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An EMG and Video Analysis of the Wrist Flexors during a Sidearm Baseball Delivery

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AN EMG AND VIDEO ANALYSIS OF THE WRIST FLEXORS DURING A SIDEARM BASEBALL DELIVERY

by

Cordell J. Mack
Bachelor of Science in Physical Therapy
University of North Dakota, 1996

An Independent Study
Submitted to the Graduate Faculty of the
Department of Physical Therapy
School of Medicine
University of North Dakota
in partial fulfillment of requirements
for the degree of
Master of Physical Therapy

Grand Forks, North Dakota
May
1997
This Independent Study, submitted by Cordell J. Mack in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Signatures)

(Faculty Preceptor)

(Graduate School Advisor)

(Chairperson, Physical Therapy)
PERMISSION

Title       An EMG and Video Analysis of the Wrist Flexors During a Sidearm Baseball Delivery

Department  Physical Therapy

Degree      Master of Physical Therapy

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ACKNOWLEDGMENTS

As Huck Finn sailed down the river to seek freedom in a new world away from the injustices of the old life, I have nearly reached the end of the old guard. Soon, I will be challenging a new arena with new social injustices to abide, the clinic. The journey over the past three years has been at times frustrating but otherwise compelling.

I would not be here without the special help received along the way. I would sincerely like to thank Sue Jeno, M.A., P.T., for all her guidance throughout the research project. Also, a special individual went above and beyond the duties as a faculty member for this project. The man, Thomas Mohr, Ph.D., P.T., showed exemplary patience in dealing with my often impatient mindset.

After several years of being the professional student, the end may soon be near. A special tribute to my motivation, Mom and Dad. Without your love, I would still be struggling to find my own identity. Thank you.
ABSTRACT

By understanding proper pitching mechanics, therapists can develop better preventative and rehabilitation programs for pitchers. The purpose of this study was to explain the joint motions and muscle activity that occur at the elbow during both an overhand and sidearm baseball pitching delivery. Three healthy adult pitchers with recreational sidearm pitching experience were examined with synchronized high-speed video digitization and surface electromyography (EMG). It was proposed that the increased valgus moment during the acceleration phase due to the sidearm delivery would subsequently show an increase in EMG activity by the wrist flexor-pronator group to provide additional varus torque in minimizing the generated valgus moment.

Results of the study did not indicate an increase in muscle activity of the wrist flexor-pronator group during the acceleration phase of the sidearm throws. However, subject #3 showed altered mechanics during the sidearm throw, and the peak muscle activity was displayed during the cocking phase rather than the deceleration phase. All other throws examined, both overhand and sidearm, resulted in peak muscle activity in the deceleration phase.

Tradition based knowledge passed from one generation to the next speaks of the harmful effects at the elbow with throwing sidearm. However, this study did not support tradition based knowledge, and it showed minimal if any muscle activation patterns which differ from previous literature.
CHAPTER I
INTRODUCTION AND BIOMECHANICS OF PITCHING

Baseball is a highly skilled team sport in which the balance of success is determined by the mix of fielding, batting, baserunning, and pitching. The fielding portion of a game can be controlled by the dominance of a pitcher. A highly skilled pitcher can make the appropriate pitches required for the defense to easily field batted balls. For example, a quality pitcher will keep baserunners to a minimum; therefore, infielders can place maximum attention on the hitter. Through the speed and control of the ball, the pitcher is often directly responsible for the outcome of every game. The biomechanics may vary slightly from pitcher to pitcher, but the common goal among throwers is to retire the batter. The purpose of this research study is to analyze the muscle activity around the elbow of two different biomechanical methods of pitching. The two methods are overhand delivery and sidearm delivery. Due to an increased valgus moment at the elbow during the sidearm throw, it is hypothesized that the wrist flexor-pronator group will show an increase in electromyographic (EMG) activity during the pitching delivery to offset the valgus moment.

The rapid acceleration of the baseball results from a complex series of events involving the entire body. Each pitcher incorporates a certain unique characteristic in their own style, but all pitchers strive to maintain the same basic elements during throwing. The basic element of pitching is the coordination of neuromuscular control
to maintain accuracy, generate velocity, apply spin, and sustain endurance. Anatomical structures are often stretched to the point of physiologic limits during the delivery. This maximal stressing is required to perform at a high level of competition, for instance, in the Major League Baseball Association. Because the physiological limit of tissues are often challenged, the difference between maximal effort of performance and injury is a fine line. For one to fully comprehend the intricacies of pitching and the injuries prevalent among pitchers, the proper biomechanics of throwing need to be understood.

Proper biomechanics during pitching can prove beneficial for all throwers. By understanding the proper and most efficient dynamics of throwing, athletes can improve their performance. With the correct biomechanics, the chance of injury should be kept to a relative minimum. Although individual styles of pitching vary slightly, a study conducted on Major League pitchers demonstrated similar body mechanics during their delivery. The vital component to the mechanics of the delivery is the vertical-horizontal position of the pitching extremity. Because of centripetal force, the arm is free to rotate around the shoulder, and the velocity of the hand is greater when the arm is near vertical. By having the arm extending towards vertical in the overhand mode of delivery, a pitcher is throwing in both the forward and downward plane (fig. 1). The increased vertical angle awards the pitcher a greater mechanical advantage with the throwing extremity reaching greater velocities during the throw. Many successful pitchers have deviated from this vertical or overhand style of delivery. These pitchers have evolved the motion by dropping the throwing
Fig 1.— An illustration of the downward plane showing that the overhand pitcher has the greater advantage of throwing in two planes.
Correct: Ball travels in two planes, forward and down

Incorrect: Ball travels in one plane

Greater angle-advantage to the overhand thrower
extremity away from vertical nearing the horizontal. The horizontal mode of delivery has been termed sidearm.

The sidearm delivery of the baseball is similar to the overhand delivery in all the basic elements, but the throwing extremity is in a different anatomical position during ball release. The horizontal position of the throwing extremity has long been under question with regard to associated medial elbow pathologies. In a study conducted on Ivy League pitchers, Albright et al found the horizontal throwing position places the thrower at a mechanical disadvantage for generating ball velocity. To compensate, a whipping or snapping of the extremity is often utilized to obtain more velocity. Frequently, sidearm throwers open their lead shoulder too soon in hopes of generating an increase in velocity, but the early opening can cause an increase in traction forces across the medial elbow. The traction forces are well documented in the literature as the primary cause of medial elbow pathology.

Both the overhand and sidearm deliveries can be divided into standardized phases consistent throughout the literature. The throw is broken down into components for helping the identification of the mechanics, but the art of pitching is continuous. The deliverance of a pitch is broken down into four phases.

1. Windup
2. Cocking
3. Acceleration
4. Deceleration and Follow-through
Windup

The windup is the initial component of the delivery. It is often quite variable among pitchers, and the individuality of motion often sets two pitchers apart. The basic underlying goal of the windup is to place the pitcher in a sound physiologic position from which to throw. For instance, a right handed thrower will begin the motion facing the target. At the end of the windup phase, the pitcher will have rotated himself perpendicular to the target with his left foot raised in the air. The raised foot will be in a position such that his whole body will be in complete balance. To this point, the thrower has not yet begun to remove the baseball from the glove. This phase expends very little energy, and the raising of the left leg to the balance position provides potential energy to be utilized in the cocking and acceleration phases.

Cocking

The most dynamic phases of the pitching sequence are cocking and acceleration. After the pitcher has reached the balanced windup position, the cocking phase begins with flexion of the support leg. Next, the support leg pushes off the rubber; thus, driving the left leg toward home plate. A vast amount of energy is generated in this phase, and the athlete wants to keep the trunk lagging behind the legs as long as possible so all stored energy can be transferred to the baseball for increased velocity.

The arms become active in the cocking phase by moving apart at approximately the same time the left leg is driven towards the target. With the left foot proceeding forward and the right throwing arm pulling backward, energy is stored for the propulsion of the baseball. The movement of the arms in conjunction with the
synchronization of the body is a highly skilled movement needed for a proper energy transfer to the baseball.  

The next critical event during cocking is the proper orientation of the upper extremity (U/E) upon left foot contact. The left foot or stride foot will land almost directly in line with the back support foot. At this time both shoulders should be abducted approximately 90 degrees with both the leading shoulder and hip rotating towards the target. The throwing arm will continue to rotate back into a position of maximal external rotation (MER). As defined by Feltner and Dapena’s study on the dynamics of the shoulder and elbow joint, MER of the shoulder for proper delivery is approximately 170 degrees. At the time of MER, the throwing extremity is near the physiologic limit of motion, and the internal rotators have been eccentrically loaded and stretched. At this point the internal rotators are capable of providing a great amount of acceleration. The end of the cocking phase and the beginning of the acceleration phase is the point marked by MER prior to forward arm movement.  

**Acceleration**  

Ball velocity is dependent upon all of the prior factors discussed in conjunction with the forward arm acceleration. The acceleration phase begins with the throwing extremity undergoing slight elbow extension. After the onset of elbow extension, the humerus begins to internally rotate at the shoulder. Internal rotation continues with the baseball released at approximately 100 degrees of shoulder abduction. Biomechanics of throwing have indicated approximately 100 degrees of abduction is the appropriate or the most efficient angle to minimize the chance of physical injury.
Within this phase, sidearm throwers differ from the overhand pitchers. The sidearm throwers allow the throwing extremity to approach the horizontal plane. This lowering of the extremity may cause a decrease in the amount of shoulder abduction at the time of ball release. However, some sidearm throwers disguise the true amount of shoulder abduction by laterally tilting at the trunk. The lateral tilt can confuse the novice eye. Although the throwing extremity appears to have decreased shoulder abduction, the lateral tilt maintains the true amount of abduction at approximately 100 degrees consistent with the overhand literature.

Upon release of the ball, the arm continues to horizontally adduct across the body with continued internal rotation and elbow extension. It is the release of the ball that initiates the beginning of the deceleration and follow through phases of the delivery.

**Deceleration and Follow Through**

The arm deceleration and follow through are crucial. Although deceleration cannot improve the quality of throw, it can minimize the risk of injury. The longer the follow through path, the more readily the forces are dissipated. In a textbook release, an overhand pitcher’s right hand will approach his left leg. For a sidearm pitcher, the right throwing extremity ends up near the left hip. Excessive distraction loads can result at the shoulder and the elbow if the thrower follows though toward the target instead of across his body. Understanding the proper biomechanics at the elbow can only occur with a sound anatomical background of the tissues, vessels, and nerves composing the joint.
CHAPTER II
ANATOMY OF THE ELBOW JOINT

The elbow is classified as a uniaxial hinge joint; its primary movements are uniplanar consisting of flexion and extension. The articulations are composed of the distal humerus in conjunction with the proximal ends of the radius and ulna. The joint is composed of three articulations as follows.

1. Humeroulnar: The joint is between the trochlear notch of the ulna and the trochlea of the humerus. The joint is permissive to movement about one axis in elbow flexion and extension.

2. Humeroradial: The joint lies between the capitulum of the humerus and the head of the radius. Joint motion occurs in two axes. Flexion and extension occur around the coronal axis in conjunction with the humeroulnar joint. Also, rotational movement about the longitudinal axis occurs to assist the proximal radioulnar joint in supination and pronation.

3. Proximal radioulnar: This articulation lies between the head of the radius and the radial notch of the ulna. It allows for rotation of the radius around the ulna; thus, it is classified as a pivot joint. The movement of the radius on the ulna is primarily for pronation and supination.

All three articulations are contained within a common fibrous and synovial joint capsule. The walls of the capsule are thin and frail in the anterior and posterior
regions. Weakness can be afforded in these regions due to muscular reinforcement by the brachialis anteriorly and the triceps posteriorly. Both the medial and lateral joint capsule walls are reinforced by the collateral ligaments of the elbow.

The collateral ligaments are thickenings of the fibrous portion of the capsule and serve as the primary static reinforcer. Both the radial and ulnar collateral ligaments have a geometric shape resembling a triangle. The radial collateral ligament arises from the lateral epicondyle of the humerus and distally the fibers intermix with the annular ligament of the radius. The ulnar collateral ligament consists of three bands named anterior, middle, and posterior. The thickest portion of the ligament is the anterior band, and it originates on the medial epicondyle of the humerus and inserts on the coronoid process to the ulna. The middle band is considerably thinner in comparison to the anterior portion. It also originates on the medial epicondyle of the humerus and inserts between the coronoid process and olecranon process of the ulna. Originating behind the medial epicondyle and inserting along the medial edge of the olecranon process is the posterior band. The posterior band is much thicker in comparison to the middle band, but it is not as thick as the anterior band.

The blood supply to the elbow is formed by an anastomosis of three major vessels. The circulation is served primarily by the brachial, ulnar, and radial arteries. In addition, each vessel gives off secondary branches contributing to the extensive circulatory network. The inferior and superior ulnar collateral arteries are secondary branches that arise off the brachial artery just superior to the cubital fossa. The profunda brachii is also a division of the brachial artery which branches off just
inferior to the humeral head. The profunda brachii artery then passes posterior to the humerus and divides into the middle and radial collateral arteries.

The brachial artery bifurcates into the radial and ulnar arteries in the cubital fossa. The radial artery is the smaller lateral branch of the brachial artery, and it gives rise to the radial recurrent artery. The radial recurrent artery will anastomose with the radial collateral artery of the profunda brachii. The ulnar artery is the larger medial division of the brachial artery, and it lies posteromedial to the elbow joint. The ulnar artery gives branches to the anterior and posterior ulnar recurrent arteries. The anterior ulnar recurrent will anastomose with the inferior ulnar collateral artery and the posterior ulnar recurrent artery will eventually anastomose with the superior ulnar collateral artery. The vast network of vessels forming the anastomosis is extremely valuable as the recurrent exchange of blood flow will maintain circulation to the elbow if the usual path of flow is obstructed.

The nerve supply about the elbow joint arises from the four major nerves crossing the junction. The major nerves supplying both motor and sensory to the elbow are the radial, median, ulnar, and musculocutaneous. The radial nerve is derived from the C6, C7, and C8 nerve roots of the brachial plexus. The nerve passes posterior to the elbow flexor musculature on the humerus, and it descends to the lateral epicondyle. The nerve provides motor innervation to the primary elbow extensors and to the wrist extensors. Branches from the radial nerve supply cutaneous innervation to the anterior lower lateral arm and postero-central aspect of the arm and forearm.
The median nerve arises from the brachial plexus with the corresponding nerve roots C5-C8, and T1. The nerve follows a course down the anterior arm where it lies medial to the biceps tendon and brachial artery. The nerve continues to pass distally and innervates the wrist flexor musculature which originates on the medial epicondyle of the humerus. It also innervates the finger flexors and several intrinsics of the hand.

The ulnar nerve arises from brachial plexus nerve roots C8, and T1. The ulnar nerve progresses distally on the medial aspect of the arm until it passes behind the medial epicondyle in the cubital tunnel. The nerve is motor to one and a half muscles in the forearm and several intrinsics of the hand. Jobe points out that length changes in the ulnar collateral ligament during elbow flexion can greatly reduce the available space in the cubital tunnel. Resultant compression injuries of the ulnar nerve arise due to lack of space in the tunnel.

The musculocutaneous nerve originates from the brachial plexus with the corresponding nerve roots of C5-C7. The nerve is motor to the primary elbow flexors. The nerve continues distally as the lateral antebrachial cutaneous nerve which is sensory to the skin over the anterolateral aspect to the forearm.

Movement about the elbow joint is uniaxial; therefore, flexion and extension are the motions which occur at this joint. Hollinshead compares the action at the elbow joint to that of a pulley. Muscle activity of brachialis, biceps brachii, and brachioradialis pull the trochlear notch of the ulna around the trochlea of the humerus during elbow flexion. Elbow flexion is limited by apposition of the soft tissue of the forearm and the arm, tension in the collateral ligaments, and posterior muscle tension.
The triceps are the most active elbow extensor, but the anconeus and gravity assist with the motion. Elbow extension is limited by the bony end range of the olecranon contacting the olecranon fossa of the humerus, tension of the collateral ligaments, and muscle tension from the anterior arm musculature.

The normal anatomical position between the humerus and forearm is not a true 180 degrees. A carrying angle exists between the upper and lower appendage of approximately 15 degrees. The deviation is through the sagittal axis in the frontal plane. The angulation is due to the shape of the articulating surfaces and results in abduction of the forearm in relation to the humerus during elbow extension. The congruency of the trochlea on the humerus and trocheal notch of the ulna allows the forearm to flex into a neutral position, but when extended the trocheal causes a slight lateral deviation of the forearm. The carrying angle is a necessity for clearance of the arms over the hips during arm swing throughout gait.

The normal elbow joint has been previously discussed, but anatomical skeletal maturity also needs to be considered when dealing with prepubescent children. Maturation factors are associated with the appearance of the secondary ossification centers in the ephipysis and subsequent fusion to the diaphysis of the long bone. Primary ossification occurs in the long bones as longitudinal expansion. At later stages, a secondary ossification center arises at the center of each ephipysis. The formation of a secondary center is referred to as an ossific nucleus. Prior to the initiation of secondary ossification, the ephipysis of the long bones is composed of a cartilaginous matrix. The first ossific nucleus to form about the elbow in a young
male is the capitulum at age two, followed by the radial head at age five. The ossific centers continue to enlarge and calcify until they fuse into their respective long bones at age 14 for the capitulum and age 16 for the radial head. The secondary ossification center of the medial epicondyle does not appear in males until approximately seven years of age, and it fuses to the humerus at approximately age 17. The trochlea appears first at the age of eight, and it becomes fused at approximately the age of 13. The appearance, maturational process, and fusion of these centers are important data to understand and consider when evaluating adolescent elbow injuries. A summary of the appearance and fusion in ages of the secondary ossification centers is given in Table 1.8

The ossific nucleus is usually homogenous throughout development up through fusion. Variations in the size or density of the nucleus are usually suggestive of abnormal skeletal development. These variations will likely disrupt the vascular growth and ossification pattern of bony development. Irregular ossification may lead to bony islets or fragmentation, and over time, the irregularities may lead to osteochondritis. Osteochondritis is defined as an inflammation to bone or cartilage.

Repetitive throwing is hypothesized to be one explanation for the unusual ossification patterns seen in adolescents suffering from medial elbow pain.6 Thus, additional research is needed to further verify tensile-force relationships on the immature skeleton. In the interim, pitching adolescents need to be closely monitored to decrease the repeated stress across the elbow joint sustained with the repetitive nature of throwing. Next, a research design was conducted on an adult population to
Table 1.—Ages of Appearance and Fusion for Secondary Ossification Centers About the Elbow

<table>
<thead>
<tr>
<th>Center</th>
<th>Approximate Age of Appearance (Years)</th>
<th>Approximate Age of Fusion (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>Capitulum</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Radial Head</td>
<td>5</td>
<td>4.5</td>
</tr>
<tr>
<td>Medial Epicondyle</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Lateral Epicondyle</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Trochlea</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Olecranon</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>
investigate muscle activity in the wrist flexor-pronator group during a sidearm baseball delivery.
CHAPTER III

METHODS

Subjects

Three University of North Dakota School of Medicine and Health Science students were invited to participate in the research study. All three of the subjects had previous sidearm baseball pitching experience. All participants were informed of the purpose of the study, their rights as human subjects, and were given an opportunity to ask any questions prior to signing the consent form (Appendix A). The study was approved for utilization by the Institutional Review Board at the University of North Dakota project number IRB-9608-012 (Appendix B).

Preliminary Health Screening

All subjects were required to complete a questionnaire of past medical and orthopedic history. Next, a manual exam of both the shoulder and elbow was performed. The exam of the shoulder capsule included the Crank Test, Clunk Test, Posterior Apprehension Sign, and Feagin Test. The elbow was cleared of any instability by Varus/Valgus Stress Test.

Instrumentation

Electromyography

Electromyographic (EMG) signals were recorded from the flexor carpi ulnaris (FCU), the flexor carpi radialis (FCR), the flexor digitorum superficialis (FDS), the
extensor carpi radialis brevis (ECRB), the pronator teres (PT), and the long head of the triceps (T). The motor points of these muscles were found on the R U/E with the use of Respond Functional Stimulation unit. The skin was prepped with alcohol prior to the attachment of the electrodes. The electrodes (Multi Bio-Sensors, El Paso, TX, 79913), coated with pre-gelled adhesive, were then attached to the skin over the motor points. The electrodes were connected to a transmitter strapped around the subjects non-throwing shoulder. The transmitter then telemetered the electrical activity of the muscles to the Peak computer system for calculation of muscle activity.

The electromyographic data was collected using a Noraxon Telemyo8 telemetry unit (Noraxon USA, 13430 North Scottsdale Rd., Scottsdale, AZ, 85254). The telemetried information from the EMG electrodes was collected by a Noraxon Telemyo8 receiver and then digitized by an analog to digital interface board installed in the Peak Analog Sampling Module (Peak Performance Technologies, 7388 S. Revere Parkway, Suite 601, Englewood, CO, 80112-9765). The digitized EMG signals were analyzed using the Peak Motus software package. The electromyographic data was synchronized with the video data using the Peak Event Synchronization Unit. To start the EMG data collection, the synchronization unit was triggered by a manual switch and EMG data was collected for a period of 10 seconds with a sampling frequency of 1080 Hz.

**Cinematography**

The entire pitching event was captured on film by four cameras at a speed of 60 Hz. The cameras used to film the motion were Peak High Speed Video 60/120 Hz
cameras (Peak Performance Technologies, 7388 S. Revere Parkway, Suite 601, Englewood, CO, 80112-9765). The video information was subsequently recorded on tape using N JVC Model BR-S378U video cassette recorders (JVC of America, 41 Slater Drive, Elmwood Park, NJ, 07407). To synchronize the video information, the cameras were genlocked together and a time code was recorded on the video tape using NISMPTE time code generators.

After recording the subject’s movements, the video taped data was analyzed using the Peak Motus Software. A Sanyo Model GVR-S955 (Sanyo, 1200 W. Artesia Blvd., Compton, CA 90220) video cassette recorder was used to play back the video for digitization.

The video was synchronized with the EMG data to relate specific joint angles with the associated muscle activity. At any specific moment during the pitching delivery, the synchronization showed which muscles were contracting and the magnitude of the firing patterns. For appropriate timing between the EMG and video, a synchronization frame was filmed prior to any subject testing. This synchronization frame served as the marker for which all joint angles were calculated in the analysis. The frame designated a coordinate system to plot all points in space as (X,Y,Z). The Peak Event Synchronization Unit (ESU) synchronized the incoming analog EMG activity with the video based upon a manually set time mark prior to any subject motion. Setting the time mark places a mark on the video screen signifying the start of EMG collection.
Anatomical landmarks were marked with reflective balls to allow joint angles to be captured on video. Participants were asked to remove their shirts and wear lycra shorts to aid in the placement of the markers. The subjects were marked bilaterally as follows: tip of acromion; lateral epicondyle of humerus; radial styloid; greater trochanter; head of fibula; lateral malleoli; and PSIS. The spine was also marked at the spinous process of T7 and the sacrum. These landmarks were electronically digitized with each landmark given a \((X,Y,Z)\) coordinate which was based upon the standardized synchronization frame. Electronic digitization of the reflective markers and subsequent reference to the synchronization frame allowed for specific joint angles to be calculated throughout the pitching delivery.

Data Collection

Following the completion of the Preliminary Health Screening, the subjects were instructed on the procedure of the experiment. They were told that upon command they would perform two overhand pitches followed by two sidearm pitches. The subjects were given ample warm up time before and after attachment of the EMG leads and reflective markers. This time allowed the subjects to become accustomed to throwing with the attachments.

The EMG and video data were collected during each pitch. The subjects listened to the command “relax,” at which time the time mark was depressed. Following, a command of “begin” the subject initiated and completed the throw. After the setting of the time mark, EMG activity was recorded for a 10 second duration surrounding the
pitching delivery. Data collection continued until each subject had performed two overhand and sidearm deliveries.

When the data collection was concluded, the electrodes and reflective markers were removed from the subject's body. The skin was cleaned with alcohol and this concluded their participation in the study.

Data Analysis

Video footage for each trial was calibrated to meters, cropped to the specific pitching sequence, and digitized using the Peak Motus system. Calculation of joint angles was performed, and reports generated to show stickman-figure representations of the motion, relative range of motion curves, and integrated EMG activity of the pitching sequence.

Descriptive statistics were employed to compare EMG activity between the overhand and sidearm pitching deliveries within the same subject. Normalization of the specific pitching events was achieved by specified anatomical occurrences previously discussed.
CHAPTER IV

RESULTS

Analysis from the second pitching trial was performed for both the overhand and sidearm deliveries for each subject. Results of the integrated EMG activity are shown in figures #2, #3, #4 for subject #1, subject #2, and subject #3, respectively. Relative ROM measurements are shown in figures #7, #8, #9 for each subject, respectively.

Results of the study show similar patterns of muscle activity in the overhand mode of delivery consistent with previous literature. For the sidearm delivery, it was hypothesized that an increase in muscle activity across the medial elbow would result from the increased valgus stress moment generated at the elbow during the acceleration phase. The findings across all subjects refute the original hypothesis. During the acceleration phase of the sidearm delivery, the EMG activity of the examined musculature was relatively silent which is consistent with the activity during the acceleration phase of the overhand delivery.
Fig 2.— Integrated electromyographic (EMG) activity of Subject #1. The vertical lines separate the specific pitching events. A, Overhand; B, Sidearm.
Fig 3.— Integrated electromyographic (EMG) activity of Subject #2. The vertical lines separate the specific pitching events. A, Overhand; B, Sidearm.
LEGEND:
W=Windup phase
C=Cocking phase
A=Acceleration phase
D=Deceleration phase
Fig 4.— Integrated electromyographic (EMG) activity of Subject #3. The vertical lines separate the specific pitching events. A, Overhand; B, Sidearm.
LEGEND:

W=Windup phase
C=Cocking phase
A=Acceleration phase
D=Deceleration phase
Fig 5.— Relative joint angles for Subject #1. The vertical lines separate the specific pitching events. Right shoulder abduction and external rotation calculated by
(180 degrees - degrees shown on figure) = anatomical Range of Motion (ROM). Right lateral trunk flexion as shown. A, Overhand; B, Sidearm.
R SHOULDER ABDUCTION

LEGEND:
W=Windup phase
C=Cocking phase
A=Acceleration phase
D=Deceleration phase

R LATERAL TRUNK FLEXION

R SHOULDER EXT. ROTATION

LEGEND:
W=Windup phase
C=Cocking phase
A=Acceleration phase
D=Deceleration phase
Fig 6.— Relative joint angles for Subject #2. The vertical lines separate the specific pitching events. Right shoulder abduction and external rotation calculated by (180 degrees - degrees shown on figure) = anatomical Range of Motion (ROM). Right lateral trunk flexion as shown. A, Overhand; B, Sidearm.
LEGEND:
W=Windup phase
C=Cocking phase
A=Acceleration phase
D=Deceleration phase
Fig 7.— Relative joint angles for Subject #3. The vertical lines separate the specific pitching events. Right shoulder abduction and external rotation calculated by \((180\text{ degrees} - \text{degrees shown on figure}) = \text{anatomical Range of Motion (ROM)}\). Right lateral trunk flexion as shown. A, Overhand; B, Sidearm.
LEGEND:
W=Windup phase
C=Cocking phase
A=Acceleration phase
D=Deceleration phase
CHAPTER V
DISCUSSION

This study found that there was no appreciable increase in EMG activity across the medial elbow for any of the participants during the acceleration phase of the sidearm delivery. Therefore, the anticipated increase in varus torque across the elbow was not evident. It was hypothesized that an increase in muscle activity of the medial forearm musculature would result in an increased varus torque to counteract the increased valgus moment generated during the sidearm throw.\textsuperscript{11}

The ulnar collateral ligament (UCL) is the primary structure contributing to the varus torque, but preliminary cadaveric work by Werner\textsuperscript{11} et al indicated that the UCL is not strong enough to withstand the valgus moment by itself. Thus, it is believed that contraction of the wrist flexor-pronator group, which originates on the medial epicondyle, also contributes to the varus torque. Findings from this study did not support the above theory.

Findings from all the subject's overhand throws were consistent with previous literature in both biomechanics and EMG activity at the elbow. Because the overhand deliveries were consistent with previous literature, the sidearm throws were compared to the overhand in both biomechanics and muscle activation. The EMG and biomechanics were analyzed according to the phases of the pitching motion.
Wind-up

In this phase, all subjects placed themselves in a sound physiologic position from which to throw. Wind-up ended with all subjects removing their right hand from the glove and the left front leg striding towards the target. Minimal EMG activity was present throughout this phase for all subject.

Cocking

Cocking is the phase through which a vast amount of potential energy is stored for subsequent propulsion of the baseball in the acceleration phase. Significant events in this phase are left foot contact and maximal external rotation (MER) of the shoulder.

Subjects #1, #2, and #3 showed similar kinematics and muscle firing patterns in this phase for the overhand delivery. All subjects reached a peak of MER in the overhand delivery of approximately 170 degrees. As defined by Feltner and Dapena’s study on the dynamics of the shoulder and elbow joint, MER of the shoulder for proper delivery is approximately 170 degrees. All subjects showed relatively moderate amounts of EMG activity throughout this phase in both types of deliveries. Subject #2 and #3 showed a near peak of muscle activity in the ECRB late in this phase just prior to the onset of the acceleration phase. This increase in the wrist extensor activity is due to the positioning of the wrist for propulsion of the baseball. It is unknown as to why subject #1 did not exhibit similar muscle activation, but video analysis revealed the subject’s wrist to be extended and cocked. This position of the wrist is consistent with subject #2 and #3, and it allows for a proper
transition into acceleration. Subject #1 also showed an increase in triceps activity in the overhand delivery. This occurrence remains unexplained.

Subject #3 differed in pitching mechanics from subjects #1 and #2 in the sidearm delivery. Both subjects #1 and #2 showed similar kinematics in this phase with both subjects reaching approximately 160 degrees MER. Subject #3 displayed a very different muscle firing pattern in the sidearm delivery as compared to subjects #1 and #2. The participant exhibited peak muscle activity for all tested musculature during this phase, whereas subject #1 and #2 showed moderate amounts of EMG activity during the sidearm delivery. The amount of muscle activity demonstrated by subject #1 and #2 is consistent with previous overhand literature for this phase.

The examined kinematics of subject #3 show 155 degrees MER, but further investigation revealed an alteration of pitching mechanics early in the delivery. Proper biomechanics during the cocking phase have the arm lagging behind the trunk to generate potential energy for acceleration. In cineotomagaphic analysis of the subject’s sidearm delivery, the participant failed to properly rotate his shoulders away from the target. This differs noticeably from the overhand throw where the shoulders rotate 90 degrees away from the target to provide a sound physiologic position from which to begin arm cocking. Subject #1 and #2 biomechanics of the sidearm delivery almost mimic the overhand delivery, and neither subject shows an alteration of muscle firing. Dillman et al stated the importance of rotating the body away from the target is to generate potential energy and reach a balanced position from which to begin the dynamics of propelling a baseball. This failure to rotate the shoulders early in the
motion caused an early opening of the left shoulder in this phase. This early opening could have led to an increased valgus moment at the elbow. The medial forearm musculature would have increased their activity to enhance the varus torque needed to offset the generated valgus moment. This is why the EMG activity of the wrist flexor-pronator group may have been at a peak during this phase for subject #3.

**Acceleration**

The arm acceleration phase was a dynamically short time frame marked from MER to ball release. In this phase, the stored potential energy from the trunk and hips are transferred to the throwing extremity. Because of the energy transfer in conjunction with the shoulder capsule being released like a coiled spring due to the MER, the acceleration phase had relatively little muscle activity across all subjects in both the overhand and sidearm deliveries. This lack of muscle activity is consistent with previous literature regarding the lack of muscle activity in forearm musculature during this phase. In a study conducted on collegiate pitchers, Jobe¹⁰ et al found this phase to be relatively silent in wrist flexor-pronator muscle activity.

Research has shown that acceleration of the arm is enhanced by internal rotator activity at the shoulder. Bassett¹³ et al had shown the pectoralis major and latissimus dorsi can potentially generate the large internal rotation torque needed to generate the vast angular velocity during acceleration. This study did not target the internal rotators, but it is expected that they would have shown moderately high levels of muscle activity in this phase.
All subjects displayed similar biomechanics in their deliveries in this phase. In the overhand delivery, all subjects released the baseball with approximately 115 degrees of shoulder abduction. In the sidearm delivery, the participants exhibited a slight decrease in shoulder abduction at the time of ball release. Also, right lateral trunk flexion was measured to give credibility to shoulder ROM measurements. Many sidearm throwers will laterally tilt at the trunk; thus, the true amount of shoulder abduction is maintained at approximately 120 degrees. All subjects had their trunk at approximately 90 degrees at the time of ball release with 95 degrees of shoulder abduction in the sidearm deliveries.

Overall, findings from this phase refute the original research question. No increase in muscle activity was found in the wrist flexor-pronator musculature across the medial elbow in the sidearm throws in comparison to the overhand deliveries.

**Deceleration**

This phase begins with ball release and ends when the arm has reached maximum internal rotation. The purpose of this phase is to dissipate the energy generated in the cocking and acceleration phase. All subjects showed peak muscle activity in the ECRB, T, FCR, FCS, PT, and FCU in the overhand delivery. This high muscle activity in the musculature of the more distal joints is reasonable, since the smaller, more distal joints would have significant kinetic energy to dissipate, and the literature shows peak muscle activity occurs in the deceleration phase for the overhand delivery. The sidearm delivery had EMG findings consistent with the overhand literature for subject #1 and subject #2. As previously discussed, subject #3 displayed peak muscle
activity in the cocking phase rather than deceleration. The subject’s altered biomechanics during the sidearm delivery may have resulted in minimal EMG activity during this phase.

Upon completion of this research study, there are several variables that accounted for increased difficulty in the data collection and analysis. First, the lighting in the laboratory was not adequately controlled during the data collection. The excess light from the windows caused significant difficulty upon automatic digitization of the anatomical landmarks. Camera #2 was placed in a sagittal orientation in reference to the participants. The light beaming from the mount of the camera caused a glare off the subjects’ bodies which posed an additional difficulty with digitization. Also, the Peak Motus software system used for analysis was the first version of the software package on the market. As a result, many software problems occurred when transferring between files.
CHAPTER VI
CONCLUSION

In this study, the biomechanics of pitching were presented and explained. The altered mechanics of throwing sidearm was compared to the overhand delivery in both joint motion and muscle activity. The differing biomechanical factor of the sidearm delivery is the throwing extremity approaching the horizontal plane.

Results of the study indicate the sidearm delivery to be very similar in biomechanics and EMG activity to the overhand delivery in the small adult population studied. All overhand pitches studied displayed muscle activation patterns consistent with previous literature. Both subject #1 and #2 showed EMG findings in the sidearm pitches similar to the muscle activity in the overhand deliveries. Subject #3 showed an alteration in the mechanics of his sidearm delivery which may have caused a resultant change in the EMG pattern.

Subject #3 displayed a failure to rotate his body 90 degrees away from the target during the wind up phase which may have caused an alteration in muscle activation patterns. This failure of proper shoulder rotation may have caused the left lead shoulder to open early during the delivery. The early opening may have resulted in an increased valgus moment at the elbow in the cocking phase which would explain the peak EMG activity recorded in the wrist flexor-pronator group during the phase. The increase in muscle activity would help the UCL with providing a subsequent increase
in varus torque needed to offset the valgus moment. The reasons for the subject’s altered mechanics in the sidearm delivery remain unexplained.

All other sidearm pitches revealed peak muscle activity during the deceleration phase. This finding challenges the original research hypothesis. It was theorized that an increase in muscle activity would occur in the wrist flexor-pronator group during the acceleration phase of the sidearm delivery due to the increase valgus moment. Analysis of all the sidearm throws reveal no appreciable increase in EMG activity during the acceleration phase. The peak muscle activity displayed in the deceleration phase in consistent with the literature of an overhand delivery for muscles of the distal joints.

The ability to pitch effectively requires proper mechanics. Improper mechanics may lead to altered performance or an increase in the physical risk of injury. Coaches, trainers, and health professional must understand the proper dynamics of throwing in minimizing the chance of injury. This can only be done if training protocols include the attainment of sufficient muscle strength and stamina required for throwing several pitches. Based on this study, throwing sidearm with the proper mechanics may not be harmful in the adult population. However, the number of innings pitched per week, pitches per outing, and types of pitches thrown should be monitored and enforced at an acceptable level in order to avoid overuse syndromes at the elbow.

Future studies are needed to determine 1) the muscle activation patterns in adolescents prior to secondary ossification at the medial elbow, 2) if similar findings would occur in competitive sidearm throwers, and 3) if the improper biomechanics that
some sidearm throwers may exhibit lead to altered muscle recruitment across the medial elbow.
INFORMATION AND CONSENT FORM

TITLE: An EMG analysis of the elbow and wrist flexors during a sidearm baseball pitching delivery.

You are being invited to participate in a study conducted by Cordell Mack, a physical therapy student at the University of North Dakota. The purpose of this study is to analyze the EMG muscle activity patterns at the elbow and wrist during a sidearm pitching delivery. From the study, we hope physical therapists will be able to construct injury prevention strategies for those pitching from an extreme sidearm position.

You will be asked to perform a total of six pitches for the experiment. Three of the pitches will be standard overhand, and the other three will be sidearm. The speed of each pitch will be taken with a JUGS recorder. All pitches will be videotaped for synchronization with the EMG unit.

The study will take approximately one hour of your time. You will be asked to report to the Physical Therapy Department at the University of North Dakota at an assigned time. You will then be asked to change into spandex shorts for the experiment. We will first record your age, gender, height and weight. During the experiment, we will be recording the amount of muscle activity you have when pitching the baseball.

Although the process of physical performance testing always involves some degree of risk, the investigator in this study feels that the risk of injury or discomfort is minimal. In order for us to record the muscle activity, we will be placing six electrodes on your elbow and forearm. Before we can apply the electrodes, we will use a small stimulator to electrically stimulate the muscles to locate the best spot to place the electrodes. The stimulator will cause a mild tingling sensation. The recording electrodes are attached to the surface of the skin with an adhesive material. We will also attach reflective markers to various bony landmarks to allow the video to measure joint angles. These devices only record information from your muscles and joints, they do not stimulate the skin. After we get the electrodes attached, we will give you a brief training session to teach you how to throw with the appendages.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection to this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only by the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his/her health. Your decision whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota.
If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigator involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Cordell Mack at (701) 775-5526. A copy of this consent form is available to all participants in the study.

In the event that this research activity (which will be conducted at the Physical Therapy Department at the University of North Dakota) results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow-up care as it is to member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payment, if any.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this study explained to me by Cordell Mack, SPT.

Participant’s Signature  Date

Witness (not the scientist)  Date
APPENDIX B
ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.

 Tradition based knowledge passed from one generation to the next speaks of the harmful effects at the elbow with throwing sidearm. Past studies have analyzed EMG data from both shoulder and elbow musculature for the normal overhead baseball pitching delivery. In these studies, an attempt was made to correlate muscle activity patterns with pathologies associated with throwing. The sidearm delivery has not been subjected to the same type of EMG investigations. The purpose of this study is to analyze the EMG muscle activity patterns at the elbow and wrist during a sidearm pitching delivery. Approximately five young adults ages 18-35 with no history of orthopedic problems at the elbow/wrist will be voluntarily recruited for the study. EMG data will be recorded from elbow and wrist musculature during overhead and sidearm deliveries. Video analysis will be recorded to synchronize timing of the phases in the delivery with the EMG recordings. Statistical analysis of these data will be conducted to determine the level of muscle activity during the deliveries. The use of human subjects is necessary because clinically based results are directly applicable to injury prevention in baseball pitchers.
PLEASE NOTE: Only information to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate, attach sections from your proposal (if seeking outside funding).

2. PROTOCOL: (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

Approximately five adult males with previous sidearm baseball pitching experience will be used as subjects. All will be free of any orthopedic problems at the shoulder and elbow/wrist. Subjects will be tested for ligamentous instability, and only those clear of laxity will participate in the study. Subjects will be informed of purpose of study, their rights as human subjects, and will be given an opportunity to ask questions prior to signing the consent form.

Electromyographic (EMG) signals will be recorded from the flexor carpi ulnaris (FCU), flexor carpi radialis (FCR), flexor digitorum superficialis (FDS), extensor carpi radialis brevis (ECRB), pronator teres, and long head of the triceps. EMG activity will be recorded through surface electrode placement. Placement of electrodes will be targeted over muscle motor points found by the Respond Functional Stimulation unit. Each subject will wear a FM placement belt pack which will relay the information. The telemetered raw EMG will be integrated by computer and saved on diskette for later retrieval and review.

Utilizing a resting signal as baseline and a five second Maximal Voluntary Contraction (MVC) elicited by the means of manual muscle testing the data will be processed by computer to achieve our relative MVC. Activity patterns of the pitching sequence will yield EMG data in each muscle tested. This activity will be expressed as a percentage of the MVC.

Video analysis will be synchronized with EMG to relate specific joint angles to amount of activity recorded throughout the event. Joint angles will be measured with the use of reflective balls taped to specific locations as follows: lateral epicondyle; medial epicondyle; tip of acromian process; longitudinal placement on wrist flexor bellies and biceps brachii belly; bilateral PSIS; spinous process of L3 and T8; and bilateral greater trochanters. Each subject will be asked to perform a full windup with both a traditional delivery and a sidearm delivery. Only pitches thrown entering an established strike zone and competitive MPH as measured by a JUGS radar gun will be utilized for analysis. The video will divide the throwing into four distinct stages defined by the following:

1. Wind-up: Early activity controlled by flexion of the U/E and torso with both hands holding the ball.
2. Cocking: A period of placing glenohumeral muscles to extreme limits of external rotation (ER). It originates as the ball is taken out of the baseball glove and ends when maximum ER of the shoulder occurs. Contact of the leading foot divides this stage into early and late phases.
3. Acceleration: Initiated from position of maximum ER of shoulder and proceeds until ball release with ball propelled towards the target.
4. Follow-through: The final component of throwing. It is characterized by deceleration in conjunction with maximal humeral internal rotation (IR).
3. **BENEFITS:** (Describe the benefits to the individual or society.)

As a result of the study, new and viable information will be available concerning medial elbow throwing injuries. An EMG study replicating the actual delivery sidearm pitchers utilize will give insight to the amount of muscle activity associated with the extreme joint positions needed to perform the task. From the data, Physical Therapists will be able to construct injury prevention strategies and expand the study to a larger sample size with varying age groups.

4. **RISKS:** (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject’s dignity and self-respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

The possible physical risks for the study are minimal. Slight discomfort is possible with the finding of motor points utilizing the Respond unit. Minor skin irritation could result from electrode placement. All subjects will not be exposed to any other risks not mentioned besides the normal risks taken by pitching a baseball. All subjects will be instructed on proper warm-up and stretching prior to participation.
5. **CONSENT FORM:** A copy of the CONSENT FORM to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no CONSENT FORM is to be used, document the procedures to be used to assure that infringement upon the subject’s rights will not occur.

All copies of consent forms will be secured for a two year period by Sue Jeno, MA, PT at the University of North Dakota, (701)-777-2831.

6. For **FULL IRB REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development  
University of North Dakota  
Box 8138, University Station  
Grand Forks, North Dakota  58202

On campus, mail to: Office of Research & Program Development, Box 134, or drop it off at Room 101 Twamley Hall. For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University’s policies and procedures governing the use of human subjects.

**SIGNATURES:**

Principal Investigator

DATE: ____________________

Project Director or Student Adviser

DATE: ____________________

Training or Center Grant Director

DATE: ____________________

(Revised 8/1992)
REFERENCES


