COMPARISON OF ULNOHUMERAL JOINT SPACE, ULNAR COLLATERAL LIGAMENT WIDTH, AND ABNORMALITY IN COLLEGIATE BASEBALL PLAYERS USING MUSCULOSKELETAL ULTRASOUND

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ABSTRACT

The purpose of this thesis is to examine the difference in ulnar collateral ligaments (UCL) between pitchers and position players in collegiate baseball players. Differences were found using musculoskeletal ultrasound and each had both the dominant and non-dominant arms examined. The following research questions guided this study: Is there a difference in ulnohumeral joint space between pitchers and position players, is there a difference in UCL width between pitchers and position players, and is there a difference in the amount of damage to the UCL between pitchers and position players? Both pitchers and position players were found to have changes when compared to their non-dominant side. Position players were found to have significantly wider ligaments than pitchers, which may suggest a difference in forces placed on the elbow. This study introduces ideas that will lead to future research to confirm this data.

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CHAPTER I. INTRODUCTION

Research was recently conducted that showed the number of days major league players are spending on the disabled list is increasing.[1] Pitching injuries accounted for 56.9% of the total number of days on the disabled list.[1] In general, this is because pitcher injuries are more severe, or require more time to recover from injuries. A large percentage of those injuries involve the ulnar collateral ligament (UCL) of the elbow. Erickson et al.[2] found that pitchers were returning to their previous level of competition after Tommy John surgery (UCL reconstruction) in an average of 20.5 months. This is a significant proportion of time considering the MLB season lasts only 6 to 7 months. Baseball pitchers are more prone to UCL injuries due to the forces placed on the elbow during throwing. Forces on the elbow can be as much as 290 newtons.[3,4] The UCL has been shown to resist an average of 33 newtons per meter before tearing. The surrounding muscles and bones usually absorb this deficit, but if that force is too much for the UCL to withstand, then injury will occur.[3,4]

Chronic throwing also causes damage to the UCL or surrounding structures. Ligament thickening and calcifications have been found to be more common in pitching arms when compared to their non-pitching arms in asymptomatic major league baseball players.[5] These results have been consistent in some studies[5,6] however, very few studies have compared pitchers and position players. Position players are not commonly studied because of the limited number or injuries to their elbows. However, if similar damage to the ligament occurs then the problem comes from throwing and not just pitching. The amount of force position players use to throw a ball is similar to pitchers, but the frequency of throws is significantly decreased.

The use of diagnostic or musculoskeletal ultrasound has dramatically increased over the last decade and have used it to aid in their diagnosis of soft tissue injuries in athletes.[7–9] A diagnostic ultrasound is non-invasive, cost effective, mobile, and faster than most other diagnostic imaging modalities.[8,10] This allows clinicians to provide immediate analysis of an injury and increase the quality of care. Multiple studies have set out to examine its efficacy in diagnosing ulnar collateral ligament sprains and abnormalities in baseball players.[5,6,10–13] These studies have shown some increases in damage to the UCL in professional and amateur pitchers.

With the increase in elbow injuries in baseball players, research needs to investigate the causes of injury. By identifying the populations that are at more risk for UCL tears, players, coaches, doctors, athletic trainers, and parents can help to limit the rise in injury rates.

Statement of the Problem

No study has compared pitchers to position players in baseball to identify differences in the UCL. Many studies[4–6,12] have examined pitchers, but position players have been left out of the research because of decreased injury rates to the elbow. However, it is not clear if similar changes occur in position players as well. If pitchers experience more significant changes to their UCL then pitching results in more UCL damage and creates more stress on the joint then simply just the act of throwing. Ulnohumeral joint space, UCL width, and damage of the UCL will be evaluated using musculoskeletal ultrasound.

Purpose of the Study

The purpose of this study was to examine the difference in the UCL between pitchers and position players. It identified baseball athletes that have developed damage to the UCL in the dominant throwing elbow and compared the amount of damage to their non-dominant arm

Research Questions

1. Is there a difference in ulnohumeral joint space between pitchers and position players?
2. Is there a difference in UCL width between pitchers and position players?
3. Is there a difference in the amount of damage in the UCL between pitchers and position players?

Definition of Terms

Ultrasound (Sonography) – An imaging method that uses high-frequency sound waves from a probe to create dynamic images within the body. Frequencies can range from 5-20 MHz.[8,9]

Echogenicity – Capacity of a structure to reflect back sound waves[9]

Hyperechoic – High reflective pattern that appears brighter than surrounding tissue[9]

Hypoechoic – Low reflective pattern that appears darker than surrounding tissue[9]

Anechoic – No reflective pattern that will appear black in the image[9]

Ulnar Collateral Ligament (UCL) – Three banded structure with most forces transmitted through the anterior band. It connects the medial epicondyle of the humerus to the trochlea of the ulna. The ligament provides partial protection from valgus stress on the elbow and is aided by the medial musculature.[14]

Valgus Stress Device – A device that applies a measured force from the lateral side of the elbow causing the medial elbow joint to open and stretch the UCL making it taut. It can provide a standard force and repeat the same force for each participant.[15]

Importance of the Study

This study provided ulnohumeral joint space, UCL width and level of damage (number of calcifications) measures of the UCL for all participating athletes. This information can be used as baseline data for a future research to use when discovering risk factors for elbow injury. If the data shows that both pitchers and position players suffer from similar amounts of damage, the research can focus on finding a way to identify risk factors for all baseball players and finding ways to reduce this risk. If only pitchers are found to have significant changes to their UCL ligament, this study can add more data to the assumption that pitching causes damage to the UCL. This can help identify predictors and signs that a major elbow injury may be imminent.

Limitations

1. Athletes had varied levels of experience when compared to other athletes in their same sport.
2. Athletes with prior injury to the elbow might not have reported injury
3. The examiner had limited experience with diagnostic ultrasound.

Delimitations

1. Athletes were chosen only if they have had no prior surgery to the elbow.
2. Ambidextrous athletes were not allowed to participate.
3. Athletes were from a NCAA Division I baseball program.

CHAPTER II. LITERATURE REVIEW

The purpose of this study was to examine the difference in ulnar collateral ligaments (UCL) between pitchers and position players. In addition, this study identified baseball athletes that have developed changes to the UCL ligament in the throwing elbow and examine the amount of damage that has occurred when compared to their non-throwing arm. The following research questions guided this study: Is there a difference in UCL length between pitchers and position players, is there a difference in UCL width between pitchers and position players, and is there a difference in the amount of damage to the UCL between pitchers and position players? The review of literature is organized into the following areas: pitching injury rates, the ulnar collateral ligament, throwing, and musculoskeletal ultrasound.

Pitching Injury Rates

When players miss games due to injury, not only does the team suffer performance wise, but the league can also lose revenue if the player is among the elite in the league. To help teams put the best team they possibly can on the field, research has focused on identifying and examining injuries and their cause so that they can prevent them in the future. Research was recently done that showed the number of days major league players are spending on the disabled list is increasing.[1] In 1989, the average disabled list days per team was 571.9. Eleven years later this number had risen to 787.1 days per team. That's a difference of just over 200 total days per team. The major league regular season only lasts for 180 days. However, it is not clear if the average number of days on the disabled list per team has risen or dropped in the years since this study.

Pitching injuries accounted for 48.4% of all disabled list reports and 56.9% of the total number of days on the disabled list.[1] Pitchers make up about half of the players on the disabled list, and also spend more time on the list than position players. This could be because the injuries to pitchers are more severe, or because pitchers require more time to recover from those injuries.

Over the last 5 years of the study, data was gathered by anatomical region as well.[1] The only area in which the frequency of injuries consistently increased over the 5 years was elbow injuries. Pitchers are the most likely to suffer from elbow injuries due to the repetitive forces placed on the elbow. A large percentage of those injuries involve the ulnar collateral ligament of the elbow.[1] When the ligament is torn, surgery is almost always required if the athlete wishes to continue throwing.[2,16,17] Multiple studies[2,16–19] have examined outcomes in pitchers after UCL reconstruction surgery. A general consensus between multiple research studies is that 80-90% of athletes returning to baseball who undergo UCL reconstruction are performing at least as well, if not better, than they were prior to their injury.[2,16,17] These studies report that most pitchers return to pitching consistently in a game in just under a year.[16,17] This is a significant proportion of time considering the MLB season lasts only 6 to 7 months and almost all levels of baseball below the MLB have shorter seasons.

The Ulnar Collateral Ligament

The UCL is the main stabilizer preventing valgus force in the elbow.[14] Baseball is a specific sport that puts large amounts of force on this ligament.[10] The ligament has three different bundles, the anterior band, the transverse band, and the posterior band. While they all play a role in medial sided elbow stability, the anterior band is the main stabilizer during throwing. This is also the portion of the ligament that is most commonly torn by baseball players.[2–4] The ligament attaches on the medial epicondyle and ends on the medial coronoid margin. Timmerman and Andrews[14] found an average width and thickness of the anterior band at 6mm and 4-8mm, respectively. They also reported that the ligament consists of two layers. The first is contained between the capsule walls and the second on the outside of the capsule with connections to the wrist flexor muscles. These two layers help strengthen the joint and prevent injury.[14]

Massive amounts of forces are transmitted through the elbow from throwing a baseball.[3,20,21] In 30-40 milliseconds, the elbow extends from 125 degrees of flexion to 25 degrees of flexion and produces an average angular velocity of 2300 degrees per second. The amount of force translates to around 290 Newtons.[3] These large amounts of force put a lot of stress on the UCL of the elbow, which is a major stabilizer of the medial side of the elbow. When the forces exceed the tensile force of the UCL ligament, it can tear and disable a pitcher's arm.

The UCL is not designed to take all of the stress created by throwing, therefore the surrounding structures must activate to protect the ligament. Chronic irritation and use of the ligament can lead to micro-tears or other dysfunctions. Especially in youth athletes, overuse can lead to fractures of the medial epicondyle, and lead to the formation of calcified bodies in the tissue.[12] Chronic injuries can also develop due to the amount of throwing that any baseball player does. Micro-tears in the ligament can create a chronic weakness and increase the risk of a complete rupture in the future.[5] This repetitive throwing also leads to lengthening of the ligament causing increased joint laxity when compared to the non-throwing arm.[4] Also, the repeated stress can cause bony hypertrophy at the attachment sites and may lead to fragmentation in the superficial joint space.[22] Multiple studies have shown that baseball players experience a lengthening of the UCL on their throwing arm when compared to their non-throwing arm.[5,6,13] Nazarian et al.[5] studied 26 asymptomatic major league pitchers and compared their dominant elbows to their non-dominant elbows. Using a standardized stress device, a valgus force was applied to the elbow and musculoskeletal ultrasound (MSK US) was used to examine the UCL of the elbow. In non-throwing arms, the average amount of laxity found was 0.5 millimeters. In throwing arms, the average was 1.4 millimeters. The dominant arm ligament was also shown to be thicker by about 1 millimeter and hyperechoic foci, uncharacteristic brighter areas in the ligament, were found in 35% of pitching elbows, but none in the non-dominant elbow. Another study by Cicotti et al.[6] examined the elbows of 368 major league baseball pitchers. In the study, they used MSK US to examine the amount of medial elbow laxity present in the dominant arm when compared to the non-dominant arm. They used a similar stress device to provide a standardized force on the medial elbow.[5] They found a significant increase in width, thickness and presence of hyperechoic foci and calcifications. This large sample size (n = 368) provides strong evidence that this data can be generalized for all major league pitchers. Similar results have been found in college baseball players as well. Sasaki et al.[13] found that both pitchers and position players incurred damage to the medial elbow, but pitchers had increased laxity when compared to the non-throwing side. Both groups also showed subjects (3/9 pitchers and 5/13 position players) that presented with osteophyte formation on the distal medial corner of the trochlea.

Throwing

The physical act of overhand throwing is an accumulation of forces generated throughout the entire body. The motion could not be completed effectively without each part functioning in a specific way. Being able to smoothly and effectively transition from segment to segment helps increase the amount of force created and allow for repeatability of the action with consistent results. Poor mechanics can alter the complex chain of events in pitching and lead to extra stress on the shoulder and elbow.[23] These forces are also the driving cause of UCL injuries in overhand-throwing athletes.[3] To better understand these forces, both the upper and lower extremity need to be examined to find where the force is generated. The throwing motion can be broken down into six different phases (Figure 1).[20,21,24] These phases apply to both position players and pitchers in baseball. There is some difference in execution of these phases between the two, but the main concepts stay the same. Each phase of throwing can be examined in both the upper and lower extremity.

Phases of Throwing

The windup initiates the process by positioning the body in place where it can generate the greatest force possible. It begins with the shifting of the center of gravity over the back (push-off) leg which then allows the thrower to raise the lead leg, starting the generation of force.[20] The phase finishes when the lead leg reaches its peak and the hands separate the ball and glove.[21] Between pitchers and position players this motion can look somewhat different. Pitchers usually accomplish this phase much slower than position players who do not have as much time to throw the ball. Position players also move toward their target with their whole body while pitchers only take one step towards their target.

Then the early cocking phase begins where the windup left off and ends when the lead leg makes initial contact with the ground.[21] As the lead leg begins to move toward the target, the hip and leg musculature of the stance leg fire and begin to propel the pitcher forward. The shoulder is abducted to 90 degrees and slight horizontal abduction occurs.[20] Hip rotation follows and is the major force generating factor in the phase. As the lead leg separates from the stance leg, the pelvis rotates quickly (up to 700 degrees per second) to become square with the target.[21]

The amount of pelvic rotation depends on the external rotation of the lead leg and flexibility of the hip. Limitations in these areas can reduce hip rotation and cause a decrease in force generation in later phases. Lack of flexibility and hip rotation dysfunction can lead to a change in upper extremity dynamics and put more stress on the shoulder and elbow.

Next, the late cocking phase begins as the lead leg is planted on the ground and concludes when the throwing shoulder reaches maximum external rotation. To facilitate maximum external rotation, the trunk moves forward and extends as the lead leg begins to straighten, forming a solid base. In this time, the anterior shoulder contracts to bring the shoulder into slight horizontal adduction. The amount of external rotation is affected by scapular retraction, elbow flexion, and acceleration of the trunk forward causing a coiling effect.[20,21] Maximum valgus torque on the elbow occurs at the end of this phase. This maximum valgus torque is when maximum force is applied to the medial elbow and will therefore cause the most stress on the UCL.[11] This force exceeds the mean valgus stress of an adult (64N.m) by about 31 newtons/meter.[19] To account for the ligaments lack of strength, dynamic stabilization of the elbow is very important. The triceps, anconeus, flexor muscles of the wrist, and shoulder rotators help decrease this stress and make UCL tears much less common.[19] Rotator cuff muscles contract to counter act the distraction forces created by trunk rotation.[21] At the end of the stage, the shoulder will be in approximately 95 degrees of flexion with elbow flexion at about 90 degrees and 170-180 degrees of external rotation of the shoulder.[20,21]

After the late cocking phase, the acceleration phase begins in the time between maximum external rotation and ball release. The scapula and rotator cuff muscles continue to stabilize the shoulder as the trunk continues to rotate and tilt. Trunk musculature flexes on the non-dominant side to strengthen the pelvic rotation and trunk rotation and tilt. Maximum internal rotation velocities can reach 7000 deg/sec.[20,21] This is caused by the contraction of the subscapularis, pectoralis major, and latissimus dorsi muscles. The elbow is initially flexed from 90 to 120 degrees, where it is most vulnerable for injury, then rapidly extends to around 25 degrees at the time of release. Release is aided by wrist and finger flexion as well.

Finally, the deceleration phase begins after ball release and ends with maximum internal rotation and arm extension.[20,21] This phase is characterized by being the most violent in the throwing motion. The posterior musculature does most of the work of dissipating forces in the shoulder by stabilizing and slowing down the rotation. However, almost every muscle connected to the shoulder has a role in eccentrically slowing the arm at some point in the phase.[21] The phase ends with the completion of humeral rotation to 0 degrees, shoulder abduction at around 100 degrees and an increase in horizontal arm adduction to 35 degrees.[21] The bicep works to decelerate elbow flexion and pronation. The follow through phase is the final part of throwing. In this phase, the body completes decelerating the shoulder and moves into a fielding position. The body rebalances itself by bringing the stance leg back to equal with the lead leg. At this point joint loads return to normal and the thrower can prepare for other actions.[20,21]

Dysfunction Leading to Injury

When the UCL undertakes more tensile force than it can handle, it tears. Studies have reported that the tensile strength of the UCL alone is between 30-35 N, but pitching has been shown to create up to 290 N of force on the elbow.[3,25] Therefore, a large portion of stress must be absorbed by the surrounding structures to keep the UCL from reaching those tensile limits. However, when these muscles, or bony structures fail, the ligament is not able to withstand the force and can tear. There are many different factors that affect the stabilization of the elbow and most rely on the flexor muscles of the anterior forearm to fire correctly and on time to reduce the amount of valgus stress put on the joint.[3] Poor control of the flexor pronator muscles can also lead to chronic damage to the UCL due to the constant stress the UCL undertakes. This leads to the creation of calcifications and can lead to joint gapping.[6] However, the increased stress on the elbow is not only caused by the inability of the flexor pronator muscles to protect the joint, there are a number of other issues that contribute to increased loads on the joint. A decrease in balance on the stance leg of pitchers has been shown to be a predictor for elbow injury in high school and collegiate baseball players. Garrison et al.[26] found that athletes with a torn UCL had decreased balance scores when compared to a healthy, control group. The authors concluded that reduced balance could alter throwing mechanics due to decreased trunk control. This can also lead to a decrease in shoulder range of motion, another predictor of elbow injury. Decreased balance may also lead to an increase in contralateral trunk tilt in throwers. Oyama et al.[27] found that pitchers with an increase in contralateral trunk tilt (Glove side tilt) have increased velocity, but also have increased joint loads when they pitch. Those pitchers with a contralateral trunk tilt of greater than 10 degrees had significantly greater peak elbow proximal force, which is directly related to joint stress. Not only is the trunk affected by the hips, but also by the arch of the foot. In research done by Feigenbaum et al.[28], researchers found that an abnormal foot posture may correlate to an increased risk in shoulder or elbow surgery. Researchers examined foot arch posture in 23 athletes and compared the data to incidence of shoulder or elbow surgery. Those athletes with abnormal foot arch posture were 3.4 times more likely to have had surgery than those with normal arch posture. This helps to show how all parts of the body affect the throwing motion and can have a large impact on injury to an athlete.

Musculoskeletal Ultrasound

Musculoskeletal ultrasound (MSK US) has been used to diagnose medical conditions for many years, but only recently has been used by sports medicine clinicians.[7,9,29,30] Advances in technology have increased the quality of images produced to the level of modern magnetic resonance imaging (MRI) machines.[7] The modality uses sound waves transmitted through a probe to produce an image. Typically, frequencies from 5 to 20 million cycles per second (MHZ) are used.[9] Higher frequencies create better resolution, but also reduce the depth of the imaging field.[8] To create the image, pulses of ultrasound from the transducer produce echoes at tissue or organ boundaries. The waves are absorbed and reflected by each individual type of tissue differently, causing differences in appearance in the image.[8] The differences in appearance can be categorized by the term echogenicity. The echogenicity, or capacity of a structure to reflect back sound waves, can be categorized into three groups, hyperechoic, hypoechoic, and anechoic. Hyperechoic tissue shows a high reflective pattern and appears brighter than surrounding tissue. Hypoechoic tissue has a lower reflective pattern, and shows areas with tissue that is not as bright as surrounding tissue. Finally, anechoic tissue does not show any reflectivity and therefore appears black in the image.[8] Acquiring images requires exposed skin and a medium, usually a water based gel, to facilitate surface adherence.

Benefits of Musculoskeletal Ultrasound

The use of MSK US has become more common as a primary diagnostic tool. Images that are acquired through MSK US are comparable in quality to MRI, which has been the gold standard in imaging for the musculoskeletal system.[7] Unlike an MRI, MSK US has the ability to capture real-time, dynamic images while the patient is moving. This allows clinicians to observe tissues at different lengths and in different positions, and may provide a more comprehensive exam of the injured body part. Dynamic images also give physicians an opportunity to perform guided injections and assist in fluid collection to ensure correct placement of the needle.[8] Compared to other imaging techniques, the use of sound waves does not prevent individuals with pacemakers, cochlear implants, or magnetic artifacts in the tissue from receiving the scans, and does not have any known contraindications for treatment.[7] MSK US machines are also much cheaper than other imaging modalities such as MRI's and CT scan, and can be portable which helps decrease insurance costs to patients.[9]

Technique and Limitations

MSK US can be ineffective at diagnosing pathologies if the operator is poorly trained in the use of the machine. Understanding the technology is important, but technique when imaging is the most important factor in getting high quality images to provide an accurate diagnosis.[7,9,29,30] Nofsinger et al.[9] developed an algorithm for clinicians to use before obtaining images to provide uniformity during all scans. The steps involve establishing the left versus the right end of the probe, using a bony landmark as a reference point when scanning, and stabilizing the angle of the probe once on the skin to maintain a steady orientation. The clinician should constantly be aware of their body position and angle of the probe to provide the most accurate picture possible on the machine. A slight change in angle or pressure can completely reverse the appearance of certain tissue. This is the concept of anisotropy, which can cause the clinician to perceive incorrect findings due to a change in echogenicity. To prevent this, a firm grip on the transducer is recommended, while also placing two or three fingers on the skin to increase contact on the skin to detect minor changes in angle.[29] Another factor that can affect the appearance of tissue is the patient's body position. Correct posture is important, especially when examining the shoulder. Forward rounding of the shoulders will cause increased difficulty in finding the structures the clinician is examining. With this in mind, proper patient position is an important factor in ultrasound technique because it will provide the clinician with the best possible image. Diagnosis is dependent on the operator being able to find the area of injury and also identify the extent of damage to the tissue.[8,9] If the operator is not experienced, they may overlook defects that would be crucial to a diagnosis. Also, as technology evolves, the operator must as well. Continuing education is a very important factor in providing the best possible care.

Another limitation is the amount of penetration achieved by the acoustic waves. Deeper structures are much more difficult to examine because of weaker signals received by the machine. The more tissue the waves pass through, the less clear the return image is. This is why MSK US is rarely used to diagnose hip and spinal pathologies. Bone reflects all sound waves and will most likely block out surrounding structures due to decreased transmission of the waves. To perform an accurate examination with MSK US, the examiner must have proper training on the machine and also understand limitations of the modality.

Tissue Imaging

Each type of tissue in the body has a different reflectivity on an ultrasound image. This allows for differentiation between structures and helps identify landmarks. Individual tissues are characterized by the amount of reflected energy received by the machine, or known as echogenicity. More echogenic structures include bones and gas-like substances, while less echogenic structures are usually fluids. The echogenicity of tissue under MSK US imaging decreases from bone to tendon to ligament to nerve, and finally to muscle.[29] The most common structures examined during MSK US are ligaments, tendons, and muscles. Ligaments connect bones to other bones, and therefore can be seen connecting joints. Ligaments appear hyperechoic and striated. Longitudinal viewing of the ligament will produce the best view; while a transverse axis may result in a hypoechoic appearance due to surrounding hyperechoic subcutaneous fat.[29] Dynamic viewing of the ligament may show gapping when force is applied to the joint. Stressing the joint can also help the examiner identify specific bands of a ligament when the ligament may have multiple parts to it.[29] For example, the UCL of the elbow has three bands, but the anterior band is the tightest when the elbow is bent. The most effective way of determining abnormalities is to compare ligaments bilaterally to check for differences. Abnormalities can present as partial to complete tears varying on the amount of disruption in the fiber.[13]

MSK US is also very commonly used to image tendons and examine abnormalities. Tendons connect muscles to bone. The tissue can be shown as hyperechoic, with a fine fibrillar pattern in a parallel direction.[8,9] When viewed in a transverse plane the tendon will appear round and hyperechoic. It is important that the beam is perpendicular to the tendon. If not, the tissue can appear hypoechoic and go undiscovered during imaging. Injury to tendons can be characterized by any gapping, disruption, or thickening of the structure. A complete tear will result in an anechoic space that disrupts the parallel appearance of the tendon. Partial tears will result in a smaller anechoic space with some parallel fibers intact. A complete examination of a tendon includes both passive and dynamic scanning. Moving the patient while scanning can aid in diagnosing certain conditions that would have been overlooked. Dynamic motions can also help orient the clinician to better identify the exact location of the pathology.

The last most common type of tissue scanned by MSK US is muscle. The appearance of muscular tissue in MSK US is hypoechoic with small sections of hyperechoic tissue. The muscle is surrounded by connective tissue that appears hyperechoic and can help outline the muscle. During dynamic scanning, muscle contraction will show movement in the tissue that can assist in identifying the individual muscle being scanned. Similar to tears in tendons, muscle tears can be identified by hyperechoic or hypoechoic fluid buildup and hypoechoic disruption in the parallel pattern of the muscle depending on the level of damage. Grade one tears will present with no disruption as compared to a grade two and three strains, which will present with partial tears or complete disruption of the fibers.[7] Blunt force injuries will show pockets of hypoechoic hematoma in the tissue that can be outlined by the torn edges of the affected tissue.[8,9] Musculoskeletal ultrasound can also be used to identify scar tissue in the muscle that did not heal correctly. The scar tissue appears hyperechoic and unchanged during muscle contraction.

Examining the Elbow with Musculoskeletal Ultrasound

Examining the UCL of the elbow begins with the patient supine with the arm at 90 degrees of abduction, 30 degrees of elbow flexion, and maximum external rotation. Scanning can be done with and without a valgus force to show changes in the ligament under stress. Most commonly, the transducer is placed longitudinally on the inside of the elbow over the medial epicondyle.[15] Once the transducer is in place, it is up to the examiner to identify the structures and landmarks to perform a correct examination. Verifying the position of the transducer takes much practice and a skilled eye to identify all of the major structures of the elbow. The common flexor tendon should be visible in the image connecting to the medial epicondyle. Just deep to this larger structure is the ulnar collateral ligament, which is slightly more echoic than the flexor tendon. Under the UCL in the image is an anechoic space that represents the bone. The medial epicondyle is identifiable as the origin of the common flexor tendon. The trochlea and ulna are found more proximal, or further up the arm. The space between the medial epicondyle and the trochlea contains the UCL.[5,15] When the elbow is stressed with a valgus force the UCL becomes tight and forms a straight line over the trochlear notch.

To standardize the amount of stress placed on the elbow, some studies have used a Telos GA-II E stress device to provide consistent and variable force to the medial elbow.[4,6,15,22] The device uses three bars that stabilize the elbow and provide force outputs from the pressure applied to the elbow. This device is only designed to apply force to the elbow and is not used to assess the amount of joint laxity alone. Another study developed a new method for assessing medial elbow joint laxity. They compared the external rotation angle with the elbow at 90 degrees of flexion and with the elbow completely extended. Their method used gravity as the force and measured, with an inclinometer, the angle that the elbow dropped once in the two positions.[31] The amount of laxity in the elbow correlates to the distance between the medial epicondyle and the trochlea. This space has been shown to be significant in terms of predicting elbow injury.[11]

Summary

Ever since the discovery of UCL tears in baseball researchers have been trying to discover ways to prevent injury and reduce the amount of time spent recovering. The UCL has been extensively studied anatomically, but biomechanically there are still questions about its full role in pitching. Studies have noted that overtime the ligament can become stretched, showing signs of thickening, and even shows signs of damage and calcifications. This means that some part of the throwing motion is damaging to the structures. However, this may not be avoidable due to the nature of throwing. The goal of the research is to identify risk factors and signs that can identify possible tears before they happen. Recent increases in the use of MSK US have resulted in some research on pitchers because it allows easy, convenient and accurate imaging. Recently, research has focused on discovering changes in pitcher's UCL ligaments because of the increase in injuries to pitchers over the last decade. This information has been very useful, but researchers are still divided on why this happens and how this information can be used to identify baseball athletes who are more at risk for serious injury. However, this research has all been done with pitchers. Little evidence of changes to a position player's elbow exists. Does that mean that these changes are not occurring in position players? If they do occur in position players to the same degree, then throwing in general is the cause of the damage. If these changes do not occur in position players, then it can be shown that the act of pitching, and not just throwing causes these changes in baseball players. Comparing the two populations will help to further understand the pathology of elbow injuries in baseball players.

CHAPTER III. METHODS

The purpose of this study was to examine the difference in ulnar collateral ligaments (UCL) between pitchers and position players. In addition, this study identified baseball athletes that have developed changes to the UCL ligament in the throwing elbow and examine the amount of damage that has occurred when compared to their non-throwing arm. The following research questions guided this study: Is there a difference in ulnohumeral joint space between pitchers and position players, is there a difference in UCL width between pitchers and position players, and is there a difference in the amount of damage to the UCL between pitchers and position players? This chapter focuses on: experimental design, participants, instrumentation, procedures, and data analysis.

Experimental Design

An observational cohort research design was used for the study. The cohort consisted of college-aged competitive baseball players in a NCAA Division I program. This was an effective sample because the population is very specific to the sport and level of experience. Since there was not an intervention applied, only observational methods were be used to gather data.

Population of the Study

A convenience and effective sample of 30 NCAA Division I baseball athletes was recruited for this study. All athletes were divided into two groups based on position. One group was pitchers; the other group was position players. Athletes who both pitch and play a position were put into the pitcher group. Pitchers were those that pitched at least one inning in the fall season prior to data collection. Each athlete was not ambidextrous, meaning able to throw with both arms. Athletes who had undergone any kind of elbow surgery or had a significant elbow injury requiring more than a month of time off were not allowed to participate.

Power Analysis

A power analysis was performed with a power = 0.80, alpha ≤ 0.05, effect size = .35, which determined the necessary sample size of N = 28 (14 pitchers and 14 position players). Participants who withdrew from the study were replaced to ensure the desired number of participants is reached.

Instrumentation

The Terason t3200™ Diagnostic Ultrasound (MedCorp, LLC., Tampa, FL) with Aquasonic® 100 ultrasound gel (Parker Laboratories, Inc., Fairfield, NJ) applied to the 15L4 Linear transducer (4.0-15.0 MHz) (MedCorp LLC, Tampa FL) was used to scan each athlete's throwing and non-throwing elbow. Diagnostic ultrasound has been shown to be very reliable in acquiring images, but the validity is dependent on the clinician's ability to use the machine correctly.[8,9] A Stretch Out Strap (Power Systems, Inc., Knoxville, TN) strap was attached to the wrist of the participant and the leg of the table closest to the elbow with the loop of the strap being the same length for each participant. The strap has 10 loops along its entire length. The loop that most closely reaches the athletes wrist was used to supply uniform force. A goniometer (Lafayette Instrument Company, Lafayette, IN) was used to measure elbow flexion angle.

Procedures

Once the athletes had agreed to participate in the study they were able to sign up for specific times to be scanned in twenty-minute increments. Upon arrival, participants were given an informed consent form that explains the procedures of the study and releases the images obtained with the ultrasound machine for the researcher to examine and study. Their height, weight, age, level of experience, handedness, and position was documented. The athlete then lay supine on a table. The athletes lay so that only the elbow and forearm of one arm was off the table with the medial elbow facing the ceiling. The ultrasound coupling gel was applied to the transducer. The ultrasound transducer was then oriented longitudinally to the forearm over the medial epicondyle of the elbow. Before stressing the joint, an initial scan was done on both elbows at 30 degrees of flexion, as measured with a goniometer, to identify the resting ulnohumeral joint space, UCL width, and identify any damage in the area. The location of the common flexor tendon origin, medial condyle, and the trochlea was identified and used as landmarks for measurement.[13] The anterior band of the UCL was seen between the medial epicondyle and the trochlea. With the transducer in place, the clinician froze the image and measure for the three variables. The caliper button on the ultrasound machine was pressed and measured the distance between two points on the screen. For length measurements, the examiner placed one point on the medial epicondyle attachment site of the UCL and on the Trochlea attachment site of the UCL. That distance was documented and saved in the image. For width measurements, points were placed on each side of the mid-portion of the ligament and the distance documented and saved on the image[6]. Calcifications were documented as the total number of independent hyperechoic areas found per elbow.

Each elbow was scanned in the position of 30 degrees of flexion with no stress and then again with valgus stress applied to the joint. Stress was applied by a strap that will be attached to the participant's non-dominant wrist first. The wrist strap connected to the table leg at a constant length. The same length of strap was used for all participants to regulate the amount of force being imparted on the elbow. To standardize the length of the strap, participants were to adjust the level of their body on the table so the shoulder is in 90 degrees of abduction against the table and their elbow is off the table. If the athlete experienced discomfort during this time he was able to notify the researcher and the amount of force was reduced to his comfort, and this was noted in research notes. Two images were acquired for each trial, there were two trials per arm, non-stressed and stressed, this made a total of four trials and eight images for each athlete. The two length and two width measurements gathered from each trial were averaged together. The same measurements were taken for each trial and the images were saved to the ultrasound device to allow for analysis after scanning. After all images were acquired, the athlete had the coupling gel wiped from the elbow. Each saved image was transferred to a flash drive for portability and security. Once each elbow had been scanned, the athlete was allowed to leave if no problems arose during the study. After the participant left, measurements were transferred to a spreadsheet containing every participant's ulnohumeral joint space, UCL width, and the number of hyperechoic calcifications. A number was assigned to the athlete and that number took the place of their name.

Data Analysis

An independent t-test was used to compare each variable (ulnohumeral joint space and UCL width) between dominant and non-dominant arms of each subject and between pitchers and position players. Also, presence of hyperechoic calcifications was compared to years of experience in baseball. Results were considered significant if the P value $< .05$. Data was analyzed with SPSS version 22.

CHAPTER IV. MANUSCRIPT

Abstract

Background

Increases in ulnar collateral ligament (UCL) injuries in baseball players have created a need to discover possible risk factors for the athletes. Diagnostic ultrasound allows clinicians to examine ulnohumeral joint space, UCL width, and identify any abnormalities in the joint that could be a cause of future injury.

Hypothesis

There is a difference in ulnohumeral joint space, UCL width, and abnormality present in collegiate baseball pitchers when compared to collegiate baseball position players.

Study Design

Observational Cohort

Methods

Twenty-Eight NCAA Division I baseball players (14 pitchers, 14 position players) were examined with diagnostic ultrasound. Exams were performed on both dominant and non-dominant elbows at 30° of flexion. Ulnohumeral joint space, UCL width, and presence of abnormality in the area were all measured and documented.

Results

In the dominant arm, the mean UCL width was significantly greater in pitchers (2.63 ±.04mm) when compared to the position players (2.17 ± .04mm). There was no significant difference in the non-dominant arms between the two groups. The difference in ulnohumeral joint spaces in both dominant and non-dominant elbows was not significant. No abnormalities or damage was found in any of the subjects.

Conclusion

Diagnostic ultrasound examinations showed that in college aged baseball players, only UCL width was significantly different between pitchers and position players.

Key Words

Baseball, Diagnostic Ultrasound, Elbow, Throwing

Introduction

Baseball players are prone to Ulnar Collateral Ligament (UCL) damage due to the forces placed on the elbow during throwing. At the elbow, forces during throwing can reach as high as 290 newtons.[3,4] The UCL has been shown to resist an average of 33 newtons per meter before tearing. The surrounding muscles and bones usually absorb this deficit, but if that force reaches or exceeds the UCLs yielding point, injury can occur.[3,4] Chronic throwing can also cause damage to the UCL or surrounding structures due to repeated micro trauma that the ligament endures. This micro trauma can lead to ligament thickening and calcifications. These findings have been found in the dominant arms of pitchers when compared to their non-pitching arms in asymptomatic major league baseball players.[5,6] No studies have compared pitchers and position players. Diagnostic ultrasound has become an effective tool at examining soft tissue structures. Multiple studies have set out to examine its efficacy in diagnosing ulnar collateral ligament sprains and abnormalities in baseball players.[5,6,10–13] These studies have shown some increases in damage to the UCL in professional and amateur pitchers. [5,6,10–13] The purpose of this study was to examine the difference in the UCL between pitchers and position players. It identified collegiate baseball athletes that have developed changes to the UCL in the throwing elbow and examined the amount of damage between the groups.

Materials/Methods

Study Population

A total of 28 subjects (14 pitchers, 14 position players) each had one ultrasound study performed. All players were recruited through convenience sampling, from the same NCAA Division I baseball team. Athletes had a mean age of 20.4 ± 1.1 years (range, 18-22 years). Athletes had a mean of 15.5 ± 1.6 years of experience (range, 12-18 years). There were 10 (71.4%) right-handed pitchers, and 4 (28.6%) left-handed pitchers. All position players were right-handed. All players were asymptomatic at the time of the ultrasound examination. Each subject could not be ambidextrous and had to have pitched or played in at least one game at the collegiate level to be included. Institutional review board approval was obtained and all participants provided written informed consent.

Methods

All ultrasound examinations were performed by the same researcher with the Terason t3200™ Diagnostic Ultrasound (MedCorp, LLC., Tampa, FL) with Aquasonic® 100 ultrasound gel (Parker Laboratories, Inc., Fairfield, NJ) applied to the 15L4 Linear transducer (4.0-15.0 MHz) (MedCorp LLC, Tampa FL). Participants were placed supine on a table with their non-dominant elbow just off the edge of the table. The elbow was positioned at 30° of flexion with the help of a goniometer attached to the elbow. This was chosen because at this angle, the UCL is the main stabilizer of the medial elbow.[6,10] The ultrasound was then preformed. The transducer was placed on the medial elbow just distal to the medial epicondyle. The epicondyle, coronoid process, and the trochlea were used as landmarks to identify the UCL. The screen was frozen when the UCL could be seen in the same screen as the ulnohumeral joint. While the screen was frozen the variables were measured. The ulnohumeral joint space was measured along with the width of the UCL in the same image. Ulnohumeral joint space was measured from the trochlea of the humerus to the coronoid process of the ulna. The UCL width was measured in the mid-portion of the ligament from deep to superficial. All images were also examined for any abnormalities or hyperechoic foci that would indicate damage to the ligament or surrounding area. All measurements and findings were then input into an electronic spreadsheet (Excel, Microsoft, Redmond, Washington). The process was repeated with the participant's dominant elbow. Exams took an average of 15 minutes each for both dominant and non-dominant arms.

Data Analysis

An independent t-test was used to compare each variable (UCL width and ulnohumeral joint space) between dominant and non-dominant arms of pitchers and position players. Presence of hyperechoic calcifications was compared to years of experience in baseball. Statistical significance was defined as $P \leq 0.05$. Data was analyzed with SPSS version 22.

Results

All data for UCL width are listed in Table 1. An independent-samples t-test was conducted to compare UCL width between pitchers and position players in both their dominant and non-dominant arms. There was a significant difference in UCL width between dominant arms of pitchers (M=2.379, SD=0.387) and position players (M=2.629, SD=0.443); t (26)=2.908, p = .007. Position players were shown to have significantly wider ligaments than pitchers by about 0.25 mm. There was no significant difference between the non-dominant arms with pitchers (M=2.4526, SD=0.654) and position players (M=2.707, SD=0.540); t(26)=1.745, p = .093.

All data for ulnohumeral joint space are listed in Table 1. There was no significant difference between the dominant arm joint space with pitchers (M=2.836, SD=0.643) and position players (M=2.65, SD=0.45); t(26)=-.887, p = .383. There was no significant difference between the non-dominant arm joint space with pitchers (M=2.671, SD=..4730) and position players (M=2.621, SD=.6542); t(26)=-.232, p = .819. Pitchers did show a slight increase in ulnohumeral joint space (0.186mm) but the difference was not enough to be significant (p = .383).

Finally, the ultrasound exams revealed no abnormalities or calcifications in either group. Without any abnormality found, no comparison testing was performed between abnormality and years of baseball experience.

Discussion

Discovering a link between UCL dynamics and future injury is a pressing issue because of the increase in elbow injuries occurring in baseball players. The most severe elbow injuries require 12-18 months of rehabilitation before return to play can be allowed.[6] This accounts for a least one full season and most of the off-season. To professional and collegiate baseball teams, this amount of time is significant to their success. Examining players to predict possible injury in the future would be incredibly helpful information for, not only those who have a vested interest in the athletes, but also the athletes themselves. Many studies have tried to identify any possible risk factors that could predict future elbow injury in baseball players, but none have made any significant process.[19,27,28,32–35] Wright et al[36] found that elbow radiographs taken at the beginning of a players career could not predict the amount of time they spent hurt in the future. The study found that pitchers could develop degenerative changes over time but that these changes did not correlate to an increased risk of injury. This leads to the continued search for risk factors or abnormalities present to predict future injury. These results provide the framework for new studies to identify the exact UCL dynamics that lead to injury.

The elbow is especially susceptible to injury in baseball players because the supporting ligament, the UCL, is not strong enough by itself to disperse the forces placed on the medial elbow. These forces, when combined with muscle fatigue, lack of flexibility, and poor mechanics can lead to injury in these joints.[4] At maximum valgus force, the ligament only generates 54% of the varus torque needed to resist valgus forces during throwing.[25] Therefore, the surrounding muscles and bony structures don't absorb about 50% of force, then the UCL is at a significant risk for injury. The large amounts of force that throwing creates, about 64N-m of valgus force, also cause chronic stress and therefore can contribute to attenuation or micro tears in the ligament.[25] Attenuation of the ligament leads to increased joint space which has been demonstrated in many studies that sought to find a difference between dominant and non-dominant elbows.[5,6,11,13,15] Cicotti et al.[6] found a significant mean difference between dominant and non-dominant arms of 0.38mm and our research showed only a 0.165mm difference. The same study also showed an average ulnohumeral joint space in the dominant arm of 3.32 ± .07mm when our subjects had an average of 2.84 ± .643mm. Both show an increase in dominant arm joint space when compared to the non-dominant arm, but our results were not significant. An increase in joint space has not been correlated to an increase in injury risk in baseball players.[5,6,13] These studies show that this increased joint space is simply an adaption over time to accommodate the significant demands that the elbow is placed under during throwing.[34]

Our study found a significant difference in UCL width when comparing the dominant arms of pitchers and position players. The position players had wider ligaments than the pitchers in this case. No study has looked at the average width of the UCL in position players before. There is not enough additional evidence to assume that position players should be expected to have wider ligaments in future studies. A possible cause of this is due to the variability of arm slots in position players. Depending on the position and situation, the athlete can throw in 2-3 different ways. For example, a short stop will throw from his normal arm slot when making a routine play, but if the throw has to be rushed, a side arm, or three quarters arm slot may be a faster way to release the ball. These different arm slots create a different angle of pull on the UCL. Certain angles may take away some of the chronic stress the ligament undergoes because the ligament is not being stressed in the same way each time. This could make the ligament stronger and more adaptive to the repetitive stress and thus leading to less micro tears and a wider ligament. Pitchers, on the other hand, use the same arm motion almost all of the time and this is the main cause of the repetitive stress than the ligament endures. Each throw causes the ligament to stretch in the same direction and overtime this constant chronic stress is what may create the micro tears in the ligament. Also, position players do not always throw at 100% intensity. This leads to less stress placed on the UCL over the length of a career. Pitchers almost always throw about 90-100% intensity. Over the course of a game they are stressing their elbow much more than the position players. Pitcher's elbows undergo significantly more high intensity use on a more often basis.

The average width of the pitcher's UCL was also thinner than the reported values in other research articles.[5,6] This study used college aged pitchers who may have less experience when compared to their major league counterparts. The increased experience of major league pitchers may have caused more micro tears in the ligament, thus increasing its width. The micro tears would create gaps in the ligament that the body would fill in with scar tissue. The increase in scar tissue would also possibly add size to the ligament thus increasing its width in the process.[14,37]

When examining ulnohumeral joint space, we found no significant difference between pitchers and position players. Previous studies have examined the amount of joint space in pitchers alone and found joint spaces within a millimeter. Only Sasaki et al.[13] included both pitchers and position player's ulnohumeral joint space, but the researchers did not delineate the two and included them as one group. This meant that we could not compare each groups together. With no significant difference between pitchers and position players the data shows that both forms of throwing cause similar amounts of damage over time.

The ultrasound exams from this study did not find any evidence of hyperechoic foci or abnormality in either group. This is contrary to what we expected and what other studies found.[5,13] In research on Major League Baseball players, Cicotti et al.[6] found 103 (28%) incidences of hypoechoic foci and 92 (24.9%) incidences of calcifications in the dominant arm compared to only 13 (3.5%) hypoechoic foci and 6 (1.6%) calcifications in non-dominant arms. Again, this may be related to the lack of years of experience in the players. It may also be related to the relatively small population that was used in the study, or experience of the researcher acquiring the measurements.

There were a few limitations in this study. We used collegiate Division I baseball players. These players have various levels of experience between them. Some of the position players may have pitched at some point in their career and some of the pitchers may have not been pitchers for very long. A player may have been a position player their entire career until they were made a pitcher in college. Less experience at a position can cause an increase in stress at the elbow due to the athlete not being trained correctly or well enough to protect themselves. It can mean a lower number of throws as a pitcher, and therefore smaller amount of time that they been subjecting their elbow to that kind of force. Another limitation was the lower number of years of baseball experience when compared to the majority of studies who used major league baseball players. These players had much more experience and tend to participate in throwing activities more often than college baseball players. This may have a significant effect on the chronic changes that occur in the medial elbow. Our study also did not include data from a stressed ultrasound. The athlete was examined with stress placed on the elbow, but the data was removed because the procedure could not be standardized to all subjects. Because of this, athletes were only studied at rest. Other studies used a standardized stress device that allowed the researchers to apply an equal amount of force to the elbow each time the subject was examined.[4–6,22] The researchers for this study were not able to obtain a similar device and because of this, our research did not include data from the stressed ultrasound. Finally, clinician experience could have played a role in the accuracy of the data collected. The primary researcher was not formally trained in MSK US of the elbow and this could have led to poor images and inaccurate measurements.

Conclusion

This research has shown that baseball pitchers and position players both experience some changes to their medial elbow and UCL. It was shown that position players had wider UCLs than pitchers. This study was the first to compare pitchers to position players directly and more research should be done to see if the differences found in this study are repeatable. This data will also hopefully lead to a discovery on risk factors to future medial elbow injury in baseball players.

CHAPTER V. DISCUSSION

The purpose of this study was to examine the difference in ulnar collateral ligaments (UCL) between pitchers and position players. In addition, this study identified baseball athletes that developed changes to the UCL ligament in the dominant elbow and examined the amount of damage that had occurred when compared to their non-dominant arm. The following research questions guided this study: Is there a difference in ulnohumeral joint space between pitchers and position players, is there a difference in UCL width between pitchers and position players, and is there a difference in the amount of damage to the UCL between pitchers and position players? This chapter focuses on: experimental design, participants, instrumentation, procedures, and data analysis.

Summary

Ever since the discovery of UCL tears in baseball, researchers have been trying to discover ways to prevent injury and reduce the amount of time spent recovering. Studies have noted that overtime the ligament can become stretched, showing signs of thickening, and even shows signs of damage and calcifications. This means that some part of the throwing motion is damaging to the structures. However, this may not be avoidable due to the nature of throwing. The goal of the research is to identify risk factors and signs that can identify possible tears before they happen. Recent increases in the use of MSK US have resulted in some research on pitchers because it allows easy, convenient and accurate imaging. Research has focused on discovering changes in pitcher's UCL ligaments because of the increase in injuries to pitchers over the last decade. This information has been very useful, but researchers are still divided on why this happens and how this information can be used to identify baseball athletes who are more at risk for serious injury. However, this research has all been performed with pitchers. Little evidence of changes to a position player's elbow exists. Does that mean that these changes are not occurring in position players? If they do occur in position players to the same degree, then throwing in general is the cause of the damage. If these changes do not occur in position players, then it can be shown that the act of pitching, and not just throwing causes these changes in baseball players. Comparing the two populations will help to further understand the pathology of elbow injuries in baseball players.

The study recruited 28 healthy collegiate baseball pitchers. Fourteen were pitchers and 14 were position players. Each was examined with the diagnostic ultrasound bilaterally to find the amount of ulnohumeral joint space, width of the UCL and to discover if any abnormalities were present in the joint or surrounding area. There was a significant difference in UCL width between dominant arms of pitchers (M=2.379, SD=0.387)and position players (M=2.629, SD=0.443); t (26)=2.908, p = .007 The other categories were not found to be significant, but showed a slight increase in ulnohumeral joint space in both groups between the dominant and non-dominant arms. The exams found no signs of abnormality or damage to the joint or surrounding area.

Discussion

The increase in elbow injuries in baseball players has caused an increased need for research. Players are missing significant amounts of time and this is causing teams and healthcare professionals to search for methods to either reduce the injury rate or discover risk factors that may lead to injury. Examining players to predict possible injury in the future would be incredibly helpful information for, not only those who have a vested interest in the athletes, but also the athletes themselves. Identifying these risk factors can help healthcare professionals keep an eye on players more susceptible and work towards reducing their risk of significant injury. There are many current risk factors for elbow injury in baseball players. Some of those include poor mechanics, poor balance, decreased flexibility in the shoulder and elbow, and weakness in the flexor pronator mass in the forearm.[26,38,35] Each of these can be modified or fixed to reduce the risk of elbow injury. This study set out to find initial data for UCL dynamics in the college aged baseball player. By examining both the soft tissue structures and the joint space using diagnostic ultrasound, ulnohumeral joint space, UCL width, and amount of damage could be examined in the same study. These variables, however, have not yet been clinically proven to identify those at a higher risk. Wright et al[36] found that elbow radiographs taken at the beginning of a players career could not predict the amount of time they spent on the disabled list. The authors reported that pitchers do develop degenerative changes over time, but that these changes did not affect the amount of time spent on the disabled list. This leads to the continued search for risk factors or abnormalities present to predict future injury.

Baseball players subject their shoulders and elbows to significant amounts of force on a daily basis. These forces, when combined with muscle fatigue, lack of flexibility, and poor mechanics can lead to injury in these joints.[4] The elbow is especially susceptible to injury because the supporting ligament, the UCL, is not strong enough by itself to disperse the forces placed on the medial elbow. At maximum valgus force, the ligament only generates 54% of the varus torque needed to resist valgus force during throwing.[25] This means that if the surrounding muscles and bony structures don't absorb about 50% of force, then the UCL is at a significant risk for injury. The large amounts of force that throwing creates, about 64N-m of valgus force, also cause chronic stress and therefore can contribute to attenuation or micro tears in the ligament.[25] No data could be found that examined the average amount of ulnohumeral joint space, and UCL width in a healthy, non throwing population. Attenuation of the ligament leads to increased joint space which has been demonstrated in many studies that sought to find a difference between dominant and non-dominant elbows.[5,6,11,13,15] An increase in joints space has not been correlated to an increase in injury risk in those throwers though. This increased joint space is an adaption over time to accommodate the significant demands that the elbow is placed under during throwing. When this occurs in asymptomatic athletes, it may go unnoticed until it reaches a point that symptoms occur and the condition becomes pathologic.[39] The continual increase in joint space is caused by chronic stress and micro tears which can lead to calcifications, scar tissue, or other conditions that contribute to pitching disability. Studies that have examined these variables have found that pitchers dominant arms have wider UCLs than their non-dominant arm.[5,6,13] The cause of wider ligaments is most likely from the formation of scar tissue created after micro tears in the ligament. These micro tears are created overtime due to chronic stress on the ligament. When comparing pitchers to themselves, this study found that pitchers had wider UCLs in their non-dominant arms. The current study also found that pitchers, when compared to position players had significantly thinner UCLs. This shows that pitchers, who tend to throw harder, and more often, lose width in their UCL overtime. If micro tears are causing this, they are causing the ligament to stretch farther than it was designed to, and causing the ligament to appear thinner upon examination. Other studies that examined UCL width did not examine or differentiate position players from pitchers so this data cannot be compared to other research studies. A possible cause of this increased UCL width in position players is due to the variability of intensity or effort when throwing in position players. Depending on the position, the athlete does not always throw at 100%. By decreasing the amount of force placed on the elbow during throwing, micro tears are less likely to happen and would prevent the ligament from thinning similar to the pitchers. Pitchers use the same arm motion and throw at 100% intensity almost all of the time and this may lead a larger amount of repetitive force applied to the elbow overtime. The larger amounts of force applied to the elbow can cause an increase in the change of micro tears in the ligament and thus leading to an overall thinning of the ligament. The average width of the pitcher's UCL was also thinner than the reported values in other research articles.[5,6] There is a chance that this is caused by the level of experience in collegiate baseball players in this study. These players have not thrown as much as major league players and this could mean less scar tissue that is present in the ligament, making it appear thinner. Another theory is that these players are still in the process of making scar tissue to fill the micro tears that have occurred in the ligament. This would make the ligament appear thinner because the tissue has not been repaired yet and the ligament is still stretched thin. The healing process can be a long time and can just be beginning for some of these players who have not spent a significant amount of time throwing when compared to their older, more experienced counterparts.

When examining ulnohumeral joint space, no significant difference between pitchers and position players was found in this study. However, pitchers did show a larger amount joint space that approached significance when compared to the position players. Previous studies have found similar results within one millimeter to the current study results.[5,6,37] One study examined cadaver elbows to establish a baseline for ulnohumeral joint space in asymptomatic elbows.[37] The authors reported that at rest, the mean ulnohumeral joint space was 2.8mm. This number was the same as the data the current study gathered. However, due to the cadaver study using flash frozen specimen, there was no active muscle contraction helping to control valgus force in the elbow. This could increase the laxity and explain the similar numbers identified in the current study. The subjects were consciously aware of the exam being performed, which may have caused unexpected muscle contraction, thus decreasing ulnohumeral joint space. The Ciccotti et al[37] study was the only one discovered that sought to provide normative data on ulnohumeral joint space in non throwing individuals.[37] All but one study examined only Major League Baseball pitchers.[5,6] Only Sasaki et al.[13] examined both college level pitchers and position player's ulnohumeral joint space. The researchers did not, however, delineate the two groups and included them as one group. With the data approaching significance, the results compare to the data from UCL width between the two groups. The pitchers, who showed significantly thinner ligaments, also showed more ulnohumeral joint space than the position players. This data was not significant, but does contradict the results from other research articles. When other researchers compared the same variables they showed both ulnohumeral joint space and UCL width were found to be greater than the non-dominant side, but they only studied pitchers. The data found in this study, coincides with the conclusion that pitchers are creating more micro tears in their ligaments and causing a thinning of the ligament, which may also become more lax and create more ulnohumeral joint space. These micro tears create excess space in the joint, which may overtime become filled in with scar tissue, or remain torn and lead to larger tears in the future.[38,39] Micro tears alone are not enough to cause significant UCL injury but overtime, if the ligament has multiple micro tears, they can become pathological.[34,39,32]

The ultrasound exams from this study did not find any evidence of hyperechoic foci or abnormality in either group. This is contrary to what we expected and what other studies found. In research on Major League Baseball players, Cicotti et al.[6] found 103 (28%) incidences of hypoechoic foci and 92 (24.9%) incidences of calcifications in the dominant arm compared to only 13 (3.5%) hypoechoic foci and 6 (1.6%) calcifications in non-dominant arms. This data shows that our sample sized was most likely too small to get an accurate picture of the problem. By not seeing any amount of damage or calcifications we were not able to compare the data to years of experience. That data could have led to a better idea of the amount of time it takes to acquire significant amounts of damage that present upon ultrasound exam. The current study also only used college aged players, which could mean a significant decrease in the amount of throws the player has made over a lifetime when compared to a Major League pitcher. Another significant source of error could be from the primary examiner. With limited experience the examiner could have missed the presence of damage or calcifications, thus missing important data.

There were a few limitations in this study. Collegiate Division I baseball players were used, which is in itself not a limitation, but these athletes are not always as specialized as their Major League counterparts. Other studies used more experienced Major League pitchers to gather their data. These players have much more experience and tend to participate in throwing activities more often than college baseball players. These players have also specialized at a position for a longer amount of time then some college baseball players. College players often change position and some pitch and play another position. This may have a significant effect on the chronic changes that occur in the medial elbow. In the current study, this led to a smaller sample size and lack of variability of levels of experience. The current study also did not include data from a stressed ultrasound. The athlete was examined with stress placed on the elbow but the data was removed because the procedure could not be standardized to all subjects. Because of this, athletes were only studied at rest. This procedure still provides effective data but can be limiting when looking at baseball players who put significant force on their elbow. Finally, clinician experience could have played a role in the accuracy of the data collected. The primary researcher was not formally trained in ultrasound of the elbow and this could have led to poor images and inaccurate measurements.

Clinical Relevance

The data found in this study contributes to additional data on UCLs in healthy pitchers. It also introduces the idea that position players may also experience similar amounts of damage to their elbows. This study found some data that coincides with other similar studies, but it also found some data that disagrees with those same studies. This supports that both position players and pitchers need to be examined to truly understand the amount of change in the UCLs of throwing athletes. The data can be used to further examine the incidence and cause of UCL tears in baseball players.

Future Research

To aid in future research of this kind, more research needs to look at the average amount of ulnohumeral joint space, and UCL width in the general population. Understanding true baseline data will help compare these athletic populations from the general public who does not usually put extreme stress on their medial elbow. Research should continue to look for a link between clinical presentation and future risk of injury to baseball players. Another variable that could be studied is the biomechanics of how the athlete throws. By examining the arm slot, and understanding the stresses that the elbow experiences throughout all phases of throwing, a more focused understanding of elbow injury can occur. The height or weight of an athlete may also affect the amount of damage the athlete's UCL may have experienced. Taller athletes, with longer arms, create more torque on the elbow because of the longer lever arm created by throwing.[20] Lighter athletes may not have the lower body strength to balance that throwing motion and may rely more on their shoulder and elbow which could lead to changes in the ligament.[20] Studying a link that connects healthy pitchers to those who get injured in the future can be a very important tool in the care of baseball players. Identifying risk factors and signs of a future injury could significantly reduce the amount of complete UCL tears that are seen and lead to much less time spent healing instead of playing. It is also important to subject position players to the same types of tests and imaging studies to have an overall picture of the damage throwing a baseball has on the elbow. The researchers who only look at pitching elbows are missing a large amount of data that they can be using to compare results. Identifying where pitchers diverge from position players could be a key factor in identifying why pitchers encounter more elbow injuries during their career. The more information that is gathered on the subject the more likely a link will be found and used to prevent future elbow injury.

Conclusion

This research has shown that baseball pitchers and position players both experience changes to their medial elbow and UCL. It was shown that position players had wider UCLs than pitchers while also having less space in their ulnohumeral joint space. UCL width therefore relates to the amount of joint space presence in the joint. By using data on position players as well as pitchers this study has discovered a difference between the two groups that has not been found before. This new data can help sports medicine clinicians understand the dynamics on why the UCL experiences changes and what are the causes of change. Position players are not studied often, and future research should focus on the position players as well as pitchers to discover risk factors for elbow injury. New information found by this study should create new research questions to find out why these variables exhibit change. If in the future, a link can be found between either variables and risk of UCL tear, then this data can be used to identify future risk of elbow injury. This study was the first to compare pitchers to position players directly and more research should be done to see if the differences found in this study are repeatable. This data will also hopefully lead to a discovery on risk factors to future medial elbow injury in baseball players.

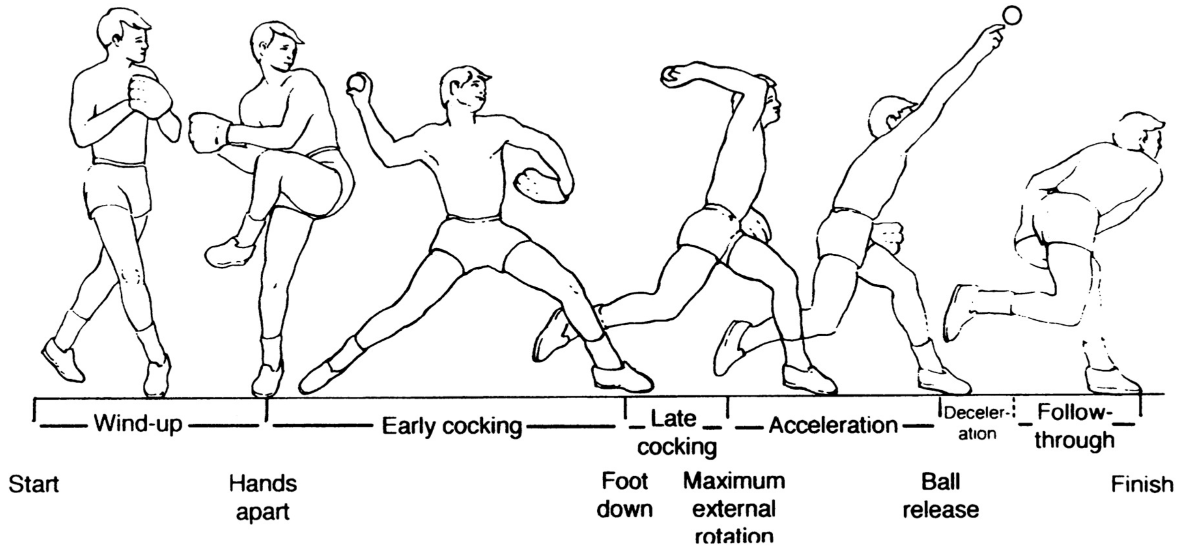

FIGURE 1. Throwing Phases
Meister, 2000

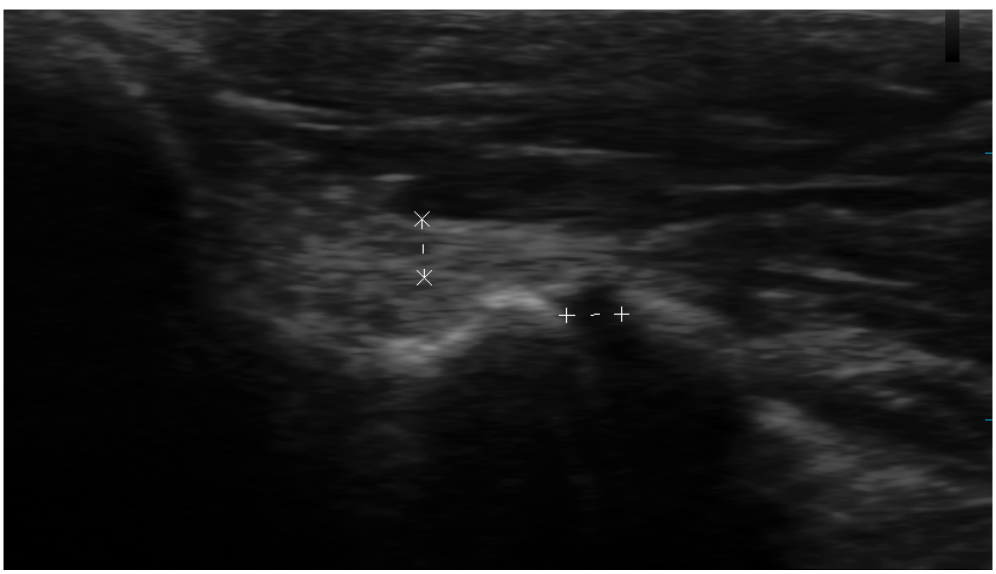

FIGURE 2. Ultrasound of the Medial Elbow
x-x = UCL Width, +-+ = Ulnohumeral joint space

TABLE 1

Joint Space and UCL Width Differences Between Pitchers and Position Players

	Position (n = 14)	Pitchers (n = 14)	Sig.
Dominant UH Joint Space, mm	2.65 ± .45	2.84 ± .64	.383
Non-Dominant UH Joint Space, mm	2.62 ± .65	2.67 ± .47	.819
Dominant UCL Width, mm	2.63 ± .44	2.17 ± .39	.007
Non-Dominant UCL Width, mm	2.71 ± .54	2.38 ± .45	.093

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APPENDIX. INFORMED CONSENT

NDSU North Dakota State University
Health Nutrition and Exercise Science
1301 Centennial Boulevard
Fargo, ND 58108-6050
1 (701) 231-7474

Title of Research Study:

Comparison of Ulno-humeral joint space, UCL thickness and abnormality in Collegiate Baseball Players Using Musculoskeletal Ultrasound

This study is being conducted by:

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Why am I being asked to take part in this research study?

You are being asked to participate in this study because you are a Division I collegiate baseball player at NDSU. You are either a pitcher or a position player who participates in the baseball program. During your time playing baseball you may have experienced a change in the ligament in your elbow that helps support the elbow during throwing. If you have had any form of elbow surgery or and significant elbow injury that required you to sit out from play for more than a month then you will not be allowed to participate.

What is the reason for doing the study?

The purpose of this study is to examine the difference in the ulnar collateral ligament (UCL/Tommy John Ligament) between pitchers and position players. It will identify baseball athletes that have developed changes to the UCL in the throwing elbow and compare the amount of damage to their non-throwing arm. This can help future research identify specific risk factors for elbow injury caused by throwing.

What Information will be collected about me?

When you enter the research lab, you will be asked to fill out a demographics questionnaire. After you have completed this, the researchers will explain how the study is going to proceed. You will be placed face up on a table with your elbow just barely off the long edge of the table. Once you are comfortable, your arm will be placed in the position we need it to be and we will begin scanning your elbow with the diagnostic ultrasound.

The diagnostic ultrasound machine takes pictures of your muscles, bones, ligaments, and tendons similar to an ultrasound for a baby. The researcher will then find the ligament on the inside of your arm and freeze the image. Once frozen, the researcher will measure the width of the ligament and the amount of space in the joint. The image will be saved to examine it after the study ends.

The next step will be to place your arm in a loop of a strap that will pull your wrist to the floor while keeping your elbow on the table. This is to simulate the effects of throwing and opening of the joint. If it is painful at all we will adjust the length of the strap. We will then repeat the same steps as before on the same elbow.

The last step is to examine the other arm in the same way. The opposite arm will be placed in the same position and examined twice again, once without the strap and again with the strap providing force. Once both arms have been scanned you will be free to go.

Where is the study going to take place, and how long will it take?

The study will take place in room 14 at the Bentson/Bunker Field House. The study will take up to 30 minutes.

What are the risks and discomforts?

There are no expected risks or discomforts from participating in this study. It may be uncomfortable to be in the position with the strap holding your arm down. If you feel that you need a break let the researcher know and we can stop the research until you are comfortable enough to participate again. If the discomfort is too much you may leave and we will not use your data.

What are the benefits to me?

You are not expected to get any benefit from being in this research study.

What are the benefits to other people?

This data could help future researchers develop risk factors for elbow injuries in baseball players. By collecting this data, the goal is to provide baseline data to those researchers so they can say for sure what factors contribute to elbow injury in baseball.

Do I have to take part in the study?

Your participation in this research is your choice. If you decide to participate in the study, you may change your mind and stop participating at any time without penalty or loss of benefits to which you are already entitled.

What are the alternatives to being in this research study?

Instead of being in this research study, you can choose not to participate.

Who will see the information that I give?

We will keep private all research records that identify you. Your information will be combined with information from other people taking part in the study. When we write about the study, we will write about the combined information that we have gathered. We may publish the results of the study; however, we will keep your name and other identifying information private. If you withdraw before the research is over, your information will be retained in the research record OR removed at your request, and we will not collect additional information about you.

Can my taking part in the study end early?

Your participation in the study is voluntary so if you choose not to participate fully, your data will not be used. You may, at any time, request the scanning to stop and you will be removed from the study.

What happens if I am injured because of this research?

If you receive an injury in the course of taking part in the research, you should contact Matthew Bummer at 623-825-6685 or Kara Gange at 701-231-5777. Treatment for the injury will be available including first aid, emergency treatment and follow-up care as needed. Payment for this treatment must be provided by you and your third party payer (such as health insurance or Medicare). This does not mean that you are releasing or waiving any legal right you might have against the researcher or NDSU as a result of your participation in this research.

What if I have questions?

Before you decide whether to accept this invitation to take part in the research study, please ask any questions that might come to mind now. Later, if you have any questions about the study, you can contact the researchers, Matthew Bummer at (623) 810-6685 or matthew.bummer@ndsu.edu, or Kara Gange at 701-231-5777 or Kara.Gange@ndsu.edu.

What are my rights as a research participant?

You have rights as a participant in research. If you have questions about your rights, or complaints about this research, you may talk to the researcher or contact the NDSU Human Research Protection Program by:

Telephone: 701.231.8908 or toll-free 1-855-800-6717

Email: ndsu.irb@ndsu.edu

Mail: NDSU HRPP Office, NDSU Dept. 4000, PO Box 6050, Fargo, ND 58108-6050.

The role of the Human Research Protection Program is to see that your rights are protected in this research; more information about your rights can be found at: www.ndsu.edu/irb .

Documentation of Informed Consent:

You are freely making a decision whether to be in this research study. Signing this form means that you have read and understood this consent form you have had your questions answered, and you have decided to be in the study.

You will be given a copy of this consent form to keep.

Your signature Date

Your printed name

Signature of researcher explaining study Date

Printed name of researcher explaining study