of reliability for the peak torque measures ranged from r=.95 to r=.99. Reliability coefficients for the goniometric measures were r=.89 and r=.97 for assessment of shoulder external and internal rotation, respectively (Table 2). Appendix D presents the raw data from which the reliability coefficients for strength and range of motion were determined.

Reliability of the radar gun was determined by having the City of Charlottesville's Police Department calibrate the instrument immediately before and after the pretest and posttest sessions. The radar gun calibrations obtained by the police department were identical for all test sessions indicating accuracy of function for the instrument used in this investigation.

Range Of Motion

Table 3 presents the means and standard deviations for the pretest and posttest range of motion (ROM) measures. The ROM values for external rotation ranged from 97.36 to 104.42 degrees. The ROM values for internal rotation ranged from 67.64 to 72.83 degrees.

The ANOVA for ROM revealed a significant ($p<.01$) difference between pretest and posttest means for both external and internal rotation (Table 6). There was a significant ($F(1,31)=30.48$, $p<.001$) (Appendix I) increase across time and a significant ($F(2,31) = 4.3$, $p < .05$) (Appendix I) increase for group by time interaction for external rotation. Likewise, there was a significant ($F(1,31) = 38.09$, $p < .001$) (Appendix K) increase across time and a significant ($F(2,31) = 3.56$, $p < .05$) (Appendix K) increase for group by time interaction for internal rotation. Tukey's Post-hoc testing (Appendices J and L) for minimum pairwise differences between means revealed greater increases in range of motion for the weight and tubing groups ($p < .01$) than for the control group (Figures 7 and 8).

Strength

Table 4 presents the means and standard deviations for the pre and post-test strength measures. The greatest strength values were found during eccentric contraction of the internal rotator muscle group and ranged from 41.00 to 58.46 Newton Meters across groups and time. The lowest values were found during concentric contraction of the internal rotator muscle group and ranged from 27.81 to 38.36 Newton Meters across groups and time.

The ANOVA did not reveal a significant difference between pre and post-test strength measures on any of the variables. There was an absence of a significant finding across time as well as an absence of significant group by

Figure 7. External Rotation Group x Time Interaction

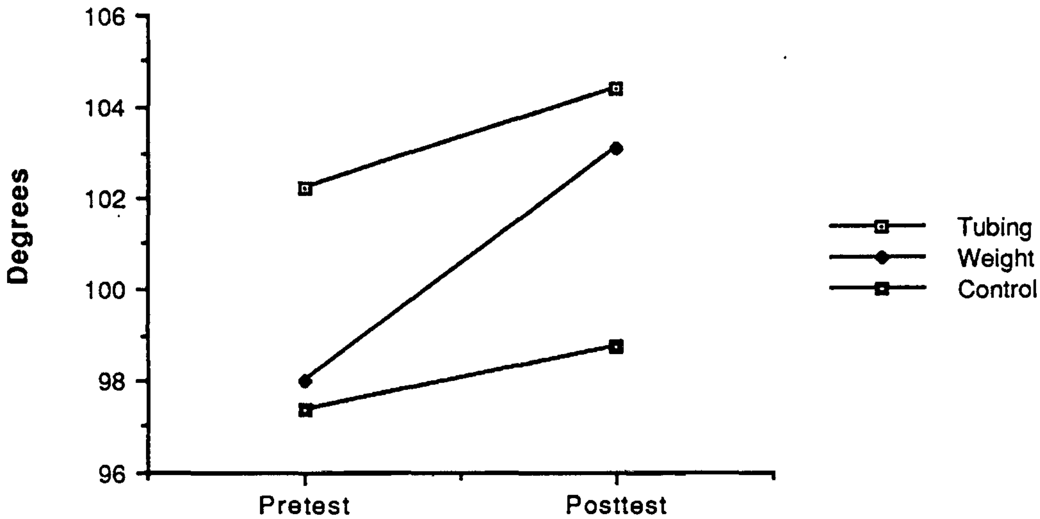
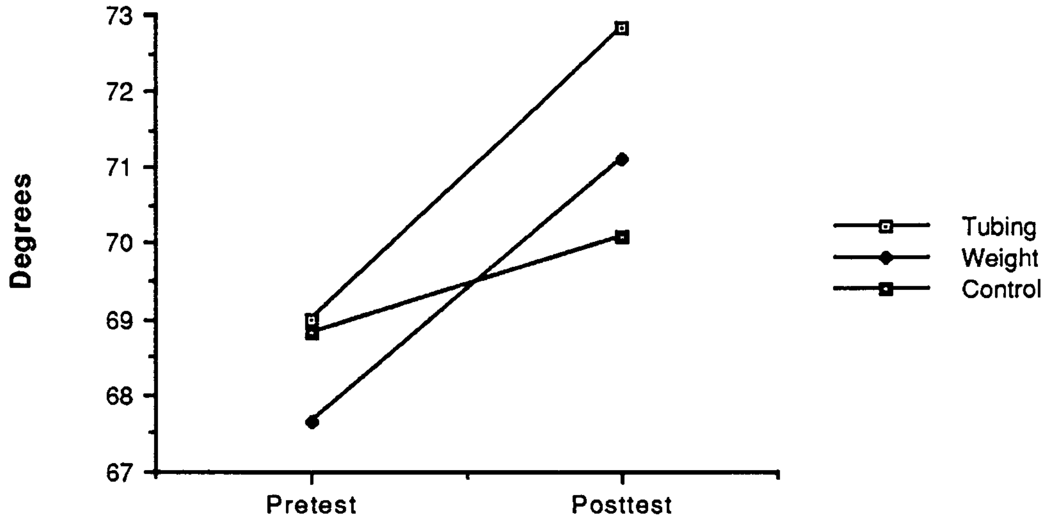


Figure 8. Internal Rotation Group x Time Interaction



time interaction for all groups (Appendices M - P).

Throwing Velocity

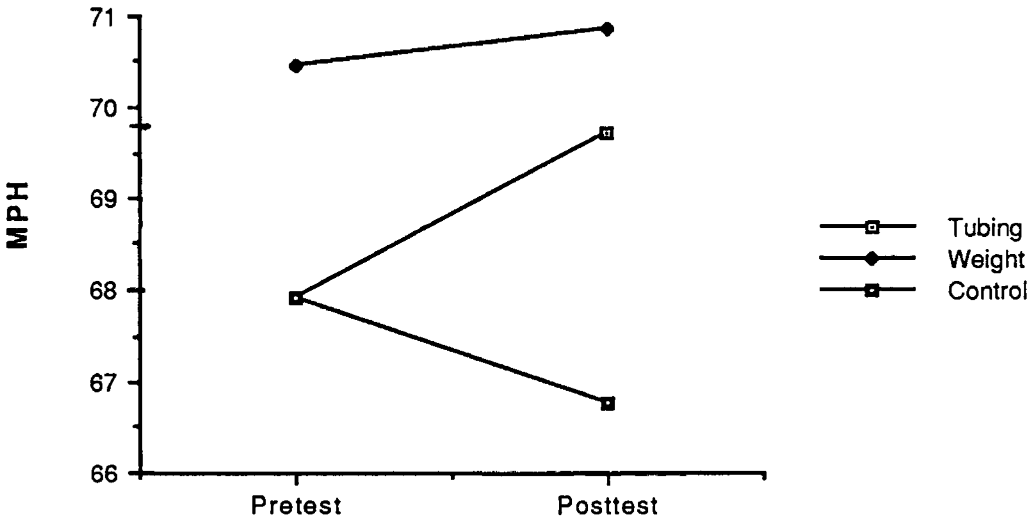
Table 5 presents the means and standard deviations for the pre and post-test throwing velocity measures. The pretest throwing velocity values ranged from 67.86 to 70.46 miles per hour. The posttest throwing velocity values ranged from 66.76 to 70.86 miles per hour.

The ANOVA revealed a significant ($F(2,31)= 4.42$, $p<.05$) group by time interaction for velocity (Table 6). Appendix Q shows the summary table for throwing velocity. Tukey's Post-hoc testing (Appendix R) for minimum pairwise differences between means revealed the tubing group had a significant ($p<.01$) increase in throwing velocity while the control group had a significant decrease ($p<.01$) in throwing velocity (Figure 9). No significant change in throwing velocity was found in the weight group.

Correlation Coefficients

To determine the relationship between throwing velocity, strength, and range of motion, Pearson Product Moment correlation matrices were generated for the pre-test, posttest, and pretest to posttest difference scores (Tables 7 - 9). For the pretest values there were significant ($p<.01$) correlations between velocity and

Figure 9. Throwing Velocity Group x Time Interaction



concentric internal torque (r=.56), velocity and concentric external torque (r=.52), velocity and eccentric internal torque (r=.52), and velocity and eccentric external torque (r=.47). A negative correlation (p<.01) was found between velocity and internal rotation (r=-.40) for the pretest scores.

For the posttest values, there were significant correlations (p<.01) between velocity and eccentric external torque (r=.60), velocity and concentric external torque (r=.55), velocity and concentric internal torque (r=.55), and velocity and external range of motion (r=.52) (Table 8). A non-significant correlation was found between throwing velocity and internal rotation (r=-.19).

For the pretest to posttest change values, there was a positive correlation between concentric internal rotation torque and throwing velocity (r=.46, p<.01) (Table 9). Changes in other strength and range of motion values were not related to changes in throwing velocity (Table 10).

Table 10. Pearson Product Moment Correlation Coefficients Between Velocity (Pre, Post, Delta) And Range Of Motion And Strength (Concentric and Eccentric Torque)

	VELOCITY		
VARIABLE	PRE	POST	DELTA
Degrees External Rotation	.38*	.52+	-.03
Degrees Internal Rotation	-.40*	-.12	.11
Concentric External Torque	.52+	.55+	.13
Eccentric External Torque	.47+	.60+	-.05
Concentric Internal Torque	.56+	.42*	.46+
Eccentric Internal Torque	.52+	.55+	.08

*$p<.05$
+$p<.01$

Chapter Five

DISCUSSION

The purpose of this study was to examine the effects of two training programs on throwing velocity, range of motion, and several strength parameters of the rotator muscles of the shoulder. The training programs were weight training and surgical tube training. Range of motion measures included degrees of external and internal rotation of the shoulder joint. Strength parameters measured in this repeated measures experimental design included concentric and eccentric external rotation strength, and concentric and eccentric internal rotation strength of the shoulder muscles.

Reliability of Measures

Reliability coefficients were computed from eight control group subjects on the range of motion and strength measures with test-retest measurements taken not less than one or more than three weeks apart. The test-retest coefficients for the goniometric range of motion measures were r=.89 for internal rotation and r=.93 for external rotation. This result is similar to Boone et al. (1978) who reported reliability coefficients of r=.84

for goniometric measures of shoulder external rotation with the humerus abducted to 90°.

The test-retest reliability coefficient of r=.94 for concentric and eccentric peak torque in this study compares favorably with previous reliability studies. Hageman et al. (1989) reported reliability coefficients of r=.83 to r=.93 for concentric and eccentric shoulder external rotation peak torque using the KIN-COM dynamometer. It should be noted that their test position was with the arm abducted to 45°. Other researchers (Barbee and Landis 1984, Hart et al. 1981, Johnson and Seigal 1978, and Perrin 1986) have reported reliability coefficients from r=.73 to r=.94 using isokinetic dynamometers for assessment of shoulder rotation strength. However, these reported reliability coefficients were on isokinetic dynamometers other than the KIN-COM used in this study.

Shoulder Joint Range Of Motion

Range of motion of the shoulder joint in this investigation was assessed through standard goniometry. The shoulder was in a 90 degree abducted position and the scapula was stabilized for all measurements of external and internal rotation.

The posttest mean external and internal rotation values in this study were 100.65 and 71.67 degrees, respectively. This is considerably less than the respective mean values of 136.5 and 84.0 degrees for external and internal rotation reported by Brown et al. (1988), and less than the respective mean external and internal rotation values of 105.2 and 82.3 degrees reported by Coleman (1982). However, Brown et al. (1988) and Coleman (1982) studied professional baseball players and they failed to stabilize the scapula during measurement of range of motion. Brown et al. (1988) and Pappas et al. (1985) acknowledge that without stabilization of the scapula it is difficult to determine the exact contribution of trunk extension and movement of the glenohumeral and scapulothoracic joints to the total amount of rotation.

Previous research (Andrews and Gillogly 1985, Brown et al. 1988, Tullos and King 1969) suggests that excessive external rotation is a typical finding in experienced and highly skilled pitchers. These authors noted that throwing athletes typically show a marked increase in external rotation of the throwing shoulder and relative loss of internal rotation when compared with the nonthrowing side. The probable mechanism for this increased external rotation is from extreme forces placed on the anterior shoulder structures during the mechanics of pitching. Furthermore, Andrews and Gillogly (1985) and Tullos and King (1969) suggested that an absence of this adaptive alteration in range of motion is likely an indication of pathology. The subjects in this investigation had fewer years of experience and lower levels of skill than the professional players used in the previous studies. As such, it is reasonable to expect lower range of motion values than the professionals examined in the previous studies.

The large difference between the means of external (100.65°) and internal (71.67°) rotation found in this study concurs closely with earlier research (Andrews and Gillogly 1985, Brown et al. 1988, King et al. 1969, Tullos and King 1972). However, the amount of internal rotation in this investigation (71.67°) far exceeds the 45° value needed for proper throwing mechanics as established by previous research (Pappas 1985).

Degrees of external rotation between pretest and posttest scores showed increases of 1.3%, 5.2%, and 2.1% for the control, weight, and tubing groups, respectively. The degrees of internal rotation between the pretest and posttest showed increases of 1.8%, 6.6%, and 5.5% for the control, weight, and tubing groups, respectively. No other studies were found that examined the effects of training regimens on range of motion at the shoulder joint. The small increases in the control group's external/internal rotation range of motion may be due to measurement technique and unexplained error. Boone et al. (1978) found shoulder goniometric techniques have a standard error of measurement of 2% with a reliability coefficient of r=.82 for experienced physical therapists in the clinical setting. Thus, this could account for part or all of the increased range of motion found in the control group and for part of the increase found in the two experimental groups in this study. Notwithstanding the potential for measurement error, the two treatment groups did have a significantly ($p<.01$) greater increase in range of motion than the control group. There was not a significant difference between the two experimental groups in increased range of motion.

Pearson Product Moment Correlation procedures were executed on the posttest results and revealed that external rotation significantly correlated ($p<.001$) r=.52 with throwing velocity. This agrees with the findings of Sandstead (1968). However, three strength measures, eccentric external rotation (r=.60), concentric external rotation (r=.55), and eccentric internal rotation (r=.55), had correlation coefficients slightly higher with throwing velocity than did external rotation.

It is interesting that the weight group showed a significant ($p<.01$) increase of 5.2% in degrees of external rotation but a non-significant increase of .4 miles per hour in throwing velocity. In contrast, the tubing group had a significant ($p<.01$), but smaller, increase of 2.1% in degrees of external rotation but did have a significant ($p<.01$) increase of 1.9 miles per hour in throwing velocity. This study and the one by Sandstead (1968) determined that external rotation significantly correlates with throwing velocity. As such, the weight group would be expected to have had a larger increase in throwing velocity than the tubing group. However, the opposite relationship was found in this investigation. These results indicate a failure to fully understand the relationship between throwing velocity, shoulder range of motion parameters, and the other variables associated with throwing velocity. It is not clear, from this or other studies, if throwing velocity of an individual pitcher can be enhanced solely by increasing external rotation through an exercise training program.

Neither experimental group in this investigation showed the loss of internal rotation associated with an increase in external rotation reported by others (Andrews and Gillogly 1985, Tullos and King 1969) in experienced and highly skilled players. Two possible explanations are offered for this finding. First, the majority of the subjects in this investigation were not highly experienced in terms of the number of years they had thrown regularly at near maximum effort when compared to the professional subjects used in the earlier studies. Thus, the subjects in this investigation had not yet approached the physiological limits of external range of motion seen in older, more experienced professional subjects. Secondly, this investigation lasted eight weeks and the subjects did not throw during this time. Therefore, there was no stimulus to initiate the adaptive alteration response seen with experienced professional subjects.

Strength

None of the three groups in this study showed a significant change in any of the four strength variables between pretest and posttest scores. The control group had small decreases ranging from .4% to 2% on all four strength variables. This finding seems reasonable since some of the control group subjects had engaged in regular weight training and or baseball/softball competition prior to the beginning of this study, but were asked to refrain from such activities during the eight weeks between the pre and posttest periods. Therefore, with a decrease in activity and stress to the shoulder rotator musculature, a decrease in throwing performance was not an unexpected finding.

The absence of significant changes in strength for the two experimental groups is difficult to interpret. The failure to find pretest to posttest strength increases is especially unusual for the weight training group, since this group experienced increases in the amount of resistance used for all exercises during the eight week training period. Four possible explanations are offered for this finding.

The first possible explanation concerns the position of the humerus during isokinetic testing. Donatelli and Greenfield (1987) suggested that movement of the humerus in abduction normally occurs in the plane of the scapula. This plane of movement is approximately a 30-45° angle to the frontal plane (i.e., the scapula moves on the curvature of the rib cage and is not perfectly parallel to the frontal plane). They suggest that movement of the humerus in this plane allows the muscles surrounding it to function at an optimal length-tension relationship. The testing position was with the humerus abducted to 90° with the axis of the humerus running parallel to the frontal plane. Thus, the testing position was not in the plane of the scapula and the optimal length-tension relationship of the rotator muscles may not have been achieved, thereby preventing maximal contractions.

Brown et al. (1988) suggested that the traditional position for testing shoulder rotation strength (i.e., with the arm abducted 90°) presents some problems. Though it more closely mimics the position of the arm during the late cocking phase of throwing than the neutral position (i.e., the neutral position is with the elbow held to the side flexed to 90°), and allows for better trunk stabilization, the traditional position places the humerus in a less stable position. This less stable position causes apprehension on the part of the subject which inhibits the production of a full effort during isokinetic testing. Others (Hagberg 1981, Hageman et al. 1989, Soderberg 1987) cite increased risk of injury, rapid fatigue of the shoulder musculature, and a resulting pain, as contraindications for isokinetic test of the shoulder rotators from the traditional position of 90° abduction. However, Hinton (1988) and Soderberg (1987) found external rotation peak torque was higher in the traditional position than in the neutral position, but found the opposite was true for internal rotation peak torque.

The second possible explanation concerns the range of rotation when the humerus is abducted to 90°. Brown et al. (1988) and Hinton (1988) tested internal rotation torque through a 70 degree range (70° to 0°) because rotation ranges greater than this (i.e., 70 to 90°) place the humerus in a less stable position. Thus, subjects may respond to this less stable position with apprehension thereby producing less than a maximal effort. In this investigation the test range was 85°to 0° which may have hindered maximal internal rotation efforts in particular.

The third possible explanation concerns a discrepancy between exercise and test position. The exercises done by both the weight and tubing groups were by and large performed in the plane of the scapula and/or with complete freedom of scapular movements. However, the pre and posttest strength assessment was done in a plane other than the plane(s) in which the exercises were performed. Thus, the test position may have violated the principles of specificity of training and action specificity, which may have inhibited transfer of maximal strength to the isokinetic dynamometer.

The fourth possible explanation concerns mode and velocity of strength assessment. The testing was performed on an isokinetic dynamometer at a fixed speed of 150°/sec. However, all training was done isotonically with speed of movement being much different from strength assessment. In general, the weight group trained at speeds slower than the testing speed, whereas the tubing group exercised concentrically at very rapid speeds and exercised eccentrically at very slow speeds. It may be that training on one mode and testing on another did not allow the subjects to fully adjust the strength increases (if any) to the test protocol. Previous research by Rasch and Morehouse (1957) indicates that testing in a mode that differs from the exercising mode does not produce reliable test results. They found subjects showed strength gains during testing when muscles were tested in the same mode (isotonic) they were exercised in while little or no strength gain was observed when tested in an unfamiliar mode (isometrically).

Conflicting findings have been reported on the relationship between training speed and assessment of peak torque. Caiozzo (1980), Carr et al. (1981), and Sherman et al. (1981) reported improvements in peak torque only at training speed, while others (Caiozzo et al. 1981, Coyle et al. 1981, Lesmes et al. 1978, Moffroid and Whipple 1970) found improvements in peak torque at the training speed and speeds below the training speed. Timm (1987) reported a physiological overflow of 120° above and below the specific isokinetic exercise speed.

Ellenbecker et al. (1988) designed an experimental study where one group exercised using concentric isokinetic internal and external shoulder rotation and another group trained using eccentric isokinetic internal and external shoulder rotation. He found significant gains in concentric strength for both the concentric and eccentric trained groups, and significant eccentric strength gains in the concentric trained group. However, there was not a significant increase in eccentric strength by the eccentrically trained group. A functional test analysis showed an increase in maximal tennis serve velocity ($p<.005$) in the concentrically trained group, but there was no significant increase in the eccentrically trained group. His conclusion was that when designing a preventive conditioning or rehabilitation program, the concept of specificity of muscular contraction appears to be very important.

Reliability of the strength assessment procedure was very good in this investigation. As such, these observations are offered as possible explanations for lack of strength increases in the two experimental groups.

Throwing Velocity

The statistical analysis indicated that only the tubing group significantly increased from the pretest to posttest throwing velocity measurements. This increase in throwing velocity was made in the absence of any significant increases in strength. Thus, this investigation failed to demonstrate a cause and effect relationship between strength and throwing velocity. However, the Pearson Product Moment Correlation procedures executed on the Delta scores revealed a significant ($p<.01$) correlation between throwing velocity and concentric internal rotator strength. This muscle group is active during the acceleration phase of the throwing motion. As such, this finding seems to suggest a trend toward concentric internal rotation torque and increases in throwing velocity. The literature would seem to support this observation (Pawlowski and Perrin

1989, Swangard 1965, Sullivan 1970, Thompson and Martin 1965).

The findings of this investigation seem to support the principles of "specificity of exercise" and "action specificity" with respect to the increased throwing velocity in the tubing group (Logan et al. 1965, Logan and McKinney 1977). Furthermore, the results are similar to those reported by Logan et al. (1965) who found significant increases in throwing velocity in a group exercising with an Exer-Genie at a resistance of two and one-half pounds in a motion that mimics the throwing motion. The resistance of the tubing in this study was low, thus allowing the subjects to go through the particular exercises rapidly and explosively. Low resistance helps prevent unnatural muscle contraction patterns from synergistic muscles used in the act of throwing. Not only could the exercises be done rapidly and explosively, but they could be done in the pattern almost identical to the actual throwing motion. Not only were the throwing muscles, movement patterns, and speed of execution of the upper torso and limbs similar to that actually involved in throwing, but the legs and hips were also involved in similar manner in the tubing exercise program.

It has been documented that the lower body contributes approximately 47% of the total effort to throwing velocity (Toyoshima et al. 1974). Thus, the tubing group may have had an advantage over the weight group in that the leg actions of lifting, stepping, pushing, and the actions of rotating the hips and torso closely mimicked that of actual pitching. Training these lower body and torso patterns of movement is difficult, if not impossible, with weight training. Coaches, athletic trainers, and athletes should recognize these potential advantages when planning conditioning programs.

The control group's throwing velocity significantly ($p<.01$) decreased during the eight week duration of this study. Some of the subjects in the control group had engaged in physical training, such as weight training and swimming, on a regular basis for a period of three months or more prior to this experiment. Other subjects in the control group had been playing baseball or softball on a competitive basis two to four times per week in the two to three months immediately before their participation in this study. All control subjects were asked to refrain from regular strength training, swimming, and from playing baseball or softball between the first test session and the final test session of this study. Thus, a significant decrease in physical activity could have resulted in a loss of both upper and lower extremity muscle tone and the neuromuscular patterns associated with the throwing motion. It seems plausible that this decreased neuromuscular activity and exercise through specific movement patterns could result in a decrease in throwing velocity.

Recommendations

Further research is needed to determine if tube training alone or in combination with weight training is the most effective technique for increasing throwing velocity. Ideally, future research would include varsity baseball players as subjects and multiple levels of tube resistance.

A greater understanding of the effects of both weight training and tube training on strength increases in the shoulder rotators as assessed on an isokinetic dynamometer is needed. Likewise, more research is needed on the effect of humeral position on assessment of shoulder rotation strength.

Conclusions

Within the parameters of this investigation, tube training was effective in producing a significant increase in throwing velocity. Weight training did not produce a significant increase in throwing velocity. Both treatment protocols were effective in producing significant increases in external and internal rotational range of motion.

Neither training protocol was effective in producing significant increases in the strength of the external and internal rotator muscles of the shoulder. This lack of a significant increase in strength was true for both concentric and eccentric modes of contraction.

Eccentric external torque, concentric external torque, eccentric internal torque, degrees of external rotation, and concentric internal torque all had a significant correlation with throwing velocity on the posttest scores. Only concentric internal torque had a significant relationship with throwing velocity on the change scores.

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APPENDIX A

Personal Data For Subjects By Group

Group	SUBJECT #	AGE (yrs)	Height (in)	WEIGHT (lb)	DOMINANT ARM (Right-Left)
	11	18	67	155	Right
	14	18	71	160	Right
C	15	28	73	230	Right
O	16	20	68	160	Right
N	20	20	68	155	Right
T	24	20	74	175	Right
R	30	21	74	170	Right
O	31	22	68	160	Right
L	32	23	69	190	Right
	33	21	67	130	Right
	35	21	70	160	Left
		21.92±2.7	69.91±2.7	167.73±25.3	
	2	25	70	174	Right
	5	27	70	158	Left
W	8	20	73	175	Right
E	12	20	74	178	Right
I	13	20	73	178	Right
G	19	20	71	174	Right
H	21	21	77	220	Right
T	23	21	66	230	Right
	26	20	70	180	Left
	29	19	74	198	Right
	34	19	75	180	Right
		21.10±2.5	72.10±3.1	185.91±8.7	
	1	21	74	188	Right
	3	19	71	168	Right
	4	19	76	192	Right
T	6	21	69	165	Right
U	7	18	68	164	Left
B	9	24	74	172	Right
I	10	22	73	171	Right
N	17	20	71	170	Right
G	22	20	76	190	Right
	25	20	67	150	Left
	27	21	67	148	Left
	28	18	68	148	Right
		20.25±1.7	71.17±3.3	168.83±15.4	

APPENDIX B

CONSENT TO PARTICIPATE IN AN EXPERIMENT

Title Of Study: Effect Of Two Strength Training Programs On Throwing Velocity

We invite you to participate in a study of the effect a weight training strength program and a surgical tubing strength program on baseball throwing velocity and on concentric and eccentric strength of the shoulder girdle muscles.

You were selected to participate in this study because you are over the age of 18 and have had experience playing either baseball or softball and are therefore an accomplished thrower.

Investigational Procedures

If you choose to participate in this study, you will visit the University of Virginia research laboratory on the main floor of Memorial Gym for the first day of testing. During this session, your age, height, weight, baseball/softball experience, and injury history to your throwing arm will be recorded. You will have a test, performed on the Kin Com isokinetic exercise machine, of the concentric (you actively contract to move a lever arm) and eccentric (you actively resist a moving lever arm) muscle strength of the shoulder throwing muscles. The test will be undertaken for your throwing arm at a pre-set speed of 180 degrees per second. These measurements will yield information about your strength and power in the cocking and acceleration phases of pitching. You will perform three submaximal warm-up repetitions followed by three maximal test repetitions for both concentric and eccentric strength measurements. You will be allowed 30 seconds of recovery between tests. This session will last approximately 45 minutes.

On the second day of testing you will meet in the University of Virginia's indoor practice facility, The Cage, at University Hall where your shoulder flexibility (degrees of external rotation) and throwing velocity will be measured. Following measurement of flexibility you will be encouraged to take an adequate warm-up of calisthenics, stretching, and throwing until you feel you are ready to throw for maximum velocity. You will throw off a regulation mound to a target 60 ft. 6 in. away. You will take three maximum attempt throws with each throw recorded in miles per hour. Your throws will be measured by a K-15 radar gun (Doppler Corp., Chanute, Kansas). This session will last approximately 30 minutes.

You will be randomly assigned to one of three groups. Group A will participate in a weight training program designed for baseball pitchers by the University Strength and Conditioning Staff. This group will meet three times per week, under the supervision of a strength coach staff member, for approximately 40 minutes each session. Group B will participate in a strength training program designed by this investigator using surgical tubing. This group will meet three times per week, under the supervision of a strength coach staff member, for approximately 40 minutes each session. Group C will serve as a control group and will not engage in any regularly organized fitness and conditioning activities for the upper extremities during the experimental study. The treatment protocols (strength training programs) will last nine weeks.

At least two, and not more than four days, after the last strength training sessions, all subjects will again be measured for concentric and eccentric shoulder muscle strength (test day one), flexibility, and velocity of throw (test day two).

<u>Risks and Benefits</u>

Research studies often involve some risks. The risks of this study include those of the strength testing, velocity testing, and strength training. In rare instances, strain of a muscle may occur with these tests or exercise programs. However every effort will be made to minimize this risk by incorporating a warm-up prior to each testing and exercise session and having a strength training staff member present at every session. In addition, it is possible in any experiment that harmful effects which are not know could occur. Of course, we will take every precaution to watch for and prevent any harmful side effects.

If you participate in this study, you may experience the satisfaction that comes with involvement in research and discovery. You may also increase your shoulder girdle strength as well as your throwing velocity. You will have access to the final results of the experiment. In addition we will provide you with a copy of both strength training programs used in the study and, should you desire, a surgical tube will be made available for your keeping regardless of which group you were in. We greatly appreciate your assistance in our research effort and hope that you will find the experience rewarding and of benefit to your future baseball/softball endeavors. We do not guarantee or promise, however, that you will receive any of these benefits.

<u>Alternatives to Participation in This Study</u>

Because your participation in this study is totally voluntary, the alternative is not to participate in this study.

<u>Privacy of Records</u>

Any information that we learn about you that can be individually traced to you will be used responsibly and will be protected against release to unauthorized people. In addition to the members of any health care staff who usually have access to your file, your records will likely be shown to members of the investigation team and faculty interested in the results of this study. If you sign this form, you have given us permission to release information to these other people. The results of this study may be published in the medical literature, but no publication will contain information that will identify you.

<u>Payment</u>

You will receive no payment for participating in this study. In the event you suffer physical injury directly resulting from the research procedures, no financial compensation for such things as lost wages, disability, or discomfort is available, but medical treatment that is not covered by your insurance will be

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provided free of charge at the University of Virginia.

If you have an questions concerning financial compensation for injuries caused by the experiment, you should talk to Byron S. Shenk at (804) 977-3860.

Conclusion

Your decision whether or not to participate in this study will not hurt your care at the University of Virginia. Even if you decide to participate, you may stop and withdraw from the study at any time without hurting your care at the University of Virginia. Of course, we will tell you anything we learn during the study that may help you decide whether to continue.

You are making a decision whether or not you will participate in this study. If you sign this form, you have agreed that you will participate based on reading and understanding this form. If you have any questions, please ask Byron S. Shenk at (804) 977-3860 or David Perrin, Ph.D. at (804) 924-6187.

If you have any questions regarding research subjects' rights, please contact Dr. John A. Owen Jr., Chairman of the Human Investigation Committee of the University of Virginia at (804) 924-2109.

You will receive an unsigned copy of this form to keep.

____________________	____________________
Witness	Subject
____________________	____________________
Member of Research Team	Date

APPENDIX C

Data Collection Form

A. PRETEST DATA

Name____________________ Subject Number________ Phone Number________

Age______ Height______ Weight______ Dominant Side R L

Shoulder Internal ROM- Right Side_______ Left Side_______
Shoulder External ROM- Right Side_______ Left Side_______

Eccentric Internal Torque - Right Side_____ Left Side___
Eccentric External Torque - Right Side_____ Left Side___

Concentric Internal Torque - Right Side____ Left Side___
Concentric External Torque - Right Side____ Left Side___

Pretest Velocity- #1._____ #2._____ #3._____ Highest ___

B. POSTTEST DATA

Shoulder Internal ROM- Right Side_______ Left Side_______
Shoulder External ROM- Right Side_______ Left Side_______

Eccentric Internal Torque - Right Side_____ Left Side___
Eccentric External Torque - Right Side_____ Left Side___

Concentric Internal Torque - Right Side____ Left Side___
Concentric External Torque - Right Side____ Left Side___

Posttest Velocity- #1._____ #2._____ #3._____ Highest___

APPENDIX D

RELIABILITY RAW DATA

Pretest Scores

	Subject Number							
	03	04	17	21	25	31	32	33
Degrees External Rotation	104	102	93	96	97	93	100	103
Degrees Internal Rotation	66	71	81	56	74	74	65	75
Concentric External Torque	26	23	24	31	34	26	32	36
Eccentric External Torque	30	35	32	37	42	32	47	41
Concentric Internal Torque	24	30	24	28	28	14	31	35
Eccentric Internal Torque	38	43	41	34	48	28	47	51

Posttest Score

	Subject Number							
	03	04	17	21	25	31	32	33
Degrees External Rotation	104	96	94	97	97	93	103	101
Degrees Internal Rotation	72	70	82	59	72	77	66	76
Concentric External Torque	27	25	24	35	38	28	29	36
Eccentric External Torque	33	32	30	37	40	34	46	41
Concentric Internal Torque	24	29	25	29	28	18	31	32
Eccentric Internal Torque	41	43	43	33	44	30	45	43

APPENDIX E

Raw Data For Degrees Of External And Internal Rotation For The Muscles Of the Shoulder

Group	Subject #	PRETEST SCORES External Rotation	PRETEST SCORES Internal Rotation	POSTTEST SCORES External Rotation	POSTTEST SCORES Internal Rotation
	11	104	62	102	63
	14	96	68	101	69
C	15	91	60	92	62
O	16	93	81	95	82
N	20	96	56	93	55
T	24	96	71	97	72
R	30	92	76	93	77
O	31	100	65	106	68
L	32	104	75	101	76
	33	96	78	101	77
	35	103	65	105	70
	2	85	60	90	61
	5	90	68	92	72
W	8	94	67	101	76
E	12	96	65	104	72
I	13	96	77	104	85
G	19	99	62	105	66
H	21	99	76	110	84
T	23	97	87	103	86
	26	104	61	105	67
	29	118	60	118	61
	34	100	61	102	63
	1	102	76	104	78
	3	94	68	102	71
	4	110	60	111	61
T	6	110	70	110	79
U	7	111	66	116	76
B	9	95	57	96	62
I	10	104	66	107	72
N	17	102	81	102	80
G	22	101	72	104	76
	25	99	68	102	70
	27	94	78	95	84
	28	105	66	106	65

APPENDIX F

Raw Data For Concentric External And Internal Torque Measured In Newton Meters

Group	Subject #	PRETEST SCORES Concentric External	PRETEST SCORES Concentric Internal	POSTTEST SCORES Concentric External	POSTTEST SCORES Concentric Internal
	11	32	39	26	20
	14	28	25	32	27
C	15	45	44	45	49
O	16	24	24	26	25
N	20	31	28	32	33
T	24	33	22	27	26
R	30	28	18	28	18
O	31	32	31	34	26
L	32	43	37	36	32
	33	32	27	33	25
	35	30	34	32	25
	2	32	31	33	31
	5	39	54	36	37
W	8	35	34	38	36
E	12	30	22	28	22
I	13	32	35	35	29
G	19	41	31	42	27
H	21	59	58	58	56
T	23	35	43	37	45
	26	38	37	50	45
	29	50	42	52	48
	34	50	35	46	33
	1	36	41	38	39
	3	27	39	23	30
	4	46	43	43	38
T	6	34	34	33	29
U	7	41	42	40	35
B	9	39	29	34	32
I	10	37	34	39	29
N	17	28	22	26	20
G	22	30	19	38	17
	25	28	32	32	34
	27	33	34	35	37
	28	33	22	33	28

APPENDIX G

Raw Data For Eccentric External And Internal Torque Measured In Newton Meters

Group	Subject #	PRETEST SCORES Eccentric External	PRETEST SCORES Eccentric Internal	POSTTEST SCORES Eccentric External	POSTTEST SCORES Eccentric Internal
	11	26	42	31	37
	14	37	36	34	36
C	15	48	56	47	58
O	16	32	41	32	37
N	20	37	34	33	38
T	24	40	38	38	37
R	30	34	32	34	30
O	31	47	47	48	44
L	32	49	63	41	43
	33	40	37	39	34
	35	39	58	35	46
	2	35	53	44	56
	5	55	58	51	51
W	8	38	50	40	54
E	12	37	36	32	37
I	13	43	56	45	51
G	19	46	54	50	52
H	21	68	106	74	89
T	23	43	50	45	58
	26	57	53	67	62
	29	60	64	62	66
	34	55	63	52	52
	1	38	42	43	56
	3	35	42	35	43
	4	69	76	65	59
T	6	48	51	41	51
U	7	51	57	53	56
B	9	49	41	39	40
I	10	45	47	47	44
N	17	30	35	29	29
G	22	39	34	44	39
	25	37	38	37	49
	27	46	48	50	59
	28	43	34	42	43

APPENDIX H

Raw Data For Throwing Velocity Measured In Miles Per Hour

Group	Subject #	PRETEST SCORES Velocity MPH	POSTTEST SCORES Velocity MPH
	11	76.5	67.2
	14	64.1	62.6
C	15	73.2	74.8
O	16	57.6	54.6
N	20	59.1	56.4
T	24	70.8	71.8
R	30	62.8	62.3
O	31	78.6	78.4
L	32	68.2	70.5
	33	67.6	68.1
	35	68.4	67.7
	2	66.9	69.3
	5	70.1	68.9
W	8	78.4	80.4
E	12	62.5	62.3
I	13	66.7	66.3
G	19	65.3	64.4
H	21	78.0	79.4
T	23	61.1	58.5
	26	71.8	72.4
	29	79.8	81.0
	34	74.5	76.5
	1	70.6	71.3
	3	77.7	76.5
	4	77.0	78.9
T	6	72.5	74.6
U	7	80.0	79.5
B	9	62.6	63.7
I	10	68.3	68.5
N	17	50.2	54.7
G	22	67.4	71.4
	25	68.3	68.2
	27	56.2	61.1
	28	63.5	68.2

APPENDIX I

Analysis Of Variance For Pretest and Posttest Change In Degrees For External Range Of Motion

SOURCE	SUM OF SQ.	DF	MEAN SQ.	F	SIG. OF F
GROUP	316.679	2	158.339	2.04	NS
ERROR	2406.242	31	77.621		
TIME	140.156	1	140.156	30.48	p<.001
GROUP X TIME	43.539	2	21.769	4.73	p<.05
ERROR	142.561	31	4.599		

APPENDIX J

Tukey Post-hoc Test For Minimum Pairwise Difference Between Means For Weight Group And For Tubing Group x Time (Interaction) For Degrees Of External Rotation

---

Minimum Pairwise Difference = qt $\sqrt{MS(error)}$ / $\sqrt{s}$

qt (2,31) = 2.89 @ alpha .05
3.89 @ alpha .01
MS(error) = 4.599
s = 34

Minimum Pairwise Difference = 3.89 $\sqrt{4.599}$ / $\sqrt{34}$ = 2.873$^{\pm}$

$^{+}p<.01$

APPENDIX K

Analysis Of Variance For Pretest to Posttest Change In Degree Of Internal Range Of Motion

SOURCE	SUM OF SQ.	DF	MEAN SQ.	F	SIG. OF F
GROUP	25.752	2	12.876	.10	NS
ERROR	3945.379	31	127.270		
TIME	172.364	1	172.364	38.01	$p<.001$
GROUP X TIME	32.183	2	16.091	3.56	$p<.05$
ERROR	140.288	31	4.525		

APPENDIX L

Tukey Post-hoc Test For Minimum Pairwise Difference Between Means For Weight Group And For Tubing Group x Time (Interaction) For Degrees Of Internal Rotation

---

Minimum Pairwise difference = qt $\sqrt{MS(error)} / \sqrt{s}$

qt (2,31) = 2.89 @ alpha .05
3.89 @ alpha .01

s = 34

Minimum Pairwise Difference = 3.89 $\sqrt{4.525} / \sqrt{34}$ = 3.187$^{\pm}$

$^{+}p<.01$

APPENDIX M

Analysis Of Variance For Pretest And Posttest Change In Newton Meters Concentric External Rotation Torque

SOURCE	SUM OF SQ.	DF	MEAN SQ.	F	SIG. OF F
GROUP	881.531	2	440.765	4.77	p<.05
ERROR	2863.561	31	92.372		
TIME	1.216	1	1.216	.16	NS
GROUP X TIME	10.396	2	5.198	.67	NS
ERROR	239.197	31	7.716		

APPENDIX N

Analysis Of Variance For Pretest And Posttest Change In Newton Meters For Eccentric External Rotation Torque

SOURCE	SUM OF SQ.	DF	MEAN SQ.	F	SIG. OF F
GROUP	1556.307	2	778.153	4.57	p<.05
ERROR	5279.277	31	170.299		
TIME	.182	1	.182	.02	NS
GROUP X TIME	43.533	2	21.766	2.28	NS
ERROR	295.913	31	9.546		

APPENDIX O

Analysis Of Variance For Pretest And Posttest Change In Newton Meters For Concentric Internal Rotation Torque

SOURCE	SUMS OF SQ.	DF	MEAN SQ.	F	SIG. OF F
GROUP	941.285	2	470.643	3.56	p<.05
ERROR	4092.580	31	132.019		
TIME	50.782	1	50.782	2.64	NS
GROUP X TIME	2.634	2	1.317	.07	NS
ERROR	595.731	31	19.217		

APPENDIX P

Analysis Of Variance For Pretest And Posttest Change In Newton Meters For Eccentric Internal Rotation Torque

SOURCE	SUMS OF SQ.	DF	MEAN SQ.	F	SIG. OF F
GROUP	3000.758	2	1500.379	5.854	p<.001
ERROR	7949.489	31	256.435		
TIME	22.405	1	22.505	.72	NS
GROUP X TIME	99.411	2	49.705	1.60	NS
ERROR	965.731	31	31.153		

APPENDIX Q

Analysis Of Variance For Pretest And Posttest Change In Miles Per Hour For Throwing Velocity

SOURCE	SUMS OF SQ.	DF	MEAN SQ.	F	SIG. OF F
GROUP	125.910	2	62.955	.58	NS
ERROR	3369.820	31	108.704		
TIME	2.335	1	2.335	.81	NS
GROUP X TIME	25.371	2	12.685	4.42	p<.05
ERROR	89.062	31	2.873		

APPENDIX R

Tukey Post-hoc Test For Minimum Pairwise Difference Between Means For Tubing Group x Time (Interaction) For Throwing Velocity

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Minimum Pairwise Difference = qt $\sqrt{MS(error)}$ / $\sqrt{s}$
qt (2,31) = 2.89 @ alpha .05
3.89 @ alpha .01
MS(error) = 2.873
s = 34

Minimum Pairwise Difference = 3.89 $\sqrt{2.873}$ / $\sqrt{34}$ = 1.859$^{\pm}$
$^{+}$p<.01