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Effects of throwing on rotator cuff strength and proprioception

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EFFECTS OF THROWING ON ROTATOR

CUFF STRENGTH AND

PROPRIOCEPTION

by

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ABSTRACT

Effects of Throwing on Rotator Cuff Strength and Proprioception

by

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This study was performed to examine declines in strength and proprioception after a single bout of overhand baseball throwing. Twenty-three university students volunteered for this study and were placed into three groups. Subjects completed a pretest consisting of joint position sense testing (ARPP), isotonic strength testing (1 RM IR and ER), and isokinetic strength testing (concentric IR and ER at 120°/s). Following this, excluding control, subjects completed an overhand throwing session consisting of 75 throws at 75% of perceived maximum effort at a distance of 60 feet 6 inches. This was followed by a posttest that was identical to the pretest. The results revealed a significant difference in the ARPP pre and post-test values for the recreationally active group and the baseball players, but no such difference for the control group. Both isotonic and isokinetic test showed no significant difference from pre to post-test.

TABLE OF CONTENTS

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CHAPTER 1

INTRODUCTION

Statement of the Problem

Due to its anatomy, the shoulder joint must rely heavily on surrounding musculature and neuromuscular control for stability.[1] For an overhand thrower, dynamic stability is essential for injury prevention and performance.[1,2] Together the rotator cuff muscles (RTC) and the proprioceptive abilities of the shoulder joint provide the synergistic muscular contractions required to maintain glenohumeral joint stability.

The rotator cuff musculature acts as a sleeve and compresses the humeral head in the glenoid cavity.[3] This compression is caused by involuntary muscular contractions which provides mechanical restraint to humeral translation and provides dynamic stability at the glenohumeral joint.[4]

Neuromuscular control is also important for dynamic stability of the glenohumeral joint.[1] Proprioception, an aspect of neuromuscular control, is defined as the afferent neural input to the central nervous system from specialized nerve endings called mechanoreceptors.[2] Proprioceptive information transmitted from mechanoreceptors influences reflex activity and joint stiffness to provide shoulder joint stability.[5]

Sterner et al attributed deficiencies in proprioception (as measured by joint position sense) and strength to lead to joint injury and a decrease in athletic performance.[1] It has been shown that strength and proprioceptive abilities decline in the presence of fatigue.[1,2,6,7] Laboratory studies have demonstrated both strength and proprioceptive deficiencies within the shoulder joint following fatigue exercises using isokinetic testing devises.[2,6] However, research has yet to examine functional activity, such as throwing, and its effect on shoulder muscle strength and proprioception. Because overhand throwing places a tremendous amount of stress on the shoulder joint there may be a decrease in these vital aspects of dynamic stability. A single overhand throw produces distraction forces at the shoulder complex at 1 to 1.5 times body weight.[8] Additionally, humeral rotation velocities have been measured at over 6,000°/sec.[9] The high stress caused by repetitive throwing may lead to short and long term decreases in shoulder muscle strength and proprioceptive function and therefore may increase the risk of injury. It is therefore the goal of this study to quantify any declines in strength and proprioception after a single bout of overhand throwing.

Purpose of the Study

The purpose of this study was to test internal and external rotator cuff strength and joint position sense after a single bout of overhand throwing. It was not believed that the throwing would result in a decline of the internal rotators due to the larger muscle mass. However, it was hypothesized that an overhand throwing session would result in a decline in strength of the external rotators and a decline in joint position sense. This hypothesis may have implications for overhand throwers in regards to injury prevention and performance. This is based on the research that has shown declines in strength and neuromuscular control can lead to injury and a decrease in athletic performance.

Statement of Hypothesis

Null –

1. There is no difference in strength pre and post throwing of the internal and external rotators using isokinetic testing.
2. There is no difference in strength pre and post throwing of the internal and external rotators using isotonic testing.
3. There is no difference in joint position sense pre and post throwing of the internal and external rotators.

Alternate-

1. There is a significant difference in strength pre and post throwing of the internal and external rotators using isokinetic testing.
2. There is a significant difference in strength pre and post throwing of the internal and external rotators using isotonic testing.
3. There is a significant difference in joint position sense pre and post throwing of the internal and external rotators.

Limitations of Study

1. Subject population was limited to 23 individuals ranging from ages 18-26 years.
2. Only internal and external rotational movements where analyzed.

CHAPTER 2

LITERATURE REWIEW

Phases of Throwing

Throwing is a total-body mechanism that places a tremendous amount of stress upon the entire shoulder. During throwing humeral rotational velocities have been measured at over 6,000°/sec.[8,9] Throwing involves transferring forces from the lower extremity and the trunk to the distal segments of the upper extremity. It has been reported that the upper extremity is responsible for generating only 50% of forces that generate throwing speed.[10] Therefore, a substantial amount of force is propelled from the lower extremity through the arm. Because of the numerous shoulder injuries from throwing, it has been suggested that the soft tissues of the shoulder are the "weak link" of the throwing machinery.[10,11] Overhand throwing can be broken down into 5 phases: the wind-up, cocking, acceleration, release/deceleration, and the follow through.[10,12]

The Wind-up Phase: Beginning with initial motion the wind-up phase is a relatively slow motion phase that prepares entire body for throwing. It is designed to raise the center of gravity and place the body in an optimal position to achieve maximal power and speed during the later stages of throwing.[10] Maximal power and speed are achieved in a later phase through the potential energy created in this phase. With the contralateral leg lift and trunk rotation the body prepares it self for throwing. The majority of muscular activity is occurring in the lower extremity, however, the deltoid and the supraspinatus are acting to abduct the arm. Contribution of other shoulder musculature is minimal during this phase, which ends when the hands separate.[3] In this phase there is very little injury potential because only mild to moderate forces are exerted on the arm.[10]

The Cocking Phase: A continuation of the wind-up, this phase is sometimes divided into two phases, early and late.[13,14] It begins with the trunk slightly moving forward over the lower extremity. The shoulder is in a position of 30° to 90° of abduction and 120° to 160°of external rotation while the elbow is flexed 90°. Additionally, the scapula is retracted maximally by the trapezius and rhomboids allowing for maximal external rotation of the humerus. There is a great deal of strain placed upon the anterior shoulder, as the humerus is maximally externally rotated. With maximal external rotation the internal rotators are placed on stretch. This stretch prior to the internal rotators contracting to propel the ball forward is referred to as the "stretch shorten cycle" and maximizes the generation of power and speed that will come during the next phase (acceleration).[14] Due to the extreme external rotation the infraspinatus and teres minor act as struts to prevent the humeral head from translating anteriorly over the glenoid labrum.[14] This is possible due to their anatomical position and the contraction of those muscles during movement. During late cocking the raised foot is planted increasing the stress on the anterior stabilizers. Simultaneously, the internal rotators (pectorlis and subscapularis) are acting eccentrically to decelerate the externally rotating arm and prevent excess rotation. Additionally, the muscle spindles, Ruffini receptors, and pacinian corpuscles are all stimulated to prevent excessive external rotation and injury. Injury potential during this phase is high because of the extreme external rotation and the stress on the anterior stabilizers. This phase ends and acceleration begins with forward shoulder movement.

The acceleration phase begins with the shoulder, arm, and hand moving forward. Simultaneously, the trunk begins to move over the lower extremity. Together these movements create substantial internal rotation force. This force is amplified by the "stretch shorting cycle", previously discussed, when the arm goes from maximal external rotation (cocking) to a sudden concentric action of the internal rotators. The movement at the shoulder is primarily internal rotation and elbow begins to extend from the 90 degree flexed position. Maximal tension is placed on the anterior shoulder musculature during acceleration as it attempts to pull the humerus forward to "catch up" with the trunk. For this to occur there must be stabilization, both static and dynamic, of the scapula and the humeral head in the glenoid so that the internal rotation takes place around a fixed point.[15] Both the middle trapezius and rhomboids are acting eccentrically while the upper trapezius and the serratus anterior are acting concentrically to provide this stabilization. The arm remains in a position of 90° of abduction while a great deal of lateral bending is occurring at the trunk. The majority of muscular demand is from the internal rotators (pectorlis and subscapularis) during this phase, as they contract concentrically to accelerate the arm. Injury to the anterior shoulder musculature i.e. the pectorlis and subscapularis, is common during this phase because of the high velocity required to forcefully move the humerus to a position of adduction and obtain maximal velocity during the release.[15] Acceleration ends with ball release.

The Release/Deceleration Phase: This phase is the most violent phase of throwing. Following ball release the thrower must decelerate the arm creating a large amount of stress on the shoulder. In fact, there is as much as a 2.5cm gap between the glenoid and the humerus during this phase due to the traction created during the acceleration of the arm.[15] This is often described as throwing your arm off. During this phase the shoulder adducts and internally rotates in an attempt to dissipate the massive forces generated during acceleration. Additionally, the trunk rotates to decrease the relative speed of the arm in relationship to the body. The infraspinatus, teres minor supraspinatus, middle trapezius, serratus anterior, and the rhomboids all must act eccentrically to decelerate the arm leading to very high tension in these muscles. Because this phase causes a 75% increase in tension in the posterior capsule injury potential is greater than in any other phase.[9,16] Again, this is due to the eccentric demand placed on the posterior muscles to dissipate the forces compiled during cocking and acceleration.

Follow-through Phase: This phase begins with the thrower concluding the deceleration phase. The primary purpose of this phase is to place the throwers body in a position optimal for fielding. The force created during the throwing motion are mostly dissipated with deceleration, therefore, there is a very low injury potential.

For throwing to be achieved properly and injury free each of the phases described above must be precise and rhythmic. During cocking the internal rotators must be able to prevent excessive anterior translation. Additionally, the mechanoreceptors must be functioning and able to recognize extremes in joint position and limb movement. During deceleration the external rotators must be able to handle the stress of discontinuing the forceful internal rotation created during acceleration. If the arm was allowed to continue forward without the coordinated contracting of the decelerators the humerus would literally be pulled from the socket. If the musculature is unable to provide stabilization and mechanoreceptors are unable to recognize joint position the risk of injury in the shoulder complex increases.

Anatomy of the Shoulder Complex

The anatomy of the shoulder functions to suspend the arm from the trunk and allow proper positioning of the, upper and lower arm, and hand in space. The shoulder is the most mobile joint in the human body, normally possessing the ability to a full 360 degree of range of motion (ROM).[17] This mobility is due the structure and function of the three joints that make up the shoulder complex: the glenohumeral joint, the sternoclavicular joint, and the acromioclavicular joint. These joints are composed of the sternum, clavicle, scapula, and humerus bones which makes up the shoulder girdle.

The anterior aspect of the shoulder girdle is composed of the clavicle. The clavicle is an S-shaped tubular bone. The medial aspect of the clavicle with the sternum makes up the sternoclavicular joint, while the lateral aspect connects to the acromion to form the acromioclavicular joint. The clavicle serves important functions in the shoulder. First, it forms a strut that holds the glenohumeral joint away from the trunk, allowing for greater range of motion. Secondly, the clavicle increases the power of the "arm-trunk" mechanism, by providing stability and power to the shoulder and upper extremity.[18] This mechanism is of great importance in overhead activities such as throwing because it increases the lever arm allowing for greater force production. Lastly, the clavicle serves as a point of pectoral girdle muscle attachments, particularly, pectoralis minor.[19]

The posterior aspect of the shoulder girdle is composed of the scapula, a triangular shaped bone which aligns medially to the thorax via ribs two through seven. The superior, lateral aspect of the scapula forms the glenoid fossa, which is the area of attachment for the head of the humerus (the final bone of the shoulder girdle). The glenoid fossa houses the glenoid labrum. The glenoid labrum in conjunction with the glenoid fossa forms the glenoid cavity which provides a socket for the humerus. The stability of the glenohumeral joint is increased by a larger surface area between the fossa and the humeral head provided by the labrum. Without the labrum the glenoid fossa is only one third to one quarter the size of the humeral head.[17] The glenoid labrum also serves as a point of attachment for the tendon of the long head of the biceps brachii.[20] Finally, the scapula projects 2 bony prominences, the coracoid process and the acromion process, which articulates with the clavicle as already discussed. The coracoid process serves as a point of attachment for the short head of the biceps brachii, coracobrachialis and pectoralis minor.

As discussed the humeral head is situated in a relatively small glenoid fossa allowing for tremendous mobility. Although the labrum serves to deepen the glenoid cavity, it does not provide the stability of a true ball and socket joint. Therefore, the dynamic relationship of the musculature and the ligaments of the shoulder girdle are vital to maintain the integrity of the joint,[21] and must also be discussed.

The important ligaments of the shoulder include the coracohumeral ligament, the inferior, superior and middle glenohumeral ligaments. The coracohumeral and superior glenohumeral ligaments limit inferior translation and external rotation of an adducted shoulder.[22] During the cocking phase of throwing these ligaments limit anterior translation of the humeral head.[15] The middle glenohumeral ligament limits anterior translation of the humeral head when the arm is abducted between 60° and 90°, which is the position of the glenohumeral joint for nearly 50% of overhand throwing. Lastly, the inferior glenohumeral ligament prevents increased superior migration and excess translation of the humeral head on the glenoid during abduction and external rotation.[22]

In addition to ligaments the shoulder muscles also provide stability. The muscles of the shoulder provide additional support to the glenohumeral joint and those muscles can be divided into three major groups: 1) scapular guidance musculature consisting of the trapezius, serratus anterior, and the rhomboid major and minor 2) glenohumeral guidance musculature which include the pectoralis major, deltoid, and the biceps brachii and 3) stabilizing musculature or the rotator cuff (RTC) consisting of the supraspinatus, infraspinatus, teres minor, and subscapularis.[15]

As part of the scapular guidance section the trapezius, the serratus, and the rhomboids will be discussed. The trapezius is a broad muscle with attachments on the spine from the occipital protuberance down between T8 and L2. The insertions are on the lateral clavicle, acromion, and the scapular spine. The primary and secondary actions of the trapezius are to act as a positioner of the glenoid through elevation of the scapula. In addition, the trapezius retracts the scapula which is important during the late cocking phase of throwing.[15] For maximal velocities to be achieved the arm must be maximally externally rotated, when the scapula retracts it allows for an increase of external rotation of the humerus.[17]

The serratus anterior is activated with all shoulder movements and is vital for successful completion of scapulohumeral movement. It originates from ribs one through nine and inserts on the costal surface of the scapula.[17] he serratus anterior protracts the scapula which assists in providing a stable base for the humeral head. This is important because for overhand throwing to be performed effectively the humerus must rotate on a fixed point.[15]

The rhomboid minor rises from C7 and T1 whereas the rhomboid major originates off C2 through C5. Together they insert on the medial boarder of the scapula. Each of these muscles causes retraction of the scapula, which serves as a stabilizing function for scapulohumeral movements and increases external rotation of the humerus during late cocking.[22]

The next group is the glenohumeral guidance musculature which include the pectoralis major, deltoid, and the biceps brachii. The pectoralis major originates off the medial clavicle, manubrium, sternum, and the costal cartilage of ribs one through six. The insertion of the pectoralis major is on the lesser tubercle of the humerus. This muscle assists in downward movement of a raised arm and trunk support. Additionally, the pectoralis major horizontally adducts the arm and acts as an internal rotator.[22] During the acceleration phase of throwing the pectoralis major acts concentrically to forcefully internally rotate the arm.[15]

The deltoid covers the lateral aspect of the shoulder and is composed of three sections: anterior, middle, and posterior deltoids. It originates off the lateral clavicle, scapular spine, and acromion. It inserts on the humerus at the deltoid tubercle. The deltoid provides movement of the shoulder in all three planes, including elevation in the scapular plane, abduction in the coronal plane, and flexion in the saggital plane.[22] The deltoid is the prime initiator of abducting the shoulder during wind up and the early cocking phases of throwing.[4]

The biceps brachii is composed of a long and short head. The long head originates on the glenoid labrum and the short head off the coracoid process of the scapula. Together they insert on the proximal radius. The biceps brachii functions mainly to flex the elbow, however, it does assist with shoulder flexion as well. Additionally, the long head functions as a stabilizer of the humeral head due to the compressive forces caused by shoulder elevation.[23]

The final group of the shoulder musculature is the stabilizing group or the rotator cuff (RTC) which is composed of: the supraspinatus, infraspinatus, subscapularis, and the teres minor muscles. Each of these muscles originates on various aspects of the scapula and insert on the head of the humerus. The tendinous sheath formed by the distal ends of these four muscles surround the glenoid cavity, the humeral head, and the joint capsule forming a "sleeve" around these structures.[3] The "sleeve" of the RTC muscles provides the primary stability of the shoulder by compressing the humeral head into the glenoid cavity.[3] This compression helps prevent excessive glenohumeral joint motion and is achieved through co-contraction of all the RTC muscles. This mechanism of increased dynamic stability is called the force couple mechanism. The co-activation of the RTC muscles and the resulting force coupling are more important to the stability of the glenohumeral joint then the static constraints previously discussed.[22] Although all the RTC muscles act to compress the humeral head in the glenoid cavity for stability each has an individual function for movement.

The infraspinatus originates on the posterior scapula below the scapular spine and inserts on the greater tubercle. This muscle functions mainly as external rotator accounting for approximately 60% of external rotational force.[22] The infraspinatus also acts as a buttress of the humeral head against posterior subluxation force of internal rotation.[22] It also assists in horizontal extension of the humerus during the cocking phase of throwing. Additionally, the infraspinatus acts as a decelerator during the follow-through phase of throwing.[15]

The teres minor muscle originates on the inferior lateral border of the scapula and inserts posterior to the greater tubercle of the humerus. The teres minor is closely related to the infraspinatus and therefore acts as the remaining 40% of external rotational torque.[22] This muscle is also a decelerator of the arm during the follow-through phase of throwing. Additionally, the infraspinatus and the teres minor are the most active stabilizers of the humeral head in the glenoid fossa.[22]

The supraspinatus originates on the posterior surface of the scapula superior to the scapular spine in the suprascapular fossa and inserts superior to the greater tubercle of the humerus. This muscle initiates glenohumeral abduction, contributes to forward elevation, and compresses the humeral head into the glenoid cavity.[22] Additionally, it assists the subscapularis and infraspinatus in resisting the superior shear forces of the deltoid in early abduction.[22] During overhand throwing this muscle along with the deltoid abducts the arm in the early cocking phase of throwing.[15]

The fourth RTC muscle, the subscapularis, runs along the anterior surface of the scapula and inserts on the lesser tubercle of the anterior aspect of the humerus. This muscles act as an internal rotator of the shoulder while stabilizing the glenohumeral joint from anterior translation. This is especially important during the cocking phase of throwing in which the arm is maximally externally rotated.[23]

Coordinated contraction of the RTC muscles plays a significant role in the maintenance of stability at the glenohumeral joint.[24] During overhand throwing as well as all active arm movements, the RTC muscles produce a combined muscular contraction which acts to stabilize the humeral head in the glenoid fossa.[4] Without this compressive load created by the synergistic muscle contraction dynamic stability would be altered and instability would occur.[4] Additionally, the RTC muscles must adequately counteract the deltoid muscle. If not, the translational force of the deltoid would pull the humerus upward into the acromion,[25] causing impingement of the rotator cuff tendons.

For proper shoulder function the interaction of the RTC on the shoulder must be precise and the magnitude of force must be coordinated to avoid unwanted translation and grinding of the humeral head on the glenoid.[19,26,27] However, in the presence of fatigue that may be associated with overhand throwing this balance may be hindered leading to failure of the dynamic stabilizers and possible injury. Levine et al stated that athletes who use overhand throwing and develop fatigue are at an increased risk for injury because of failure of the force coupling relationship which leads to systematic shoulder instability.[24]

As discussed in the Phases of Throwing section each muscle of the shoulder girdle plays a significant role in overhand throwing. Some are required for creating and dissipating the explosive velocities achieved during a throw while others are required for control and stabilization. The importance of the neuromuscular control of these muscles and its role in dynamic stabilization of the shoulder complex will be discussed in the next section.

Proprioception of the Shoulder

The sensory mechanisms of proprioception are equally as important as the musculature and ligaments for proper shoulder function. Proprioception is required for proper function and stabilization of the shoulder joint.[28] Proprioception is the ability to determine where ones limb is in space and when the limb has moved.[29] It is divided into two sub-modalities: joint position sense and sense of limb movement. Each of these is vital to maintain joint stability by sending sensory information from the mechanoreceptors about the joint. This information includes speed of limb movement, capsular and ligament stretch, muscular activity, and joint position sense. This information may then lead to an effective change in muscle activity as a response to unexpected perturbations.[30] An example of this can be seen in RTC muscular contractions to stabilize the glenohumeral joint and prevent excessive humeral head displacement, during an overhead activity.[4] This multitude of information comes from a variety of sources within the muscles, capsules, and ligaments.

The two main groups of receptors that relay proprioceptive information are: 1) Tenomuscular mechanoreceptors, which include the muscle spindle and the Golgi tendon organs (GTOs) and 2) mechanoreceptors located in the joint capsule and ligaments, which include pacinian corpuscles and Ruffini receptors.

Together muscle spindles and GTOs provide the central nervous system (CNS) with information on the static length of muscles, rate at which muscle length changes, and the forces the muscles generates. With this information individuals are able to perceive changes in limb position and detect movement generated by their limbs.[31] This information can then be used for coordinated movements and protection from injury.

The muscle spindle senses changes in muscle length and acts to limit overstretch and injury.[32] In addition, it recognizes the rate at which the muscle is being stretched. This information is sent by sensory impulses through afferent axons to the spinal cord. The spindle contains fibers controlled by efferent nerve impulses in order to respond to the relayed information, allowing the spindle to avoid an over stretch injury.[33,34] This is of extreme importance during the deceleration phase of throwing. As the posterior RTC is stretched the spindles are stimulated to protect the muscles and the entire shoulder structure by causing reflexive contraction against an over-stretch eccentric injury. Additionally, during late cocking when the arm is maximally externally rotated the spindles are stimulated for protection from an external rotation overstretch injury.

The GTOs are located in the musculotendinous tissue and are spaced along this area at various intervals. Each GTO passes a small bundle of muscle tendon fibers. This positioning allows them to provide the CNS with feedback concerning muscle tension.[32] Like the muscle spindles, the GTOS are sensitive to increases in muscle tension.[35] Additionally, these receptors are coded for joint position and direction allowing for recognition of joint movement.[2] Unlike the muscle spindle, which contracts in the presence of muscle tension, the GTOs inhibit muscle contraction to relax contracting muscles and in an attempt to avoid an overstretch injury.[4]

Sensory information is also used to detect movement and changes in limb position through two main receptors found in joint capsules: Ruffini receptors and pacinian corpuscles.

The Ruffini receptors are slow adapting receptors and are found in the joint capsule. They relay information to the CNS on the position of a joint and any changes related to joint movement.[36] With an increase in tension the Ruffini receptors stimulate compensatory muscle contraction protecting the joint from overstretch and injury.[37] An example of this in throwing is during the cocking phase when the arm is maximally externally rotated. The Ruffini receptors sense overstretching and cause a compensatory muscle contraction to avoid injury.

The pacinian corpuscles are also found in joint capsules and act similarly to the Ruffini receptors in that they are stimulated when a joint is near the end range of motion. However, pacinian corpuscles are rapid adapting.[34,38] Additionally, the pacinian corpuscles are stimulated by changes in joint direction, and act to protect the joint in extremes of motion.[5] Like the Ruffini receptors these mechanoreceptors are vital in preventing an overstretch injury during the late portion of the cocking phase.

Due to its anatomy the shoulder must rely on the surrounding musculature and neuromuscular control for stability.[28] The highly complex system of mechanoreceptors is responsible for adapting to unexpected changes in motion, facilitating movement, and providing synergistic muscular contraction to maintain normal joint function.[30] The mechanoreceptors are important for the force coupling relationship, in that they are stimulated when enhanced co-contraction is needed for stability. Additionally, these mechanoreceptors are essential for providing joint stiffness. Joint stiffness is defined as the ratio of change in force per change in length.[32] This characteristic has been shown to be a beneficial component of a functioning stabile joint.[32] When the shoulder joint is unexpectedly moved beyond normal limits, the mechanoreceptors in the muscle, ligaments, and capsule trigger a chain of events to prevent excessive motion and thus protect from injury.

In the presence of fatigue the ability of the mechanoreceptors described above may be limited. It is believed that repetitive overhead motions may be a mechanism for disruption of the normal afferent feedback loops that help stabilized the shoulder joint by reflex muscle activity (quoted).[39] This may be due to the stress caused by repetitive throwing which may lead to fatigue. Recently, studies have examined the relationship between shoulder proprioception and fatigue.[2,40,41] Fatigue, as defined by a 50% peak torque decrease in these studies, was shown to significantly decrease proprioceptive abilities in each of the sited studies. This has significant clinical implications for a variety of reasons. First mechanoreceptors are responsible for joint stability and normal joint function. However, in the presence of fatigue, these receptors are slower to respond and/or may fail to detect a stimulus leading to symptomatic shoulder instability and joint injury.[30] Second, if the receptors are unable to recognize extremes in joint position they will be unable to provide a stimulus for protection leading to an increased mechanical stress on the structures of the shoulder.[5] And finally, a decrease in proprioceptive awareness has been shown to lead to a decrease in athletic performance.[5,40]

Common Overhead Throwing Injuries to the Shoulder

The requirements of throwing place a tremendous amount of stress on the shoulder complex. Due to the amount of force generated during normal throwing all structures of the shoulder complex are at risk for injury.[8]

Many overuse injuries as well as acute injuries have been attributed to RTC muscle weakness and fatigue caused by throwing.[9] A thrower's shoulder must have enough laxity to allow for excessive external rotation during the cocking phase, but must be stable enough to provide dynamic stability throughout the throwing motion.[9,42,43] Wilk el al refer to this as the "thrower's paradox".[4] Due to fatigue this balance is frequently compromised leading to numerous injuries in the overhead throwing athlete.[9] The stresses across a joint during the throwing motion may cause acute isolated injuries to the rotator cuff, labrum, and capsule.[8] Often times these injuries are due to instability caused by fatigue of the dynamic stabilizers of the shoulder.[9]

Rotator cuff lesions or tears can be attributed to chronic repetitive microtrama, acute macrotrama, or a combination of the two. These injuries usually occur in the supraspinatus, infraspinatus, and teres minor due to high shear forces during the deceleration phase. For a ball to be propelled at 80mph the arm must be traveling at 80mph and it is the responsibility of the posterior rotator cuff muscles to dissipate the forces created by the pectoralis major and subscapularis. Additionally, the tendinous insertion of the supraspinatus receives poor blood supply making it particularly vulnerable to repetitive overload stress and tearing.[8,44]

The labrum is also susceptible to injury during throwing due to the "grinding factor" that is associated with throwing.[45] The grinding factor is a result of increased translation of the humeral head across the labrum during acceleration and deceleration.[45] This translation combined with compression and rotation can cause grinding and possible tearing of the labrum.[23] The translation of the humeral head on the labrum increases as a result of dynamic stabilizers fatiguing.[45]

Fatigue of the dynamic stabilizers of the shoulder can also lead to superior migration of the humeral head, called subacromial impingement.[46] This impingement leads to friction as the supraspinatus and/or the biceps tendons are compressed under the inferior surface of the acromion as the glenohumeral joint is abducted or flexed to 90° e.g. overhand throwing. With continued overhead throwing the friction increases until an injury and or irritation occurs.[47]

Injury and Fatigue

Fatigue is defined by Penderson "as an acute impairment of performance that includes both an increase in perceived effort necessary to exert a desired force and the eventual inability to produce this force."[28] It is believed that repetitive overhand throwing produces fatigue. In particular, it places a stress and eventual fatigue on the rotator cuff muscles as they position and decelerate the humerus during the cocking phase and deceleration phases of throwing. This fatigue may lead to a decrease in shoulder strength and a decrease in joint position sense. Deficiencies in these areas have been shown to lead to joint injury and a decrease in athletic performance.[5,30,40] Clinically induced muscular fatigue has been reported to produce decreases in both shoulder strength and joint position sense.[1,2,5,7,41]

Joint Position Sense as a Measure of Proprioception

Active reproduction of passive positioning (ARPP) is a common measure of proprioception. Although joint position sense is only one aspect of proprioception it is one of the most commonly used measures of proprioception.[1,2,5,7,41] Lephart et al reported that active joint position sense stimulates both joint and muscle mechanoreceptors and is a more functional assessment of the afferent pathways.[7] Voight et al using a fatigue model consisting of a 50% decrease in peak torque, found pre-fatigue mean values of ARPP at 3.3 ± 1.15° from the reference position and post-fatigue mean values at 6.6 ± 1.75° from the reference position.[2] Similarly, Lee et al using the same fatigue protocol found pre and post fatigue values at 2.57° ± 1.02° and 4.96 ± 1.73° respectively.[41] Lastly, Myers et al reported lower mean absolute angular error values of 4.72 ± 2.43° and 5.58 ± 2.23°.[5]

Isotonic Testing

Two types of strength test were utilized in this study, isotonic and isokinetic. In Isotonic testing provide additional information on the strength of the internal and external rotators. Schmitz et al showed that isotonic contractions result in greater motor unit recruitment thus providing more insight to the strength of the shoulder complex.[48]

Isokinetic Testing

Strength ratios of the internal and external rotators of throwing athletes are of extreme importance. For this study, isokinetic testing was done to measure the pre and post values of the subjects. Isokinetic testing has been shown to be a safe, reliable, and valid measure of muscle strength.[49] Previously, Sirota et al examined professional baseball players with an isokinetic concentric test of the internal and external rotators.[21] These tests were performed at 120°/sec. and found mean torque values at this speed of 47.3 ± 13.4 Nm for the internal rotations and 43.4 ± 11.5 Nm for external rotation. Also at this speed, Giannakopoulos et al examined recreationally active males and found internal rotation values at 27.2 ±11.1 Nm and external rotation values at 22.3 ± 7.0 Nm.[25] The difference in values at these same speeds may be attributed to the fact Sirota examined professional athletes whereas Giannakopoulos examined recreational athletes.

CHAPTER 3

METHODOLOGY

Participants

Twenty- three healthy male college students, (age= 22 ± 2.9 yr , ht= 178 ± 11.3 cm, wt= 72 ± 7.7kg, 22 right-handed 1 left-handed) volunteered for this study. Six of those students were members of the University of Nevada, Las Vegas varsity baseball team. The remaining seventeen students were recruited from the general student population. These seventeen subjects were physically active for a minimum of 30 minutes, three times per week. All subjects were free of current and previous shoulder injury. Procedures were approved by the Office for the Protection of Research Subjects at the University of Nevada, Las Vegas.

Participant Preparation

Subjects attended one familiarization session prior to testing, during this time subjects were familiarized with testing apparatuses and all test procedures. A minimum of 48 hours (no longer then 72 hours) after the familiarization subjects returned for testing.

Data Collection

The preferred throwing arm considered dominate was used for testing. Prior to testing subjects completed a five-minute warm-up on an upper body erogmeter followed by five 30-second stretches of the rotator cuff muscles. Subjects were then pre-tested on three tests in the following order: ARPP, 1 repetition maximum (RM) isotonic, and Peak Torque isokinetic. The order for conducting those was maintained from pre to post test.

The ARPP test was conducted using an electronic goniometer placed at the distal end of the ulna and radius just between the styloid processes. The placement of the goniometer was marked on the subjects' skin to ensure equal placement on both pre and post test. Subjects were then internally or externally rotated 30 degrees and this position was held for ten seconds. Following this they were returned to starting position and instructed to actively return to the held position. Subjects were internally or externally rotated randomly for three trials, however, each subject had the same sequence from pre test to post test. After instructions were given and prior to beginning testing subjects were blindfolded exclude visual cues. Absolute angular error (the difference between the reference angle and the angle reproduced by the subject) was measured in degrees. The average of three trials was taken.

Internal ARPP sense was initiated by positioning the arm at 90° of external rotation, 90° of shoulder abduction, and 90° of elbow flexion. The examiner then passively internally rotated the shoulder 30° and held this position for 10 seconds. The examiner then passively returned the arm to the starting position of 90° - 90° - 90° and asked the subject to actively replicate the 30° movement of internal rotation and hold that position for 5 seconds. The subjects were then passively returned to the starting position.

External ARPP was initiated by positioning the arm at 0° of internal rotation, 90° of shoulder abduction, and 90° of elbow flexion. The examiner then passively externally rotated the shoulder 30° and held this position for 10 seconds. The examiner then passively returned to arm to the starting position of 0° - 90° - 90° and asked the subject to actively replicate the 30° movement of external rotation and hold that position for 10 seconds.

During Isotonic 1 RM testing, both internal and external rotation of the humerus in the dominant arm were tested. For internal rotation subjects laid supine with dominant arm at 90 degrees of shoulder abduction, 90 degrees of elbow flexion, neutral pronation/ supination in the frontal plane and 90 degrees of glenohumeral external rotation. They then moved the weight into a position of maximal internal rotation. During isotonic external rotation testing subjects laid prone with their dominant arm at 90 degrees of shoulder abduction, 90 degrees of elbow flexion, neutral pronation/ supination in the frontal plane and 0 degrees of glenohumeral internal rotation. They then moved the weight to a position of at least 90 degrees of external rotation. The first set was 5 submaximal repetitions at no more than 10 lbs (4.5 kg). The second set was 3 submaximal reps at no more than 15 lbs (6.81 kg). The 3rd, 4th and 5th sets were each 1 repetition, in an attempt to achieve their 1 RM. If subjects successfully overcame the resistance the weight was increased in an attempt to achieve their 1 RM. The amount of weight increased was determined by an estimation method where subjects rated the difficulty on a scale of 1-10. The increases in weight never exceeded 5 lbs (4.5 kg) and no subject completed more than 5 total sets. Subjects were given 3 minutes of rest between each set. Subjects were then given 3 minutes of rest prior to the next phase of testing.

Isokinetic testing was completed using a KIN-COM® isokinetic dynamometer. Each subject was seated in the KIN-COM® with the dominate arm in the padded arm rest and shoulder positioned to 90 degrees of shoulder abduction, 90 degrees of elbow flexion, 90 degrees of internal rotation, and neutral pronation/ supination. Isokinetic testing began with a sub-maximal (their perception of 50% of maximal) warm-up of ten repetitions at 120 degrees per second. This was followed by a 3 minute rest period. Immediately following the 3 minute rest period, subjects completed three maximal repetitions of internal and external rotation of the shoulder at 120 degrees per second. Mean peak torque values of the three repetitions of internal and external rotation were used for analysis. Subjects were given 3 minutes of rest prior to the next phase of testing.

Following pre-testing subjects were given 3 minutes of rest prior to participating in a throwing session. Only groups 1 and 2 were included in this portion of the testing. The control subjects were excluded, and sat comfortable in the lab for 20 min. Throwing was done with examiner monitoring distance and rate of throwing. The throwing session consisted of 75 throws at 75% of subject perceived effort and was done at 60 feet 6 inches. The pace of throwing was 1 throw per 15 seconds, approximately 20 minutes. Immediately following the throwing session subjects were again tested in the same manner as the pretest.

Statistical Design

The study was a 2 [Test Time (pre and post)] x 3 [Group (baseball players, recreational athletes and control)] mixed subject design with the factor test having two levels pre and post and the factor group having three levels baseball players, recreational athletes and controls.

The dependent measures of interest were AARP of both internal and external rotators as measured by the mean absolute angular error, 1 RM isotonic strength (Kg) of the internal and external rotators, and isokinetic mean peak torque (Nm) values measured at 120 degrees/sec for both internal and external rotation. Means and standard deviations of each measure were computed. Differences between test times and groups were analyzed with repeated measures ANOVA. Appropriate post-hoc testing was conducted to determine group differences. The data was analyzed on the Statistical Package for the Social Sciences (SPSS version 11.5 for Windows). Significance was preset at an alpha level 0.05.

CHAPTER 4

RESULTS

Analysis of ARPP, quantified as absolute angular error revealed a time-by-group interaction ($F_{2,20}$ = 5.78, P = .010). Post hoc analysis revealed a significant difference in the pretest and post-test values for the recreationally active group (2.27 degrees of error, 103%) and the baseball players (1.73 degrees of error, 116%), but no such difference for the control group. Mean and standard deviations for ARPP for all three groups are presented in Table 1. Univariate analysis of variance of between-subjects for the pretest revealed no significant difference among the three groups ($F_{2,20}$ =1.41, P=0.267). Lastly the between subjects test for the post-test revealed no significant difference among the three groups ($F_{2,20}$ = 1.78, P = 0.195).

Table 1. Error ARPP values (means ± SD) in degrees

	Pre	Post	Change	% Change
Rec. Active	2.20 ± 1.15	4.47 ± 2.15*	1.73	116%
Baseball Players	1.49 ± 0.71	3.22 ± 0.88*	2.27	103%
Controls	2.59 ± 1.52	3.05 ± 1.51	0.46	17%

* Indicates a significant difference pre to post-test

No significant differences existed between isotonic IR pre and post-test after throwing 75 times for any of the groups ($F_{2, 20}$ = 1.69, P= .210). Additionally no significant differences existed between isotonic ER pre and post-test for any of the groups ($F_{2, 20}$ = 1.90, P= .175). A univariate analysis of variance of between-subjects for the group revealed no significant difference among the three groups ($F_{2, 20}$ = 2.17, P= .1405). Mean and standard deviations for these tests are presented in Table 2.

Table 2. Isotonic ER and IR values (means ± SD) in lbs.

	IR		ER	
	Pretest	Post-test	Pretest	Post-test
Rec. Active	35.00 ± 4.53	34.75 ± 4.62	22.00 ± 5.04	21.63 ± 5.04
Baseball	42.00 ± 6.16	42.00 ± 6.16	26.17 ± 3.66	26.17 ± 3.66
Control	40.33 ± 9.17	39.11 ± 8.70	23.00 ± 3.87	21.56 ± 3.75

No significant difference existed between pre and post test for isokinetic IR peak torque for any groups following throwing ($F_{2, 20}$ = 0.72, P= .776). Additionally no significant difference existed for isokinetic ER for any of the groups ($F_{2, 20}$ = 0.63, P= .543). However, there was a significant difference among the three groups. Using a Tukey's post hoc test it was determined that the baseball group had a significantly higher mean then the recreationally active group during ER (P= 0.003) and IR (P= 0.004), as well as the control group during ER (P= 0.003) and during IR (P=0.0001). Mean and standard deviations for these tests are presented in Table 3.

Table 3. Isokinetic Peak torque for ER and IR of the shoulder (means ± SD) values in Nm

	IR		ER	
	Pretest	Post-test	Pretest	Post-test
Rec. Active	39.63 ± 5.45	40.00 ± 7.25	30.25 ± 7.10	29.38 ± 8.11
Baseball	50.83 ± 5.27	50.67 ± 6.50	42.00 ± 5.83	41.83 ± 4.21
Control	35.78 ± 4.11	35.33 ± 5.00	29.89 ± 4.85	30.44 ± 4.77

CHAPTER 5

DISCUSSION

The purpose of this study was to examine strength and joint position sense after a single bout of overhand throwing. It was hypothesized that overhand throwing would result in a decline in strength of external rotators of the shoulder with both isokinetic and isotonic testing due to the demand placed on the external rotators during throwing. Additionally, it was hypothesized that there would be a significant decline in joint position sense after throwing. Lastly, it was thought that there would be no decline in either strength values for the internal rotators.

Joint Position Sense

Our results indicated that overhand throwing decreased proprioception of the shoulder as measured by joint position sense. This was because the two throwing groups had a significant increase in absolute angular error (103% for the rec. active and 116% for the baseball players) where as the control group did not exhibit such a large alteration in joint position sense (17%). The mechanism responsible for this reduction of proprioception following throwing is believed to be caused by a decrease in the muscle spindles receptivity. Muscle spindles, which are believed to be responsible for joint position sense[34] are believed to become temporarily dysfunctional following throwing. This reduction in joint position sense measured here supports the theory proposed by Voight et al that desensitized muscle spindle causes an interruption in afferent feedback to the central nervous system.[2] What causes the desensitizing is not completely understood, however, it may be due to increases in intramuscular concentration of lactic acid, bradykinin, and serotonin. Pedersen et al found increased concentrations of these contractile substances and concluded that these concentrations affect the muscle spindle and proprioceptive ability.[28]

Due to the results of this study it can be concluded that throwing effects joint position sense. In our throwing subjects absolute angular error increased 103% for the recreational active individuals and 116% for the baseball players of what is was at pre test levels. It can be hypothesized that overhand throwing interferes with shoulder joint position sense and therefore shoulder function may be impaired by loss of muscle coordination and may lead to an eventual decline in dynamic shoulder stability.

Although no other studies have examined throwing and its effects on joint position sense, some have examined fatigue and its effect on joint position sense.[2,6,40] These studies defined fatigue as a 50% decline in maximum peak torque and found that shoulder propriception was indeed impaired. The results of our study indicate that proprioception may be impaired with a much lower level of fatigue. This hypothesis is supported by the fact that our throwing subjects did have a decline in joint position sense without having significant declines in strength measured isokineticlly as well as isotonically.

Isotonic Testing

Isotonic testing at a 1 RM was done for internal and external rotation and measured in pounds. Our results indicated that there was no significant decline in the amount of weight lifted from pre to post test after a bout of overhand throwing. These findings are not surprising for internal rotation. It was hypothesized that there would be no decline of the internal rotation based on the large muscle mass responsible for internal rotation. It was believed that the demand of 75 throws at 75% velocity was not great enough to cause any decrements in these larger muscles. However, it was hypothesized that there would be a decline in the external rotators based on the eccentric demand placed on the smaller external rotator cuff muscles during a bout of throwing. However, our results indicate otherwise. After finding no significant decline it was concluded that the demand of 75 % velocity is not intense enough to cause any decrements in strength due to a less intense eccentric, follow-through phase. However, it is believed that a higher intensity (i.e. a greater eccentric demand) would cause decrements in external rotator cuff strength. Additional reasons for no decline may be due to repetition, or the amount of time from throwing to post testing.

Isokinetic Testing

Maximal isokinetic testing of internal and external shoulder action was done at 120°/s as an additional testing tool for muscle strength. Three repetitions were completed and mean peak torque was calculated. Again it was hypothesized that the demand of throwing 75 throws at 75% velocity would not be sufficient to cause a decrement of the internal rotators but it would however cause a decline in the external rotators. Our results indicated that neither the internal or external rotators were impaired. These findings were anticipated for the internal rotators. Again we hypothesized that the demand of 75% velocity was not a great enough eccentric demand on the external rotators.

Clinical Significance

Although our results showed no significant decline in shoulder strength but a significant decline in shoulder joint position sense we still believe the results from this study have clinical relevance. Many times the decision to allow a pitcher to continue to perform is based on velocity as measure by a radar gun. However, the subject's ability to recognize joint position sense after throwing 75 throws at 75% of maximum was altered with no apparent decline muscular strength. Clinically, this can be seen in many pitchers after a large number of throws there is little or no decline in velocity, however their command or control of pitch location has decreased. It is believed that this loss of command may be due to a decline in the ability to recognize joint position or arm angle. This may lead to a change in arm angle and ultimately a disruption of their pitch command.

Additionally, it has been shown that proprioception by way of neuromuscular control is responsible for joint stability.[39] As one continues to throw there may be an alteration in joint mechanics caused by a decline in proprioception. This may lead to systematic instability from a decrease in reflex stabilization and eventual injury. Another finding can be seen in the fact that proprioception has been shown to be important in recognizing joint position in extreme joint position (i.e. full external and internal rotation or the wind up and follow-through phases of throwing.) If joint position sense is limited there may be increased mechanical stress on all structures responsible for joint stability.

APPENDIX I

BIOMEDICAL SCIENCES INSTITUTIONAL REVIEW BOARD APPOVAL

TO: Dr. Mack Rubley
Kinesiology Department (351)

FROM: Office for the Protection of Research Subjects

RE: Status of Human Subject Protocol Entitled: **Effects of Throwing on Rotator Cuff Strength and Proprioception** OPRS# 0311 - 1048

Notification of IRB Action by Dr. John Mercer
Chair, UNLV Biomedical Sciences Institutional Review Board

This memorandum is notification that the UNLV Biomedical Sciences Institutional Review Board reviewed and approved the subject protocol. Research on the project may proceed once you receive a hardcopy of this memo from OPRS. This approval is effective from March 16, 2004, the date of IRB approval, through February 23, 2005 a period of one year from the initial IRB review.

Should the use of human subjects described in this protocol continue beyond February 23, 2005, it will be necessary for you to request an extension and undergo continuing review. Should you initiate any changes to the protocol, it will be necessary to request additional approval for such change(s) in writing through the Office for the Protection of Research Subjects.

If you have questions or require any assistance, please contact the Office for the Protection of Research Subjects at OPRSHumanSubjects@ccmail.nevada.edu or call 895-2794.

Office for the Protection of Research Subjects (OPRS)
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Website: http://www.unlv.edu/Research/OPRS

INFORMED CONSENT TO BE A RESEARCH SUBJECT

Title: Effects of Throwing on Rotator Cuff Strength and Proprioception
Investigators: Mack D. Rubley, Ph.D., ATC and Joe Nocera, ATC, CSCS
Protocol Number: 0311 - 1048

This investigation is intended to examine shoulder function following an overhand throwing session. During overhand throwing a tremendous amount of stress is placed upon the shoulder muscles as they position and decelerate the arm. This repetitive stress from throwing may lead to a decrease in shoulder strength and function. A decrease in shoulder strength and function has been shown to increase the risk of injury and decrease throwing ability. It is our goal to examine shoulder strength and function following an overhand throwing session. You are being asked to participate in this study because 1) you are either a UNLV baseball player or 2) you are recreationally active for a minimum of three times per week and have experience with throwing and catching a baseball. In either case, as a subject you will assists in answering some of the questions the investigation intends to answer.

Procedures

For each experimental session, you will report to the Sports Injury Research Center (SIRC) building on the UNLV campus. For ease of testing, it would be best if you reported to the lab with clothing that you are comfortable working out in. You will first report to the SIRC to be familiarized with the testing devices. During this session you will go through a mock test to ensure comfort and understanding of testing protocol. This will last approximately 60 minutes. Forty-eight hours later you will be asked to return to the SIRC for testing. Testing will consists of three parts: pre-test, throwing session, and post-test. Total testing time will be about 60 minutes.

Prior to pre-testing you will first warm-up on an upper body "bike" for five minutes followed by stretching of the shoulder complex. Next you will be seated in a testing device with your throwing arm in a shoulder apparatus. Your arm will be positioned in a similar position as when throwing a baseball, upper arm perpendicular to the torso and the elbow bent to 90°, much like raising your arm for a high five. In this position you will then be tested to assess your shoulder strength. During strength testing you will rotate your arm forward and backward much like throwing a baseball. The strength test will begin by you completing a 10-repetition warm-up. After 3 min of rest you will be asked to maximally rotate your arm forward and backward three times in the same manner as the warm up. Following this you will be allowed to rest again for 3 minutes.

Next, with you seated in a chair with the same arm positioning, we will determine your shoulder position sense, how well you understand how far you are moving your shoulder. Before starting this test you will be blindfolded to prevent you from seeing your arm positioning. The examiner will position your arm at a reference angle, hold the angle for ten seconds, and then move your arm back to the starting position. Immediately following this you will be instructed to replicate the reference angle without any assistance, and hold that position for 5 seconds. This will be repeated 3 times. Following this, the blindfold will be taken off you will be removed from the apparatus and positioned on a table for another measure of shoulder strength using "free weights."

For this test you will be positioned lying on your back and your throwing arm will again be positioned a similar to throwing a baseball, upper arm perpendicular to the torso and the elbow bent to 90°, much like raising your arm for a high five. In this position you will rotate your arm forward with as much weight as you can lift pain free and with proper form. Following this you will lie on your stomach, with your arm perpendicular to the floor. Again you will lift as much as you can pain free and with proper form, however you will be rotating your arm backward, towards the ceiling. You will be given 3 minutes of rest between each set of lifts.

You will then go outside the SIRC where the throwing session will begin. For the throwing session you will be provided a standard baseball glove, a standard baseball, and a partner. You will stand 60 feet 6 inches from your partner and throw 75 times at approximately 75% of maximal effort. You will be instructed as to the pace of your throwing, approximately 1 throw per 15 seconds.

Immediately following the throwing session you will return to the lab to conclude your testing with the post-test. The post-test will be conducted in the same manner as the pre-test.

Risks

There are no more than minimal risks to the qualified subjects. Risks include being hit with a baseball and muscle strain during testing and/or throwing. These risks are minimized by a proper warm-up and pre-screening those who are recreationally active and who have experience at throwing and catching a baseball. Additionally, all procedures will be done in the presence and with the instruction of a trained examiner.

You may experience some discomfort in the shoulder from fatigue during throwing and testing. This should be no greater then normal discomfort that is associated with physical activity and strength training. This soreness may last 24 hours after the session and should not interfere with normal daily activity.

Benefits

The main benefit to the subject is the knowledge of the strength of one's shoulder and ability of shoulder positioning sense. Additionally, you will gain knowledge of shoulder strengthening exercises and the proper way to perform them.

It is our intention to report and publish the results of this study. Only group data will be reported, all personal data will be kept confidential, in a locked file cabinet at UNLV.

This information is intended to give you some impression of the procedure stresses, and the risks associated with this study. If you have any questions, either now or in the future, feel free to ask. Participation in this study is voluntary. You are free to withdraw your consent and to discontinue participation in this study or refuse to undergo any particular test at any time without prejudice. For specific questions regarding this study, contact Joe Nocera (702) 528-4233 or Mack D. Rubley (702) 895-2457.

For general information regarding the rights of research subject, contact: Brenda Durosinmi Human Protections Administrator, Office for the Protection of Research Subjects, University of Nevada Las Vegas, Las Vegas, NV 89154: phone: (702) 895-2794.

I agree to participate in this research project entitled "Effects of Throwing on Rotator Cuff Strength and Proprioception." The study and procedures have been explained to me and my questions have been answered to my satisfaction. I understand that I may withdraw from the study at any time. I have read the description of the study and give my consent to participate. I will receive a copy of this form to keep for future reference.

______________________________ ______________

Participant Signature / Printed Name Date

I hereby certify that I have explained the proposed study and its risks and potential complications.

______________________________ ______________

Witness Date

SUBJECT INFORMATION AND INJURY HISTORY QUESTIONNAIRE

Subject #:____

Height:____________cm Weight: _______________kg Age:__________ yrs

Are you currently seeing a physician or taking medication for any medical problems?

Yes _____ No ___

How many years of baseball experience do you have? _

How many days per week are you physically active? __

To the best of your knowledge do you have any injury or illness that would impair your ability to throw or catch a baseball? Yes_______ No________

To the best of your knowledge do you have any injury or illness that would impair your ability to exercise your dominant arm? Yes_______ No________

To the best of your knowledge do you have any condition that will impair your ability to participate in this study? Yes_______ No______

TO THE BEST OF YOUR KNOWLEDGE, HAVE YOU HAD ANY OF THE FOLLOWING? CIRCLE ALL THAT APPLY, PLEASE INCLUDE ANY OTHER MEDICAL CONDITIONS NOT LISTED.

Injuries to the arm, including the elbow and or shoulder	Cardiac Disorder
Surgery	Hypertension
Joint disease	Disease affecting the sensory system
Nervous disorder	Compromised local circulation

APPENDIX II

EXCEL RAW DATA

ARPP

Rec. Active			Baseball Players			Controls		
Subjects	Pre	Post	Subjects	Pre	Post	Subjects	Pre	Post
1	0.66	3.66	1	0.5	2.5	1	0.5	1
2	2.33	3.33	2	1.66	3.33	2	2	2.33
3	2	3	3	1	4.5	3	3.33	3.33
4	1.66	2.5	4	2.5	2.66	4	4.33	5
5	2.33	7.33	5	2	4	5	1.33	1.66
6	4.66	8.33	6	1.33	2.33	6	3	2.33
7	1.5	3.33				7	3.66	4
8	2.5	4.33				8	4.5	5.5
						9	0.66	2.33
	Pre	Post		Pre	Post		Pre	Post
Mean	2.21	4.48	Mean	1.50	3.22	Mean	2.59	3.05
Std. Dev	1.16	2.15	Std. Dev	0.71	0.88	Std. Dev	1.52	1.52

Isokinetic ER

Rec. Active			Baseball Players			Controls		
Subjects	Pre	Post	Subjects	Pre	Post	Subjects	Pre	Post
1	24	18	1	46	47	1	25	26
2	30	30	2	36	39	2	31	33
3	46	44	3	35	40	3	27	25
4	24	22	4	41	37	4	29	30
5	32	33	5	44	41	5	32	34
6	27	27	6	50	47	6	24	26
7	32	35				7	28	29
8	27	26				8	33	31
						9	40	40
	Pre	Post		Pre	Post		Pre	Post
Mean	30.25	29.38	Mean	42	41.83	Mean	29.89	30.44
Std. Dev	7.11	8.11	Std. Dev	5.83	4.22	Std. Dev	4.86	4.77

Isokinetic IR

Rec. Active			Baseball Players			Controls		
Subjects	Pre	Post	Subjects	Pre	Post	Subjects	Pre	Post
1	38	40	1	55	58	1	30	28
2	41	40	2	45	43	2	31	30
3	47	47	3	44	44	3	35	36
4	35	31	4	52	50	4	34	34
5	45	52	5	57	58	5	40	41
6	32	33	6	52	51	6	35	33
7	44	43				7	35	35
8	35	34				8	40	37
						9	42	44
	Pre	Post		Pre	Post		Pre	Post
Mean	39.63	40.00	Mean	50.83	50.67	Mean	35.78	35.33
Std. Dev	5.45	7.25	Std. Dev	5.27	6.50	Std. Dev	4.12	5.00

Isotonic ER

Rec. Active			Baseball Players			Controls		
Subjects	Pre	Post	Subjects	Pre	Post	Subjects	Pre	Post
1	15	15	1	30	30	1	16	16
2	20	20	2	23	23	2	21	16
3	25	22	3	31	31	3	22	21
4	22	22	4	26	26	4	25	25
5	30	31	5	22	22	5	25	25
6	16	16	6	25	25	6	22	20
7	26	25				7	21	21
8	22	22				8	25	25
						9	30	25
	Pre	Post		Pre	Post		Pre	Post
Mean	22.00	21.63	Mean	26.17	26.17	Mean	23.00	21.56
Std. Dev	5.04	5.04	Std. Dev	3.66	3.66	Std. Dev	3.87	3.75

Isotonic IR								
Rec. Active			Baseball Players			Controls		
Subjects	Pre	Post	Subjects	Pre	Post	Subjects	Pre	Post
1	30	30	1	40	40	1	25	25
2	32	32	2	32	32	2	32	32
3	35	35	3	45	45	3	30	30
4	35	35	4	40	40	4	45	45
5	45	45	5	50	50	5	50	50
6	32	31	6	45	45	6	46	45
7	36	35				7	40	35
8	35	35				8	45	45
						9	50	45
	Pre	Post		Pre	Post		Pre	Post
Mean	35.00	34.75	Mean	42.00	42.00	Mean	40.33	39.11
Std. Dev	4.54	4.62	Std. Dev	6.16	6.16	Std. Dev	9.18	8.71

APPENDIX III

SPSS OUTPUT

EXERCISE = Isotonic ER

Analysis: 3 (group) by 2 (time: pre/post) mixed model ANOVA

Between-Subjects Factors[a]

		Value Label	N
GROUP	1	recreation	8
	2	baseball	6
	3	control	9

a. EXERCISE = Isotonic ER

Descriptive Statistics[a]

	GROUP	Mean	Std. Deviation	N
PRETEST	recreation	22.0000	5.04268	8
	baseball	26.1667	3.65605	6
	control	23.0000	3.87298	9
	Total	23.4783	4.40939	23
POSTTEST	recreation	21.6250	5.04090	8
	baseball	26.1667	3.65605	6
	control	21.5556	3.74537	9
	Total	22.7826	4.52223	23

a. EXERCISE = Isotonic ER

Tests of Within-Subjects Effects[b]

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
TIME	4.109	1	4.109	3.566	.0736	.436
TIME * GROUP	4.386	2	2.193	1.903	.1752	.348
Error(TIME)	23.049	20	1.152			

a. Computed using alpha = .05

b. EXERCISE = Isotonic ER

Tests of Between-Subjects Effects[b]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
GROUP	**151.502**	**2**	**75.751**	**2.168**	**.1405**	**.391**
Error	**698.715**	**20**	**34.936**			

a. Computed using alpha = .05

b. EXERCISE = Isotonic ER

No significant main effects or interaction for this analysis

EXERCISE = Isotonic IR

Analysis: 3 (group) by 2 (time: pre/post) mixed model ANOVA

Between-Subjects Factors[a]

		Value Label	N
GROUP	1	recreation	8
	2	baseball	6
	3	control	9

a. EXERCISE = Isotonic IR

Descriptive Statistics[a]

	GROUP	Mean	Std. Deviation	N
PRETEST	recreation	35.0000	4.53557	8
	baseball	42.0000	6.16441	6
	control	40.3333	9.17878	9
	Total	38.9130	7.40340	23
POSTTEST	recreation	34.7500	4.62138	8
	baseball	42.0000	6.16441	6
	control	39.1111	8.70983	9
	Total	38.3478	7.18337	23

a. EXERCISE = Isotonic IR

Tests of Within-Subjects Effects[b]

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
TIME	**2.691**	**1**	**2.691**	**2.756**	.1125	.352
TIME * GROUP	**3.298**	**2**	**1.649**	**1.689**	.2100	.313
Error(TIME)	**19.528**	**20**	**.976**			

a. Computed using alpha = .05

b. EXERCISE = Isotonic IR

Tests of Between-Subjects Effects[b]

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
GROUP	**383.356**	**2**	**191.678**	**1.981**	.1640	**.361**
Error	**1934.861**	**20**	**96.743**			

a. Computed using alpha = .05

b. EXERCISE = Isotonic IR

No significant main effects or interaction for this analysis

EXERCISE = Isokinetic ER

Analysis: 3 (group) by 2 (time: pre/post) mixed model ANOVA

Between-Subjects Factors[a]

		Value Label	N
GROUP	1	recreation	8
	2	baseball	6
	3	control	9

a. EXERCISE = Isokinetic ER

Descriptive Statistics[a]

	GROUP	Mean	Std. Deviation	N
PRETEST	recreation	30.2500	7.10634	8
	baseball	42.0000	5.83095	6
	control	29.8889	4.85913	9
	Total	33.1739	7.81986	23
POSTTEST	recreation	29.3750	8.10533	8
	baseball	41.8333	4.21505	6
	control	30.4444	4.77261	9
	Total	33.0435	7.87100	23

a. EXERCISE = Isokinetic ER

Tests of Within-Subjects Effects[b]

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
TIME	.293	1	.293	.085	.7735	.059
TIME * GROUP	4.339	2	2.170	.629	.5433	.140
Error(TIME)	68.965	20	3.448			

a. Computed using alpha = .05

b. EXERCISE = Isokinetic ER

Tests of Between-Subjects Effects[b]

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
GROUP	1260.602	2	630.301	9.172	.0015	.953
Error	1374.354	20	68.718			

a. Computed using alpha = .05

b. EXERCISE = Isokinetic ER

No significant TIME effect or interaction for this analysis. However, there was a significant difference among the three groups. Tukey's test was run to determine which groups differed (see next page).

Post Hoc Test for significant difference between groups

Multiple Comparisons[a]

Measure: MEASURE_1

Tukey HSD

					95% Confidence Interval	
(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
recreation	baseball	-12.1042*	3.16565	.0029	-20.1132	-4.0951
	control	-.3542	2.84825	.9915	-7.5602	6.8518
baseball	recreation	12.1042*	3.16565	.0029	4.0951	20.1132
	control	11.7500*	3.08936	.0031	3.9340	19.5660
control	recreation	.3542	2.84825	.9915	-6.8518	7.5602
	baseball	-11.7500*	3.08936	.0031	-19.5660	-3.9340

Based on observed means.

*. The mean difference is significant at the .05 level.

a. EXERCISE = Isokinetic ER

The baseball group has a significantly higher mean than the other two groups.

EXERCISE = Isokinetic IR

Analysis: 3 (group) by 2 (time: pre/post) mixed model ANOVA

Between-Subjects Factors[a]

		Value Label	N
GROUP	1	recreation	8
	2	baseball	6
	3	control	9

a. EXERCISE = Isokinetic IR

Descriptive Statistics[a]

	GROUP	Mean	Std. Deviation	N
PRETEST	recreation	39.6250	5.44944	8
	baseball	50.8333	5.26941	6
	control	35.7778	4.11636	9
	Total	41.0435	7.75464	23
POSTTEST	recreation	40.0000	7.25062	8
	baseball	50.6667	6.50128	6
	control	35.3333	5.00000	9
	Total	40.9565	8.62596	23

a. EXERCISE = Isokinetic IR

Tests of Within-Subjects Effects[b]

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
TIME	.069	1	.069	.025	.8772	.053
TIME * GROUP	1.448	2	.724	.256	.7763	.085
Error(TIME)	56.465	20	2.823			

a. Computed using alpha = .05

b. EXERCISE = Isokinetic IR

Tests of Between-Subjects Effects[b]

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
GROUP	1696.868	2	848.434	14.080	.0002	.995
Error	1205.132	20	60.257			

a. Computed using alpha = .05

b. EXERCISE = Isokinetic IR

No significant TIME effect or interaction for this analysis. However, there was a significant difference among the three groups. Tukey's test was run to determine which groups differed (see next page).

Post Hoc Test for significant difference between groups

Multiple Comparisons[a]

Measure: MEASURE_1
Tukey HSD

(I) GROUP	(J) GROUP	Mean Difference (I-J)	Std. Error	p-value	95% Confidence Interval Lower Bound	Upper Bound
recreation	baseball	**-10.9375***	**2.96436**	**.0040**	**-18.4373**	**-3.4377**
	control	**4.2569**	**2.66714**	**.2704**	**-2.4909**	**11.0048**
baseball	recreation	**10.9375***	**2.96436**	**.0040**	**3.4377**	**18.4373**
	control	**15.1944***	**2.89292**	**.0001**	**7.8754**	**22.5135**
control	recreation	**-4.2569**	**2.66714**	**.2704**	**-11.0048**	**2.4909**
	baseball	**-15.1944***	**2.89292**	**.0001**	**-22.5135**	**-7.8754**

Based on observed means.

*. The mean difference is significant at the .05 level.

a. EXERCISE = Isokinetic IR

The baseball group has a significantly higher mean than the other two groups.

EXERCISE = ARPP

Analysis: 3 (group) by 2 (time: pre/post) mixed model ANOVA

Between-Subjects Factors[a]

		Value Label	N
GROUP	1	recreation	8
	2	baseball	6
	3	control	9

a. EXERCISE = ARPP

Descriptive Statistics[a]

	GROUP	Mean	Std. Deviation	N
PRETEST	recreation	2.2050	1.15687	8
	baseball	1.4983	.71477	6
	control	2.5900	1.52336	9
	Total	2.1713	1.25756	23
POSTTEST	recreation	4.4763	2.15126	8
	baseball	3.2200	.88125	6
	control	3.0533	1.51969	9
	Total	3.5917	1.71161	23

a. EXERCISE = ARPP

Tests of Within-Subjects Effects[b]

Measure: MEASURE_1

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
TIME	**24.652**	**1**	**24.652**	**39.096**	**.0000**	**1.000**
TIME * GROUP	**7.290**	**2**	**3.645**	**5.781**	**.0104**	**.812**
Error(TIME)	**12.611**	**20**	**.631**			

a. Computed using alpha = .05

b. EXERCISE = ARPP

Tests of Between-Subjects Effects[b]

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	p-value	Observed Power[a]
GROUP	**6.711**	**2**	**3.356**	**.924**	**.4132**	**.187**
Error	**72.631**	**20**	**3.632**			

a. Computed using alpha = .05

b. EXERCISE = ARPP

The TIME*GROUP interaction was significant, so simple main effects analysis was conducted (see following four pages).

Simple main effects tests for the significant Time*Group interaction

GROUP = recreation
ANALYSIS: paired t-test

Paired Samples Statistics[a]

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRETEST	2.2050	8	1.15687	.40901
	POSTTEST	4.4762	8	2.15126	.76059

a. GROUP = recreation

Paired Samples Test[a]

		t	df	Sig. (2-tailed)
Pair 1	PRETEST - POSTTEST	**-4.303**	**7**	**.0036**

a. GROUP = recreation

The posttest mean was significantly higher than the pretest mean in the recreation group.

GROUP = baseball
ANALYSIS: paired t-test

Paired Samples Statistics[a]

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRETEST	1.4983	6	.71477	.29180
	POSTTEST	3.2200	6	.88125	.35977

a. GROUP = baseball

Paired Samples Test[a]

		t	df	Sig. (2-tailed)
Pair 1	PRETEST - POSTTEST	**-3.763**	**5**	**.0131**

a. GROUP = baseball

The posttest mean was significantly higher than the pretest mean in the baseball group.

GROUP = control
ANALYSIS: paired t-test

Paired Samples Statistics[a]

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PRETEST	2.5900	9	1.52336	.50779
	POSTTEST	3.0533	9	1.51969	.50656

a. GROUP = control

Paired Samples Test[a]

		t	df	Sig. (2-tailed)
Pair 1	PRETEST - POSTTEST	**-2.152**	**8**	**.0636**

a. GROUP = control

No significant different between means.

Univariate Analysis of Variance (PRETEST)
ANALYSIS: One-way ANOVA

Between-Subjects Factors

		Value Label	N
GROUP	1	recreation	8
	2	baseball	6
	3	control	9

Tests of Between-Subjects Effects

Dependent Variable: PRETEST

Source	Type III Sum of Squares	df	Mean Square	F	p-value
GROUP	**4.304**	**2**	**2.152**	**1.412**	**.2670**
Error	**30.488**	**20**	**1.524**		
Corrected Total	**34.792**	**22**			

No significant difference among the three groups.

Univariate Analysis of Variance (POSTTEST)
ANALYSIS: One-way ANOVA

Between-Subjects Factors

		Value Label	N
GROUP	1	recreation	8
	2	baseball	6
	3	control	9

Tests of Between-Subjects Effects

Dependent Variable: POSTTEST

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
GROUP	9.697	2	4.848	1.771	.1958
Error	54.754	20	2.738		
Corrected Total	64.451	22			

No significant difference among the three groups.

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