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An Eccentric Intervention of the Flexor-Pronator Mass To Impact Overhead Throwing Distance and Velocity

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An Eccentric Intervention of the Flexor-Pronator Mass

To Impact Overhead Throwing Distance and Velocity

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Dedication

This thesis is dedicated to my grandparents

Mr. George Allen Adkins & Mrs. Nancy Adkins

And

Mr. Forney Jacob Ricker

To my parents

Mr. Stanton Allen Adkins

And

Mrs. Marjorie Ricker Adkins

To my best friend and companion

Ms. Brooke Kathleen Havens

Who gave me the strength and love to be able to achieve everything I have.

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Abstract

This study focused on the pronator-flexor mass of the elbow and its role in the overhead throwing motion. This specific muscle group is responsible for primary pronation and flexion at the elbow joint, while also reducing valgus stress from compromising the ulnar collateral ligament.

Twenty-three participants were put through a short throwing progression that was focused on their velocity and overall distance thrown from a standing position. After baseline testing was completed participants underwent a short intervention to determine if the intervention would impact all dependent variables. Experimental and non-experimental groups were compared using a repeated measures ANOVA which found no statistically significant difference.

The hypothesized relationship between the flexor-pronator group strength and the elbow range of motion would have resulted in increased overall valgus stability of the UCL due to an active warm-up which, in turn, would have increased pitching velocity and distance. This theoretical improvement would not only have decreased the possibility of injury as well as pain but improved the individual’s overall functionality.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

CHAPTER 1

INTRODUCTION

As one of the fastest human motions, baseball pitching has been demonstrated to have great injury implications due to the tremendous force and torque experienced by the shoulder and elbow (Atwater, 1979; Bigliani, Codd, Connor, & Levine, 1997; Dillman, Fleisig, & Andrew, 1993; Fleisig, Dillman, Andrews, & Escamilla, 1995; Sabick, Torry, Layton, & Hawkins, 2004; Werner, Gill, Murray, Cook, & Hawkins, 2001). The application of these forces causes the elbow to be prone to injury just as the rest of the kinetic chain is exposed. The baseball pitching motion has been subdivided into six distinct biomechanical phases (Loftice, Fleisig, Nigel, & Andrew, 2004). During the initial arm cocking phase the pitcher reaches maximum external rotation which generates the energy for the throw. The energy transfer continues until the motion finishes with the follow through phase. The energy and force is transferred from the trunk to the shoulder and follows through with the transference of energy ending in the elbow. The energy potential is a different entity from energy transfer related to the athlete alone. Energy potential is measured specifically by the physics of the ball. A good example of this is the velocity of the pitch itself. This energy potential begins at the throwers’ trunk, transfers to the shoulder, then the elbow, and finally the hand. This energy chain causes the ball to be propelled forcefully toward its intended target. Because the internal rotator complex at the shoulder is much stronger than the elbow flexor-pronator mass, there is an alarming tendency toward overcompensation at the elbow joint (Loftice et al., 2004). Due to this tendency to compensate at the elbow to distribute forces of the throwing motion, a significant strain is placed on both static and dynamic structures. Unfortunately, the elbow itself cannot slow down the forces generated by the pitching motion at the shoulder (Escamilla, Barrentine, Fleisig, Zheng, Takada, Kinglsey, and Andrews, 2007).

In competition there are two stances baseball pitchers use, depending on the placement of runners on bases. The first position, when runners are not on base, is defined as the windup. The pitcher stands erect with both feet perpendicular to the home plate. The second position is referred to as the stretch; the starting position is a side lunge with both feet facing parallel to home plate. These pitching stances differ significantly in respect to the approach the pitcher takes throughout the phases of the throwing motion. The windup is longer, allowing the pitcher to maintain balance and rhythm throughout the motion. In comparison, the stretch differs in the game making the timing different each time a pitch is thrown. The importance is force overtime in relationship to the pitching motion possibly causing a measure of fatigue or additional stress to the elbow. However, neither position was able to establish whether fatigue or starting position had an influence on the amount of force placed on the elbow (Dun, Kingsley, Fleisig, Loftice, & Andrews, 2008; Escamilla et al., 2007). However, Dun et al., (2008) and Escamilla et al., (2007) concluded that other confounding factors might have contributed to these findings. These other factors include pitching mechanics, number of pitches in a season, number of pitches per game, recovery time between innings, rest between games, muscular strength, conditioning level, age, and muscular fatigue (Escamilla et al., 2007).

Besides the amount of intrinsically generated force during throwing, extrinsic factors can also modify the stresses placed on elbow structures. Lyman, Fleisig, Andrews, and Osinski (2002) explored many external factors influencing the baseball pitcher including pitch type, pitch count, and mechanics. The slider pitch was shown to be the least frequently thrown and also shown to place the most stress onto the elbow itself. Structures stressed during this pitch are the pronator-flexor mass as well as the ulnar collateral ligament (UCL). Coincidentally, this pitch was also shown to cause a higher incidence of pain in the elbow. The curveball was shown to place less stress on the elbow; however, mastering the pitching mechanics is harder. This makes the margin of error larger, thereby causing more pain if the pitch is not thrown correctly. Thus, both of these pitches are deemed dangerous for the loads on the growth plates of prepubescent athletes (Carson & Gasser, 1998; Kocher, Waters, & Micheli, 2000). The change up is less stressful to the elbow than either the curveball or slider and the mechanics are easier to master. Therefore, this pitch generates less force on growth plates (Lyman, Fleisig, Andrews, & Osinski, 2002).

Higher pitch counts and higher levels of competition have been shown to increase elbow pain and stress. This is especially true for the 13 to 14 year-old age group. In this specific age group those who used a slider had an 86% increased risk of elbow pain (Lyman et al., 2002).

The accumulation of these extrinsic and intrinsic factors can result in decreased function at the elbow joint. Reinold et al. (2007) studied both the range of motion and aforementioned extrinsic factors to assess the pain and anatomical changes seen in the elbow as a result of pitching. A significant decrease in elbow extension was observed and was thought by the authors to be attributable to repetitive eccentric muscle contractions.

Despite these results, the repetitive nature and stress of throwing does not always result in dysfunction. Robertron and Halverson (1984) showed that with overhead pitching motion both the humerus and forearm will adapt as children age and become more experienced. The changes come defined as a lag that occurs during the pitching motion, depending on the range of motion position of either component. Stodden, Langendorfer, Fleisig, and Andrews (2006) explored the kinematics constraints of the throwing motion. The authors stated that preparatory positioning of the humerus and forearm is vital and that these positions during the arm acceleration phase have implications for preventing injury to the shoulder and elbow (Fleisig, Dillman, & Escamilla, 1995). In response to this overcompensation, pitchers have adapted to allow their elbows to withstand higher torques and forces, in turn to compete at higher levels of competition. Most of these adaptations are pure speculation by authors but all of them lead to joint pain, range of motion decrease, and possible injury. This involves the entire kinetic chain, however, for the purposes of this study the focus is placed on the implications experienced by the elbow joint.

None of the aforementioned studies have addressed the relationship between the demand of muscle to complete the action and the ability of the joint to allow for optimal positioning. Pitchers with elbow pain often have increased valgus instability of the ulnar collateral ligament (UCL) in conjunction with decreased flexor-pronator strength (Osbahr, Swaminathan, Allen, Dines, and Coleman, 2010 and Dines, Frank, Akerman and Yocum,2008). Studies involving this supply and demand battle merely scratch the surface of this problem.

Osbahr et al. (2010) speculated that when the flexor-pronator group became fatigued or inhibited the main valgus, stress on the elbow was placed solely on the UCL which could result in injury. This is a problem because the primary role of the muscle group is to dynamically stabilize the joint, preventing injury to the UCL. Dines et al. (2008) hypothesized that a glenohumeral internal range of motion decrease would result in elbow instability that could result in UCL injury. Osbhar et al. (2010) and Dines et al. (2008) both indicated the cause of the injuries to be based on a lack of sound biomechanics, repetitive forces and loads placed by different pitches. The kinetic chain related to injuries of the ulnar collateral ligament places involvement on the shoulder but it has not been speculated before that this chain may involve the elbow because of its distal placement and the stability controlled by the UCL.

Statement of Purpose

The purpose of this study was to examine the effects of an active, eccentric warm-up intervention on throwing velocity and distance in NCAA Division I baseball athletes. It was hypothesized that by following this type of sport specific eccentric warm-up both throwing distance and velocity would increase.

Definitions

Research Hypothesis: An individual's overall throwing distance and velocity can be significantly improved with eccentric intervention treatment of the flexor-pronator mass.

Dependent Variables: Elbow range of motion; Flexor pronator muscle group strength.

Independent Variables: Distance thrown; Velocity

Population: 40 NCAA Division I Baseball Players

UCL: Ulnar collateral ligament

Flexor-Pronator: Muscle group involving control of the valgus stability of the elbow. These are the pronator teres the flexor carpi ulnaris and flexor digitorum superficialis.

Eccentric: Lengthening of muscle while contracted.

Valgus: Medial stresses caused to the elbow.

Assumptions:

1. The participants were willfully providing their fullest effort in the study. This is to insure that they threw at their complete maximum potential before and after treatment was completed.
2. If participant had a past history of injury to UCL and or shoulder, an assessment was done to ensure proper rehabilitation was performed to allow participant to return to original activities of daily living without further complications.
3. If an injury was identified, the participant was removed from the study.

Limitations:

1. Subjects were NCAA division I baseball players ranging in age from 18 to 23 years.

2. Individuals had different throwing styles that may have allowed them to compensate to throw further or harder depending on their positions.
3. With two different throwing trials within a short period of time, a learning effect may have occurred allowing the subject to throw further.
4. A similar warm-up effect due to multiple throws within a short period may have caused a positive output to the shoulder as well.

<u>Delimitations:</u>

1. The low number of participants may not have showed the study’s ability to impact an individual’s increase in throwing distance due to this specific treatment.

CHAPTER 2

REVIEW OF LITERATURE

This literature review covers baseball throwing mechanics and the forces the mechanics place on the elbow. The review is broken down into six parts: 1) biomechanical breakdown; 2) kinematic constraint; 3) soft tissue failure; 4) extrinsic factors; 5) warm-up implications.

Biomechanical Breakdown

Biomechanics is "the science that examines the forces acting upon and within a biological structure and effects produced by such forces" (Adams, 1965, p. 127). With the complexity and frequency of elbow injury resulting from the baseball throwing motion, UCL injuries have been the target of frequent research. Loftice, Fleisig, Nigel, and Andrew (2004) conducted a biomechanical study to create further understanding of the elbow and its involvement in baseball throwing motion. This study was performed on cadavers and examined the torque and forces applied to the elbow throughout all the ranges of motion to which the elbow is exposed during "normal" baseball motion. Torque and forces applied to the elbow were broken down into the six phases of pitching: windup, stride, arm cocking, arm acceleration, arm deceleration, and follow-through (Werner, Fleisig, Dillman, & Andrews, 1993). During the windup phase the elbow has little or no role. The elbow's involvement starts during the stride phase where the elbow begins fully extended and finishes flexed between 80 to 100 degrees (Werner, Fleisig, Dillman, & Andrews, 1993, Feltner & Dapena, 1994; Fleisig, 1994). The arm cocking phase begins with the shoulder at maximal external rotation; the elbow torques and forces have been initiated with the start of this phase (Loftice et al., 2004). A low to moderate torque is applied to the elbow and is continued throughout the phase. The elbow torque includes a valgus torque contraction. The flexor-pronator works to functionally slow down the force from the throwing motion provided that the static elbow stabilizer or the UCL is fully intact to allow the athlete sufficient anatomical foundation to use this flexor-pronator mass. The body is forced to begin compensation by decreasing the maximal internal rotation range of motion of the involved side, with this increased external range of motion.

As a result of testing methodology, the study could not specify what musculature co-contracts to stabilize the elbow. However, the authors speculated that without this stabilization of the UCL and musculature, the UCL is prone to injury (Loftice et al., 2004). This especially occurs in later stages where forces on the elbow maximize, such as the acceleration phase. During the acceleration phase the elbow extends but does not reach full extension. With this extension and velocity associated with the motion, the elbow extensors are not able to compensate. Most of the velocity comes from other generators, including the trunk, hip, and shoulder. Because of this power, the elbow extensors are outnumbered, once again leaving the elbow vulnerable. This vulnerability then becomes an anatomical consideration which is defined as a biomechanical locking. “This locking of the brakes”, which involves the arm’s last resort to slow the valgus force down placed on the elbow; results in impingement of the olecranon fossa and trochlear groove (Loftice et al., 2004). Wilson (1983) explains the mechanism as “valgus extension overload” and as the acceleration phase continues, centrifugal force acts on the forearm to prevent elbow distraction during the movement. The elbow flexors contract to provide joint stability and assist in the slowing of elbow extension due to the lack of control experienced by the extensors.

The arm deceleration phase is the key to dissipating all the forces from the pitching motion (Loftice, et al., 2004). The phase begins immediately after the pitch has been released. Elbow flexors are the now taking over the role of deceleration, secondary to the lack of contraction of the triceps brachii, in order to prevent elbow distraction. Because of the overwhelming proximal forces which are passed onto the forearm and the rapid deceleration of extension, impingement is imminent at this phase, as well as during the acceleration phase. All of these forces and speed are increased with the progression of the player’s skill level. During the follow-through phase the elbow has no large role but simply relies on the pronator-flexor group to bring the elbow to rest in conjunction with the rest of the body. Loftice et al. (2004) stated that biomechanics plays a large role in overhead throwing, particularly the baseball throw. All hard and soft tissue anatomy must provide joint stability against these high torques generated during the arm acceleration phase because if incorrect biomechanical techniques are used or taught, they often result in excessive force and torque at the elbow, possibly resulting in injury.

Biomechanical Fatigue

Escamilla et al. (2007) explored the baseball throwing motion biomechanically from a fatigue standpoint. The fatigue was achieved by having 10 collegiate pitchers pitch seven to nine innings, engaging in 15 pitches per inning during a simulated indoor game. Fatigue was measured on a scale from zero to nine and readings were taken at the end of each inning. Pitch type was not controlled, and was solely designated by the pitcher's catcher. The pitcher threw from the stretch or the wind-up depending on whether or not the simulated game had runners on base. Whereas Werner et al. (1993), Feltner et al. (1994) and Fleisig et al. (1994) have identified six phases of the throwing motion, the authors of this study consolidated it into four phases (Escamilla et al., 2007). Within the four phases 11 kinematic parameters were taken during an entire pitching motion. With this set-up the authors compared the first two innings with the last two innings. Comparisons were made in the 11 categories after fatigue was reached. Ball velocity was significantly less in the final two innings pitched and trunk flexion was significantly decreased (Escamilla et al., 2007). With the associated flexion of the trunk, velocity and fatigue, the deceleration phase and forces applied to the elbow can be dissipated by allowing for the majority of the force to be distributed throughout the body over a longer period of time. Theoretically, an athlete that finished a pitching motion standing upright would experience more force over a shorter period of time. This would prove to be more stressful when compared to a throwing motion with the participant finishing his motion as previously described. In combination with the findings, an anticipated increase in elbow torque and forces are likely secondary to the subjective fatigue level of the athlete.

Kinematic Constraints

In order to optimize the contribution of lower and upper extremity movements, preparatory positioning of the humerus and forearm is vital (Stodden, Langendorfer, Fleisig, & Andrew, 2006). Furthermore, these positions have implications for preventing injury to the shoulder and elbow (Fleisig et al., 1995). Stodden et al. (2006) examined kinematic variables of ball velocity associated with development of the humerus and forearm. Participants included 49 children; 34 boys, and 15 girls with a mean age of 10 years. The participants in this study were minors, and although not in the target population of this study, still render significant information on current research involving the kinematics of overhead motion in relationship to stresses placed up the elbow. Eleven kinematic variables were used to describe movements of the upper extremities through the phases of throwing from stride to ball release. Based on this study, evaluations for developmental sequences of forearm action were created (Roberton & Halverson, 1984). Level one was no forearm lag; level two was forearm lag was significant; level three was delayed forearm lag. The participants were placed in the three groups based on lag of the thrower's initial maximal external rotation to ball release and whether or not the forearm lagged through the acceleration phase. This was done by utilizing the kappa coefficient (Safrit & Wood, 1995). All but one kinematic descriptor showed significant differences in levels (Stodden et al., 2006). As the experience level in the throwers increased, so did the progression of lag from the involved participant's humerus and forearm. These results showed that developmental levels were reliable in reflecting the actual kinematic differences observed in this cross-sectional group. Furthermore, this study stated the importance of proper humerus and forearm placement. This implies that as force increases with training, experienced throwers should place more emphasis on their stride foot contact. Speculation was made that higher skilled throwers utilize mechanical and neuromuscular principles, such as segmental inertial characteristics and the stretch-relax mechanism to promote increased energy generation and energy transfer to ball release. The authors indicated that in order to substantiate these ideas, there was a need for more empirical testing (Stodden et al., 2006).

Soft Tissue Failure

Previous speculation has indicated a potential correlation between the flexor muscle groups and the elbow joint’s stability specifically in relation to the ulnar collateral ligament (Loftice et al., 2004). Combined flexor-pronator and ulnar collateral ligament injuries occur in older players, and results in this group had a lower return rate compared to those reported for isolated ulnar collateral ligament reconstructions (Osbahr, Swaminathan, Allen, Dines, Coleman, & Altchek, 2009). One hundred and eighty-seven male baseball players between the ages of 14 and 42 years participated in this study (Osbahr et al., 2009). Outcomes for surgery were rated on a scale from one to five with one being excellent and five being poor. Excellent ratings accounted for only 12.5% while the poor ratings accounted for 62.5% of the participants. Although combined flexor pronator muscle group and UCL injuries spanned across the study’s population, the results showed that 33 years of age was a significant predictor for the combined injury. Of the participants age 33 and older, 88% had a combined flexor-pronator strain and a compromised UCL. (Osbahr et al., 2009). All eight of the 187 participants were treated for the combined injury. These eight participants suffered from chronic elbow pain and half complained of acute onset elbow pain as well. The surgical findings on these patients found that seven had complete ulnar collateral ligament (UCL) tears, one had a partial

UCL tear, and six of the eight had severe flexor pronator injury. The injury to the muscle group was characterized in three groups: severe tendinosis (n=1), partial tears of the muscle group (n=2), and complete rupture (n=3). Of these patients, only two required debridement of the elbow and four patients had additional surgical work done. Three participants received an ulnar nerve transposition and one received olecranon osteophyte debridement (Osbahr et. al., 2010).

Osbahr et al. (2010) further indicated the ulnar collateral ligament anterior band is the main valgus constraint for the elbow, while the flexor pronator mass serves as the dynamic, secondary stabilizer. Davidson, Pink, Perry, and Jobe (1995) found through cadaver dissection that the flexor carpi ulnaris and the flexor digitorum superficialis are in line to provide optimal support to the UCL during valgus stress experienced in the phases of throwing. Park and Ahmad (2004) conducted a cadaver study that evaluated the pronator flexor mass's role in assisting UCL stabilization against valgus torque. Co-contraction of the flexor carpi ulnaris and flexor digitorum superficialis corrected the valgus angle of a partially torn UCL, thus making them the primary and secondary stabilizers.

Extrinsic Factors

Within this biomechanically analyzed motion there are some important extrinsic factors that need further examination. Dun (2008) focused on the extrinsic factor of stances. He observed twenty-eight professional baseball pitchers and compared fastballs thrown from the stretch versus the wind-up. He observed differences in shoulder and elbow kinematics in relation to position of front foot contact, timing, and ball velocity between the stretch and wind-up (Dun, 2008).

These differences were not significant, however, it was speculated by players and coaches that the stretch position would result in a “rushed” pitching motion (Dun, 2008).

Pitch count has been the topic of many studies involving youth, especially in regards to Little League. Pitch count, pitch type, and pitching mechanics were studied by Lyman et al., (2004) who stated, “Youth baseball pitchers are at risk for elbow and shoulder problems; however, the factors associated with these problems are poorly understood and have been infrequently studied” (p.463). Pitch counts of 476 pitchers were counted. During the season each team was responsible for keeping game pitch counts. There was no record kept of pitches thrown outside of games. After every game a phone interview was conducted with each pitcher. The questionnaire was similar to the one used in the Lyman, Fleisig, and Waterbor (2001) study. The purpose of this specific questionnaire was to reproduce the Lyman et al. (2004) study’s inter- and intra-rater reliability. In addition, the questions from this particular survey were found to be much easier to understand by the younger population which enhanced the response rate among the participants. With this data, a statistical analysis was run, which only included the additional complaints of shoulder and elbow pain. A final interview was conducted at the end of each player’s season and was compared to the entry baseline before the study. Collectively, statistical analyses and regression were done on all the information from the surveys.

The main focus was to find extrinsic factors of elbow and shoulder pain. These factors included pitch types, pitch count and pitching mechanics. The survey analysis revealed that breaking pitches demonstrated higher occurrences of pain in the elbow and shoulder. A higher pitch count was also found to demonstrate a higher occurrence of pain in elbow and shoulder.

Curveballs and sliders belong to the breaking pitch group. Both pitches were shown statistically to cause shoulder and elbow pain. In addition, both pitches, because of their high rate of mechanical difficulty, can take time to perfect. This was an additional factor not controlled within the study and adds a new pain catalyst. Higher loads placed on the elbow with breaking pitches in non-skeletally mature athletes caused these subjects to be more susceptible to stress-related injuries (Carson & Gasser, 1998; Kocher & Waters & Micheli, 2000).

Pitch Count

Higher pitch counts were related to a series of injury difficulties within the study from stress-related, acute, and overuse injuries (Lyman et. al, 2002). The author demonstrated that as pitch counts increased, so did the likelihood of a pitcher having shoulder or elbow pain. Specifically, one group within the study threw from 75 to 99 pitches. Thirty-five percent of this group presented with increased elbow pain and 52% reported increased shoulder pain.

Baseball pitching injuries are most commonly due to the accumulation of microtrauma from the repetitive pitching motion (Andrews & Fleisig, 1998; Oberlander, Chisar, & Campbell, 2000). The slow development of these injuries makes it difficult to demonstrate cause and effect. Most serious pitching injuries occur at the collegiate and professional level due to the higher stresses of competition and increases in the number of pitches thrown (Oberlander et al., 2000).

Warm- Up

Bishop (2003) defines an activity lasting no longer than ten seconds as a short- term activity, which would be the time it would take to complete the overhead pitch in baseball. More specifically, the functional slow down using the pronator flexor mass during the follow through phase of pitching would be considered a short-term activity. During an active warm-up, an increase in muscle temperature has the ability to improve performance as well as prevent injury. With the increase in muscle temperature athletes reported a decrease in muscle and joint stiffness (Wright & Johns, 1961; Buchthal, Kaiser, & Knappeis, 1944), an increase in the transmission rate of nerve impulses (Karvonen, 1992), a change the force-velocity relationship (Binkhorst, Hoofd, & Vissers, 1977; Davies & Young, 1983; Ranatunga, Sharpe, & Turnbull; 1987), and an increase in glycogenolysis, glycolysis and high-energy phosphate degradation (Edwards, Harris, & Hultman, 1972; Febbraio, Carey, Snow, Stathis, & Hargreaves, 1996). Bishop (2003) summarized that a three to five minute warm-up of moderate intensity is most likely to significantly improve short-term performance secondary to the increase in muscle temperature.

Intensity of the warm-up is based upon the sufficient increase of muscle temperature but does not decrease the availability of high-energy phosphates immediately prior to tasks (Bishop, 2003). Therefore, proper recovery time during the duration of the warm-up needs to be appropriate in order to achieve an increase in performance. With the onset of exercise, muscle temperature rises rapidly within three to five minutes and reaches a plateau after 10 to 20 minutes of exercise (Saltin, Gagge, & Stolwijk, 1968).

Recovery depends upon intensity as well as duration of the warm-up. The recovery interval should allow phosphocreatine (PCr) stores to be significantly restored (Bishop, 2003). The resynthesis of PCr stores is a rapid process which is mostly completed within five minutes of exercise (Dawon et. al, 1997, Harris, Edwards, Hultman, Nordesjo, Nylind, & Sahlin, 1976).

Pyke (1968) looked at short-term performance as it related to a warm-up with a task specific exercise. Pyke (1968) reported that three maximal practice jumps did not improve vertical-jump performance. Bishop (2003) stated that such a warm-up should not be expected to increase muscle temperature. In addition, the recovery time also would not have been sufficient for recovery of the phosphorylcreatine resynthesis.

Summary

The pitching motion has been studied in many experimental and clinical research studies. None, however, have formed any foundation for a clinical study to be done on the elbow. Werner, Fleisig, Dillman and Andrews (1993) established a biomechanical baseline for the elbow in the pitching motion which was broken down into six phases as well as the forces associated with each phase. Excamilla et al. (2007) and Dun (2008) utilized the ground work Werner et al. (1993) laid to expand upon current research into extraneous variables. The variables included pitch type, timing of throw and foot contact, fatigue, age, and final positioning and stabilization (Lyman, Fleisig, Andrews, & Osinski, 2002, Dines et al., 2008, Osbahr et al., 2010). In the study it was clear that the UCL was the main anatomical constraint taking the force fully from the throwing motion. Cadaver studies disproved the integrity of the

UCL alone to withstand the torque and forces imposed by the throwing motion (Park & Ahmad, 2004; Davidson et al., 1995). In conjunction with the flexor-pronator mass, the UCL is able to perform one of the fastest motions of which the human body is capable (Dillman et al., 1993). Osbahr et al. (2010) further explained that the co-contraction of the flexor carpi ulnaris and flexor digitorum superficialis is fundamentally needed to prevent valgus instability. The failure of these to co-contract has not been fully investigated and further testing needs to be done to prove these claims. In regards to extrinsic factors, it is statistically sound that increased pitch counts precisely between 75 to 99 pitches drastically increase the risk of shoulder pain. It is hypothesized that limiting the number of pitches a pitcher will throw will diminish elbow and shoulder pain but others argue that it would hinder the games in many ways. Instead, it has been proposed to limit the number of batters the pitcher will face (Lyman et al., 2002). Pitch types, specifically breaking pitches, because of their nature and mechanics, have been shown to cause a higher amount of torque and stress, increasing the injury risk to a pitcher or overhead throwing athlete. In addition, not being technically sound with these difficult pitches has been shown to increase the rate of pain as well. Ultimately, all factors play vital roles in the game of baseball and will need to be studied further in order to understand ways to prevent and control the rate of risk for these athletes. A possible way to control this risk would be to take a common idea of a warm-up specialized to target the pronator-flexor mass. Bishop (2003) concluded that a short-term warm-up lasting less than 10 seconds will significantly improve performance. This improvement is based on the concept that the warm-up is of sufficient length, intensity, recovery and specific to the athlete’s needs.

CHAPTER 3

METHODS

Participants

The population for this study consisted of 23 participants from an NCAA Division I AA baseball program between the ages of 18-23 years. No ethnicity background was needed to be defined by this study and recruitment was solely based on availability and participant interest. Criteria for exclusion included a current history of chronic shoulder instability or impingent in the participant’s dominant throwing arm. In addition to any surgeries, underlying medical conditions and possible medications that would hinder the participant from any activities of daily living were cause for removal or exclusion from the study.

Instruments

1) The baseball used during the entire study was an NCAA division I college regulation Wilson Baseball.
2) A PVC pipe measuring 2 feet in length and one inch diameter with an elbow piece of PVC pipe was used to administer the intervention.
3) The apparatus used to monitor velocity and distance thrown was a Sportsman Full Swing Golf Simulator.

Procedures

Participants were assigned to groups based on observation of their throwing mechanics. This occurred during the initial screening. Each group consisted of approximately 6-8 individuals. Participants were then separated into a control group, experimental group for infielders and an experimental group for pitchers. Assignment to either the control group or the experimental groups was randomized.

Each participant underwent a functional throwing measurement during his individual session. Participants were asked to throw a baseball into the Full Swing Golf Simulator. Participants were given ample instruction on what to do, provided time to practice, and then required to perform three maximal throws. After each throw a resting period of 45 seconds was enforced. The Sportsman Full Swing Golf Simulator provided data on angle of throw, velocity and computed the distance the ball was in the air.

The experimental groups performed a three minute eccentric contraction warm-up following baseline measurements. Participants were seated while holding a short rod. They were instructed to perform forearm movements (turning the palm downwards and then returning to palm up) while resisting a gradual and manually applied external force creating eccentric contractions. Participants performed these exercises for 30 seconds, rested 30 seconds and then repeated the exercise/rest cycle for a total of 3 minutes. Following this intervention, they were re-assessed after a 45 second rest. The control group rested for five minutes after which the reassessment was performed.

Design

The participants were divided into three groups by position. Group 1 was labeled hitters for those participants who played within the infield positions. Group 2 was labeled pitchers and Group 3 was the control group which was a random mixture of pitchers, hitters and outfielders. Group 1 had a total of 8 participants. Group 2 had 6 participants and Group three was made up of 8 participants. The breakdown of Group 3 was three pitchers, three outfielders, one catcher and one utility player. Participants in Groups 1 and 2 were experimental groups where the warm-up intervention was performed between two throwing sessions using the Full Swing Golf Simulator.

Data Analysis

To test for group differences at baseline, a one-way analysis of variance (ANOVA) was performed on the dependent variables prior to the intervention. A one-way 2 x 3 (time x group) mixed factorial repeated measures ANOVA was utilized to measure group differences on each of the dependent variables following the intervention. A series of one-way 6 x 3 (trial x group) repeated measures ANOVAs were utilized to examine differences within trials for each dependent variable. Significance was set *a priori* at $p < .05$.

CHAPTER 4

RESULTS

Complete group demographics can be viewed in Table 1. Initial statistical analyses indicated that there were no group differences in basic anthropometric measures; age (p=.286), weight (p=.395), and height (p=.752). Furthermore, one-way analysis of variance (ANOVA) examining group differences in dependent variables at baseline revealed no significant differences in both throwing distance (p=0.549) or velocity (p=0.157) prior to the intervention.

Table 1
Group Demographic Means

Groups	Group 1 (Hitters)	Group 2 (Pitchers)	Group 3 (Control)
Average Height (cm)	184.01±7.08	187.96±3.59	187.01±5.59
Average Weight (kg)	85.43±11.34	88.45±6.73	85.05±6.96

A one-way 2 x 3 (time x group) mixed factorial repeated measures ANOVA was utilized to measure group differences on each of the dependent variables . Following the intervention, there was a significant main effect for time for both maximum throwing distance (p<.001) and maximum velocity (p<.001). There were no significant interactions between variables. On average, participants in all groups increased maximum throwing distance by 4.96 yards from pre-test to post-test. A similar increase was also recorded for maximum velocity, with a mean increase of 2.61 mph across all groups. Each specific group also showed an increase in velocity from pre- to post- test. Hitters had an average increase of 3.77 mph for velocity and an average increase of 4.44 yards for distance. Pitchers had an average increase of 12.83 mph for velocity and an average increase of 5.16 yards for total distance.

Finally, the control group had an average increase of 1.75 mph for velocity and an average increase of 5.38 yards for distance.

Individual groups for all trials, using 6 x 3 repeated measures ANOVAs were utilized to examine differences within trials for each dependent variable. Based on marginal means for velocity, trial 1 was significant in relation to all othertrials except trial 2. Trial 2 was significant between all trials except trials 1 and 4. Trial 3 was significant between all trials but trials 4 and 5. Trial 4 was significant between all trials but trials 2 and 3. Trial 5 was significant between all trials but trial 3. Trial 6 was significant between all trials. All trials compared within groups and subjects were found to be non-significant (p>.05). Similar 6 x3 repeated measures ANOVAs was used for total distance traveled trials. Trial 1 was significant between all trials. Trial 2 was significant between trials 1 and 6. Trial 3 was found significant between trials 1 and 6. Trial 4 was also found to be significant between trials 1 and 6. Trial 5 was significant only with trial 1. Trial 6 was found to be significant with all trials but trial 5. When compared between groups no significance was found (p>.05). Table 2 has Group means for all trials with dependent variables of total yards thrown and miles per hour. Below Table 2 displays averages for all pre- and post- test trials (MPH and distance thrown) in relation to the groups. Following Table 2, Figures A and B display graphically the increase overtime in relation to the averages found in Table 2.

Table 2

Group Means for Velocity (MPH) and Distance (Total Yards)

Groups	Group 1(Hitters)	Group 2(Pitchers)	Group 3(Control)
Total Yards Trial 1 AVG	74.22 ± 11.78	71.67 ± 13.9	75.63 ± 18.55
Total Yards Trial 2 AVG	84.55± 6.13	90.83 ±13.64	86.13 ± 13.44
Total Yards Trial 3 AVG	88.78± 6.83	94.67 ± 8.50	91.88 ± 6.96
Intervention			
Total Yards Trial 1 AVG	89 ± 6.91	88.17 ± 7.22	86 ± 11.76
Total Yards Trial 2 AVG	92.22 ± 8.38	95.33 ± 10.78	93.75 ± 8.61
Total Yards Trial 3 AVG	93 ± 7.57	101 ± 10.11	95.75 ± 6.34
Means of Velocity			
MPH Trial 1 AVG	65.56±8.11	69±7.92	69.38±8.31
MPH Trial 2 AVG	69.89±3.76	72.33±7.28	72.25±4.06
MPH Trial 3 AVG	72.33±4.11	74.17±7.67	75.13±3.56
Intervention			
MPH Trial 1 AVG	72±3.97	71.67±4.80	74.25±2.66
MPH Trial 2 AVG	74.67±4.46	74±4.38	74.56±3.42
MPH Trial 3 AVG	76.56±3.28	76.33±5.72	77.13±2.71

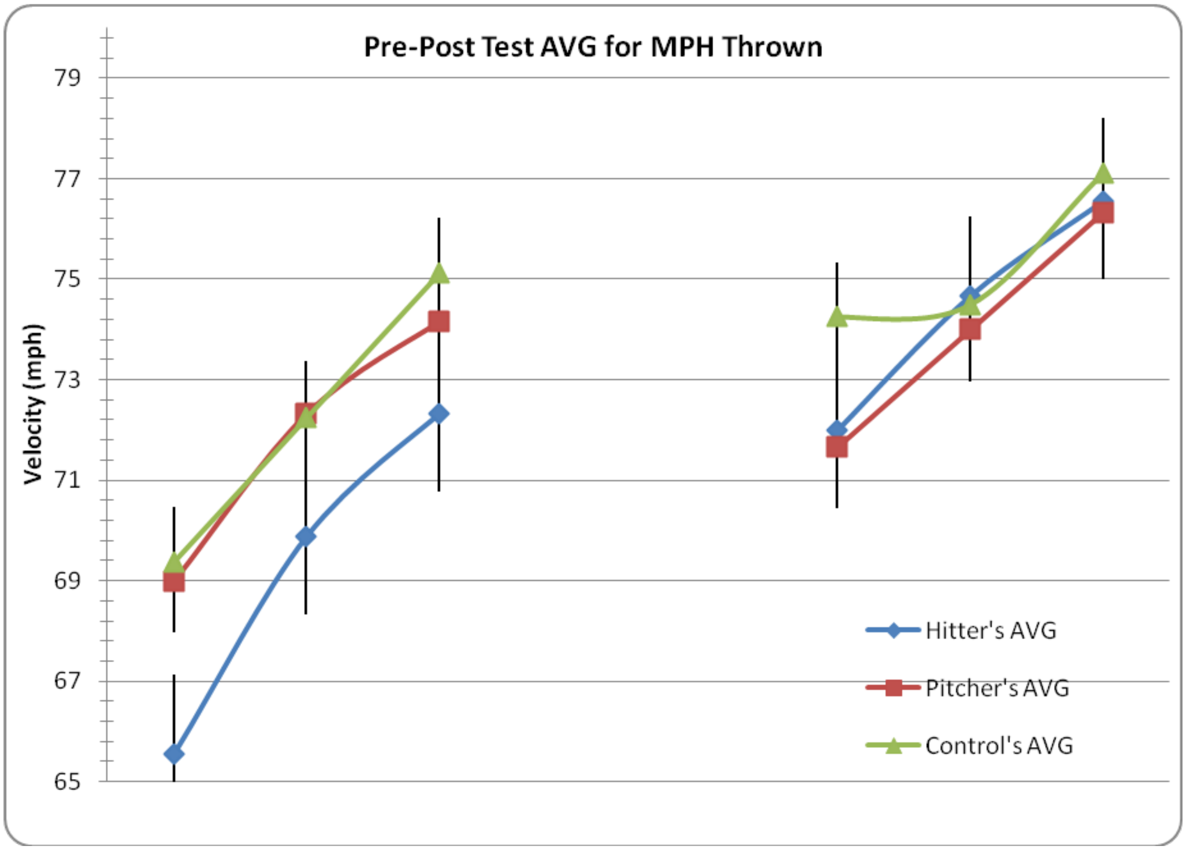

Figure A. Pre-Post Test AVG for MPH Thrown

Note: The data is displaying the average results from all three groups compared over the six trials. From baseline to the final test measurements of all 3 groups increased overtime again statistically showing the intervention had no effect. The intervention took place between test trials 3 and 4 this is shown by the break between pre and post testing trials.

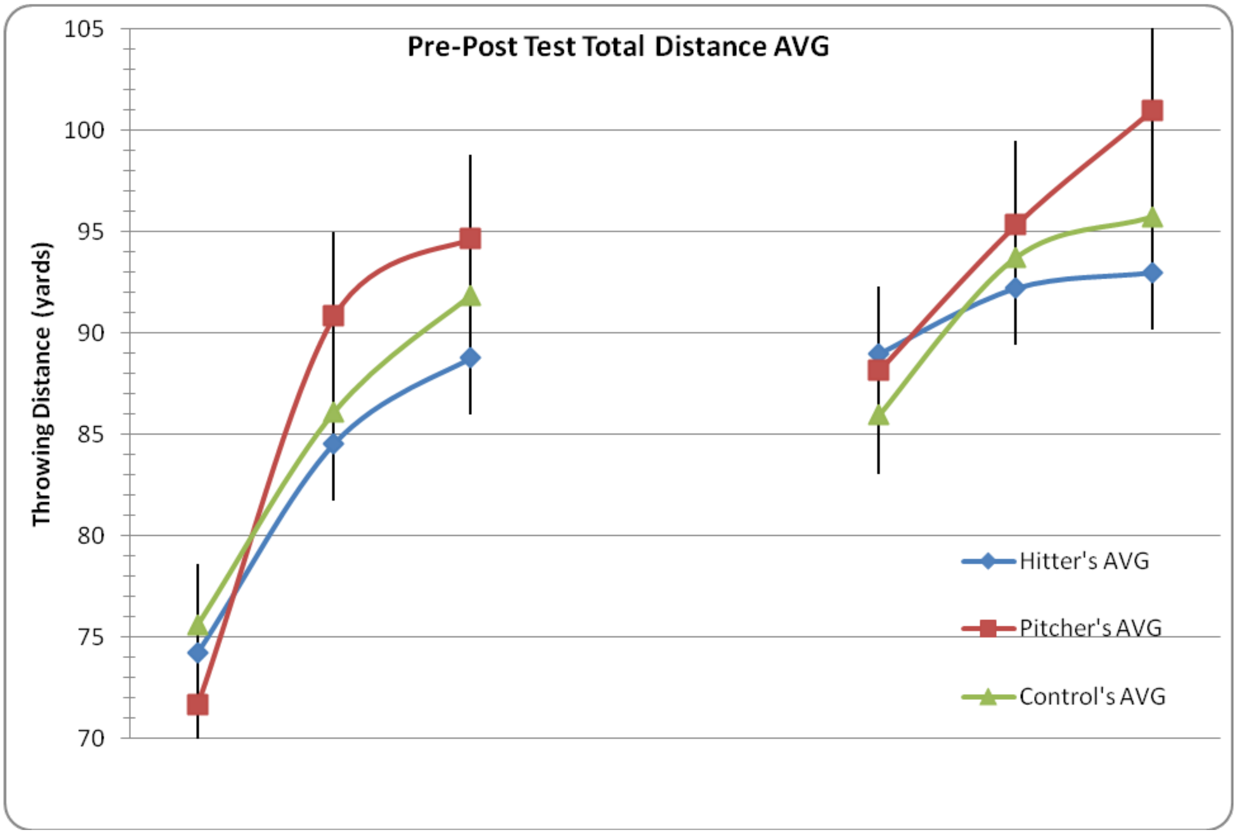

Figure B. Pre-Post Test Total Distance AVG

Note: The data shows similar results to Figure A by displaying an assumable increase in total distance thrown over both pre and post trials. This trend confirms that mass time effect to have statistical significance overall. Another trend noticed across all groups was that post intervention they all decreased in measures of maximum velocity and distance. Again the intervention is being shown as a break between trials.

CHAPTER 5

DISCUSSION

The study's main goal was to elicit an increase in throwing distance and velocity through an eccentric warm-up intervention to the pronator-flexor mass of the elbow. Previous work has suggested a significant correlation between a warm-up of the pronator-flexor mass and distance thrown (Adkins, 2011). Though theoretically supported in the literature, these findings are circumspect since there was no control group to compare against the experimental groups and throwing history was not documented.

Given the athletes' average age in this study was 20.69 years, they have had plenty of time to adapt their throwing techniques. The developmental study done by Roberton et al. (1994) described overhead throwing athletes' adaptations in three levelvs as their experience levels increased. These adaptations showed that most experienced adolescents develop a lag overtime resulting in an increased need for strength provided by the pronator-flexor mass. This was assumable given the participants current activity level and the fact that only one participant had a past history of a surgically reconstructed UCL.

The results of this study indicate a consistent improvement in both distance and velocity across baseline and post-intervention trials for all groups. These may be attributed to several factors. A learning curve is assumable given both experimental and non-experimental groups increased overtime. Normal everyday activities for these participants include a dynamic functional throwing warm-up in practice. So it is likely that the functional warm-up that they perform in practice is proper enough to elicit the responses expected in this study.

The original hypothesis that the experimental groups would increase while the control group would stay the same when comparing baseline to post-intervention velocity and distance values was not supported in this study.

From pre- to post- test the intervention displayed a decrease in all groups. In the intervention groups this decrease could be explained by the fact that the intervention may have been too strenuous or that the duration exceeded the normal capacity of the muscle group. This may have fatigued the muscle, not giving it sufficient recovery time for subsequent trials (Bishop, 2003). In regards to the control group, this time would have served as an inactivity or cool-down period. This cool-down could explain the decrease in total distance thrown and decrease in velocity for the control group.

The literature illustrates the pivotal role that the pronator-flexor mass throughout the phases of the throwing motion (Loftice et al., 2004); however, the intervention in this study may have been too limited to activate these protective effects as measured. Future testing should be done to determine the effect of a similar intervention on pronator-flexor mass strength using isokinetic testing. Another explanation might be that more longitudinal interventions may be essential to elicit these protective effects.

Further consideration needs to be placed on the primary role of the pronator-flexor mass. Primarily, the pronator-flexor mass is the dynamic stability of valgus loads placed upon the elbow during overhead motion resulting in the facilitation of the static stabilizer the UCL. This is synonymous with the relationship between the quadriceps muscle group in relation to the anterior cruciate ligament. Clinically, the signs and symptoms that would implicate pronator-flexor mass injury or UCL would be pain. Future studies should look into the significance of a longitudinal study of the clinical implications overtime using this style of warm-up on those who are suffering from pain and an injury to the pronator-flexor mass.   It may very well be that a study of longer duration may be able to show an increase in throwing distance, velocity and functionality.

Lastly, a focus needs to be placed on the slider pitch as shown in the Lyman et al. (2002) study and its correlation to pain in pitchers' elbows. Future researchers may wish to apply this study's warm-up intervention in a longitudinal design that looks at injury implications. In addition, the relationship of the pronator-flexor mass to pitch type should be examined. This research could advance the literature as well as build a foundation for future studies of the elbow in overhead motion.

Conclusion

If the idea of improving the function of the pronator-flexor mass is found to be statistically significant, it may change the game of baseball forever. Too many times the prevention of musculoskeletal injuries goes overlooked in the total care of athletes. With the inclusion of proper warm-up and strengthening of the pronator flexor mass, it would be possible to improve overall function while preventing injury. Specifically, the improved theoretical relationship between the flexor-pronator group strength and the elbow range of motion, resulting in increased overall valgus stability of the UCL due to an active warm-up , may increase velocity and distance.

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