A COMPARISON OF ULNAR COLLATERAL LIGAMENT STRESS PROTOCOLS FOR ULTRASOUND IMAGING IN COLLEGE BASEBALL PLAYERS

An Independent Research Project

Presented to

The Faculty of the Marieb College of Health & Human Services

Florida Gulf Coast University

In Partial Fulfillment of the Requirements for the Degree of

Doctor of Science in Physical Therapy

By

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2019

APPROVAL SHEET

This independent research study is submitted

in partial fulfillment of the requirements for

the degree of

Doctor of Physical Therapy

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ACKNOWLEDGEMENTS

I would like to acknowledge all that have contributed to my professional and personal growth throughout graduate school and the independent research process. I would like to thank the Marieb College of Health & Human Services at Florida Gulf Coast University for providing the equipment utilized and the support I have received during my time here. Additionally, I would like to show appreciation to the faculty of the Doctor of Physical Therapy program and all clinical instructors that I've had for their encouragement, knowledge imparted, and their ability to bring out the best in their students. In particular, I would like to recognize and thank my research committee members, Dr. Arie van Duijn, Dr. Rob Sillivis, and Dr. Jacqueline van Duijn for their efforts to help me be successful with this project and furthering my understanding of healthcare research.

A special thank you to the Florida Gulf Coast University's baseball team and the athletic training staff for supporting and participating in my research project. Good luck to all of the players and staff throughout the rest of the season and in their future endeavors

Finally, I would like to recognize my family, friends, and classmates for their unwavering support, dedication, and love in the last three years. I appreciate your efforts more than you know.

TABLE OF CONTENTS

ABSTRACT

Introduction: Musculoskeletal ultrasound imaging (UI) is an increasingly popular and reliable tool in addition to physical examination for assessment of anatomical structures and injuries. Ulnar collateral ligament (UCL) injuries in baseball players are becoming more frequent and account for a large portion of missed playing time. Studies have suggested that the ligamentous laxity of the UCL can be a predictor for future injury. There has been an effort to develop a standardized test for ligamentous laxity of the UCL using UI. **Purpose:** The purpose of this study was to assess the effect of gravity and manually applied valgus forces on humeroulnar joint gapping (HJG) compared to rest in the throwing arm of NCAA Division I collegiate baseball players using UI. **Methods:** This was a non-experimental quantitative repeated measures study. Ten NCAA Division I collegiate baseball players (mean age 20.3 ± 1.3 SD yrs) with no history of UCL injury participated. Images were obtained with a Phillips Lumify L12-4 ultrasound unit under three different conditions of valgus force. For measurement one, the subjects throwing shoulder was fully supported with the subject positioned supine with the throwing shoulder at 90 degrees of abduction, 45 degrees of external rotation, and 30 degrees of elbow flexion. For measurement two the subject's forearm was unsupported with gravity applying a valgus force. For measurement three one clinician applied a 3 kg valgus stress using a handheld dynamometer (Hoggan Scientific MicroFET 2 hand held dynamometer) 20 cm distal to the medial epicondyle while also stabilizing the humerus. Post collection measurements were performed using a DICOM reader (MicroDicom DICOM viewer). The humeroulnar joint width measurements were taken from the distal edge of the trochlea and the proximal edge of the ulna in millimeters (mm). A Shapiro-Wilk test of normality was performed to determine whether the data followed a normal distribution. Due to the non-normal distribution of data, a Friedman Test was performed to assess whether a statically significant difference in HJG existed between the three groups. After a statistically significant difference between the three groups was found, three separate Wilcoxon Signed-Rank Tests were performed to assess for difference between pairs of groups. **Results:** There was a statistically significant increase in humeroulnar joint space with a gravity applied valgus force compared to rest ($Z = -2.807$, $p < .005$). There was also a statistically significant increase in humeroulnar joint space with a manually applied valgus force compared to gravity applied valgus force ($Z = -2.805$, $p < .005$). Finally, there was a statistically significant increase in humeroulnar joint space with a manually applied valgus force compared to rest ($Z = -2.81$ $p < .005$). **Conclusion:** A gravity induced valgus force can cause a statistically significant increase in HJG compared to rest, however further joint space opening was found when adding external valgus force. Further research is needed to investigate if the amount of HJG achieved through gravity is sufficient to identify ligamentous laxity.

INTRODUCTION

As more individuals are participating in baseball and other overhead throwing activities there has been a proportional increase in injuries to the upper extremity.[1] The medial structures of the elbow are particularly prone to injury due to the valgus stress placed upon these during repetitive throwing.[1] The anterior joint capsule, ulnar collateral ligament (UCL), and radial collateral ligament complex provide approximately 50% of the overall stability of the elbow.[2] The UCL is the main stabilizer between 30 and 120 degrees of elbow flexion when the valgus forces are highest.[2] Over time these repeated stresses may result in laxity and thickness changes in the UCL, as well as an increase in humeroulnar joint width indicative of a decreased ability to absorb forces and an increased risk of injury.[3-6] Several studies have suggested the amount of humeroulnar gapping at rest versus with valgus force applied to be a key predictor for UCL injury.[4,5,7] There is currently no agreed upon standard amount of applied valgus force to stress the UCL in either clinical or practical application.[5] If gravity alone is a sufficient force to gap the humeroulnar joint this would provide a less provocative, easier, and potentially cheaper method of stress UI of the UCL. In recent years Musculoskeletal Ultrasound Imaging (UI) has shown to be an effective and reliable method for demonstrating changes over time in both the UCL and humeroulnar joint width.[8,9] It is quicker, more readily accessible, and significantly less costly compared to magnetic resonance imaging (MRI), which is often referred to as the gold standard for soft tissue imaging.[10] The purpose of this study was to compare the amount of humeroulnar joint gapping at rest, as a result of a gravity applied valgus force, and as a result of a manually applied valgus force to the elbow in the throwing arm of collegiate baseball players.

LITERATURE REVIEW

Assessment Using UI

UI is a non-ionizing imaging modality used to asses a variety of musculoskeletal structures.[11] UI offers many advantages over traditional imaging methods. UI can investigate structures from a wider range of perspectives due to it being able to be moved readily from one anatomical segment to another producing real-time images.[12] It is free from adverse effects found in other imaging techniques such as exposure to radiation.[13] It is less costly for both patient and clinician.[12] In UI a sound wave emitting transducer is held against the skin with a coupling agent. These sound waves are absorbed, deflected, or reflected back to the receiver, forming an image of anatomical structures.[14] High density tissue such as bone reflects more sound waves compared to surrounding tissue and appears white in the image. Lower density tissue, such as fluid, reflects less sound waves and appears darker than the surrounding tissue.[14] The terms hyperechoic and hypoechoic are used to describe high and low density tissues respectively. UI has the additional benefit of requiring little training to perform reliably. One study measured the reliability of a novice UI operator assessing UCL thickness.[9] This study found a novice UI operator with two 30-minute training sessions can reliably assess UCL thickness at both the apex of the trochlea and mid-substance site between distal medial epicondyle and superficial common flexor tendon. It is quicker, more readily accessible, and non-invasive compared to magnetic resonance imaging (MRI), which is often referred to as the gold standard for soft tissue imaging.[10] MRI is also less effective at visualizing partial-thickness tears of the UCL.[4] Magnetic resonance arthrography (MRA) has been proposed to alleviate this issue, but has its own limitations including cost, length of time to record images, and its invasive nature.[1,4] High-level players may also be hesitant to have contrast injected into the elbow.[4] Both methods of image collection through magnetic resonance share the same pitfall of their static, 1-position nature.[8,15] A key advantage for UI in the realm of baseball is its ability to record real-time, dynamic images.[1] Images at both rest and with valgus force can be taken quickly gathered utilizing UI.

Recently UI has been evaluated in several research studies to assess its use in athletics for the early detection of injuries. One study investigated differences in humeroulnar joint width in 30 collegiate baseball players.[7] Images were taken of both throwing and non-throwing arms, with the study finding a significant increase in humeroulnar joint width in baseball players compared to a non-baseball control group. One of the first studies utilizing UI in baseball players investigated the anterior band of the UCL in 26 asymptomatic MLB pitchers.[15] In the pitching arm the study found an increase in band thickness, more hypoechoic foci and greater laxity when a valgus stress was applied. One study measured the reliability of a novice UI operator assessing UCL thickness.[9] This study demonstrated an operator can reliably assess UCL thickness with training similar to the clinician in this study. As studies have suggested humeroulnar gapping to be a predictor for UCL injury, it seems logical to use of stress UI as part of a comprehensive pre-season screening as well as with suspected injuries.[4,15] Studies have utilized varying amounts of force to assess gapping of the joint, with no standard amount being agreed upon. Studies at times also fail to mention where the force is being applied on the forearm, leading to further discrepancies in research. Gravity induced stress may provide a simple means of gapping the humeroulnar joint but has yet to be shown to gap the joint similarly to manual applied force methods.

Ulnar Collateral Ligament Injuries in Baseball

Professional baseball players are highly susceptible to UCL injuries with up to 10% of pitchers and non-pitcher positional players undergoing at least one UCL reconstruction in their careers one study found.[16] The same study showed 16% of all pitchers undergo reconstruction surgery compared to just 3% of position players. The impact of this injury cannot be understated, with only 53% of players returning to the same or higher level of play pre-injury.[17] The throwing motion imparts a strong valgus and extension force on the elbow, particularly during the rapid acceleration phase. This phase is notable for the large forward-directed force on the extremity accompanied by rapid elbow extension. This heavily loads the medial stabilizing structures and compresses the lateral compartment. The anterior band of the UCL takes the majority of the stress as its' fiber orientation places it under the greatest amount of stress when the elbow is flexed less than 90 degrees.[3] Injuries to the UCL may occur either acutely or with chronic repetitive stress.[5] In cases of chronic repetitive stress injuries it's thought that there is a point in time where structural changes in the UCL may be detectable using UI in otherwise asymptomatic players.[5] One UI study found anterior band abnormalities, namely hypoechoic foci, in asymptomatic major league professional baseball pitchers.[12] These hypoechoic foci are suggestive of the presence of fluid, indicative of degenerative change in the ligament.[12] The study showed greater stress induced joint widening comparing throwing and non-throwing arms. Other studies found that the anterior band was thicker and more likely to have hypoechoic foci, calcifications and greater amounts of laxity with valgus stress.[6,18] These findings were similar to those found during a 10 year cross-sectional study, which also identified thickening, greater presence of hypoechoic foci, and calcifications in the throwing arm UCL of professional baseball players.[5] A recent study performed humeroulnar joint width testing without valgus stress as well as with a 5.5lb force. After the season retrospective analysis was performed on the images taken from players who suffered UCL injuries during the season. They found players with gapping of more than 5.6mm had a six times greater risk of UCL injury.[4]

Validity/Reliability

Only one study to date by Bica et al[8] has measured the reliability of UI for measuring humeroulnar joint width. This study found UI to be a reliable and precise method for demonstrating change in the amount of humeroulnar joint width with an intraclass correlation coefficients of 0.75 – 0.94. An ICC of .6 or greater is considered good reproducibility and values greater than .75 being excellent. Other studies have measured the reliability of observing the width of the anterior band of the UCL in non-athletic healthy volunteers.[18] In this study researchers found an ICC of 0.853, 0.738, and 0.698 in the proximal, middle, and distal thirds respectively of the UCL in the right elbow. For the left elbow ICC was found to be 0.890, 0.773, 0.717. ICC is a descriptive statistic used to describe how strongly units in the same group resemble each other. One study found an ICC of between .861 and .935 for novice UI operator to assess the thickness of the UCL in collegiate baseball pitcher's, demonstrating excellent reproducibility with minimal training.[9]

PURPOSE

UI has been shown to be a reliable method for evaluation of UCL integrity in valgus related baseball injuries.[5-7,10,15] Even in absence of symptoms suggestive of structural change, there may still be detectable changes in the UCL.[5] A valgus force applied by gravity would be better tolerated and more easily reproducible compared to a manually applied valgus force., especially in acute injury situations. There are no known studies to date that compare humeroulnar joint width measurements taken when a standardized valgus force is manually applied versus a gravity applied valgus. This study intends to answer the questions: Is there a significant increase in humeroulnar joint gapping (HJG) with gravity applied valgus force compared to rest in the throwing arm of NCAA Division I collegiate baseball players using UI? Is there a significant difference in humeroulnar joint width (HJG) comparing a manually applied valgus force to a gravity applied force in the throwing arm of NCAA Division I collegiate baseball players using UI?

METHODS

Study Design

This was a non-experimental quantitative repeated measures study design. This study was performed at Florida Gulf Coast University (FGCU) and was approved by the University Institutional Review Board. All participants provided written consent prior to data collection.

Participants

Ten participants were recruited from a NCAA Division I collegiate baseball team. Division I Collegiate Baseball Players. Additional players declined to participate due to apprehension to the stress testing protocol, despite the low levels of force used compared to forces experienced during the throwing motion. Inclusion criteria required participants to be active members on the baseball team. Exclusion criteria were limited to participants who had previously undergone UCL reconstruction.

Procedure

Images were obtained with a Phillips Lumify L12-4 ultrasound unit that was provided by the Department of Rehabilitative Sciences at Florida Gulf Coast University. For all measurements subjects were positioned supine with the throwing shoulder at 90 degrees of abduction, 45 degrees of external rotation, and 30 degrees of elbow flexion and full supination.[9] For measurement 1 the subjects throwing shoulder was fully supported in the position previously described. For measurement 2 the subject's forearm was unsupported with gravity applying a valgus force. For measurement 3 one member of the team's sports medicine staff applied a 3 kg valgus stress using a Hoggan Scientific MicroFET 2 handheld dynamometer 20 cm distal to the medial epicondyle while also stabilizing the humerus while the researcher perform the UI. 3kg of force applied 20 cm distal to the axis will result in 5.9 Nm of valgus stress.[9]

Post collection measurements were performed using the MicroDicom DICOM viewer. The humeroulnar joint width measurements were taken from the distal edge of the trochlea and the proximal edge of the coronoid process of the ulna in millimeters (mm).[19] The mean of three measurements from each image was used for data analysis.

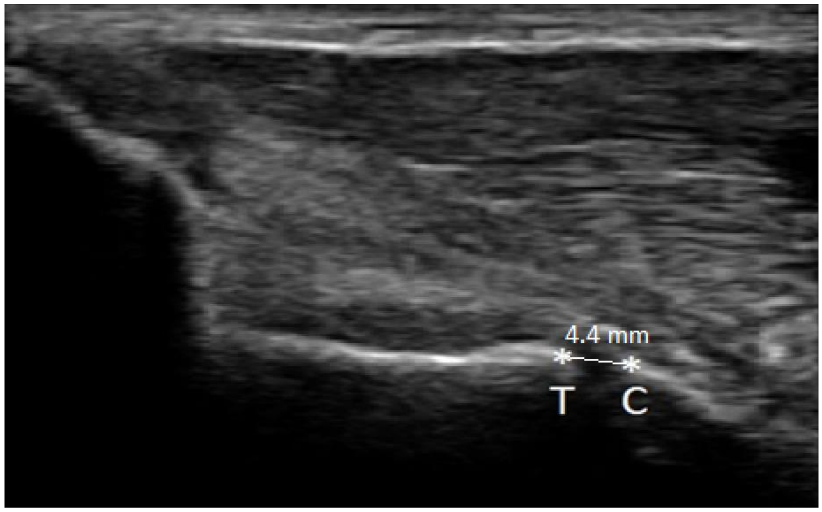

Figure 1.
Ultrasound image of collegiate baseball player medial elbow at rest showing humeroulnar joint width (asterisks). T, trochlea; C, Coronoid Process.

DATA ANALYSIS

The data was analyzed using Version 25 of IBM SPSS. All collected data was manually entered into Microsoft Excel and later exported to SPSS for analysis. A Shapiro-Wilk test of normality was performed to determine whether the data followed a normal distribution. Due to the non-normal distribution of data, a Friedman Test was performed to assess whether a statically significant difference in HJG existed between the three groups. After a statistically significant difference between the three groups was found, three separate Wilcoxon Signed-Rank Tests were performed to assess for difference between pairs of groups. The alpha level was set at 0.05.

RESULTS

The 10 participants included in the study consisted of three freshman, one sophomore, four juniors, and two seniors. Seven were right-handed throwers and three were left-handed throwers. There were eight pitchers and two outfielders. The mean age of the participants was

20.3 ± 1.3 SD years (range, 18 to 22), mean height of 72.6 ± 1.9 SD inches (range, 69 to 75), and mean weight of 188 ± 19 SD pounds (range, 160 to 215). Table 1 contains all data used for the descriptive statistics listed above.

Table 1. Participant Demographic Data

Participant	Throws	Class	Age	Height (in)	Weight (lbs)	Position
Player 1	Right	Junior	21	75	215	Pitcher
Player 2	Right	Junior	21	74	205	Pitcher
Player 3	Left	Senior	22	71	170	Pitcher
Player 4	Right	Senior	22	72	175	Pitcher
Player 5	Right	Junior	20	72	210	Pitcher
Player 6	Right	Sophomore	20	75	210	Pitcher
Player 7	Left	Freshman	19	73	185	Pitcher
Player 8	Right	Junior	20	71	170	Outfielder
Player 9	Right	Freshman	18	74	180	Pitcher
Player 10	Left	Freshman	19	69	160	Outfielder

Tables 2 through 4 contains all measures taken during data collection.

Table 2. Humeroulnar Joint Width – Measurement 1

	Measurement 1	Measurement 2	Measurement 3	Mean Score
Player 1	7.1	7.4	7.2	7.2
Player 2	4.3	4.4	4.4	4.4
Player 3	3.3	3.7	4.3	3.5
Player 4	3.2	3.2	3.1	3.2
Player 5	3.3	3.4	3.3	3.3
Player 6	3.8	3.9	3.8	3.8
Player 7	4.6	4.6	4.8	4.7
Player 8	4.9	5.3	5.1	5.1
Player 9	3.5	3.6	3.6	3.6
Player 10	3.5	3.8	3.7	3.7

Table 3. Humeroulnar Joint Width – Measurement 2

	Measurement 1	Measurement 2	Measurement 3	Mean Score
Player 1	7.8	7.9	7.8	7.8
Player 2	4.9	5	4.9	4.9
Player 3	5.1	5.3	5.2	5.2
Player 4	3.5	3.5	3.6	3.5
Player 5	3.7	3.8	3.8	3.8
Player 6	4.2	4.2	4.3	4.2
Player 7	5.6	5.5	5.4	5.5
Player 8	5.6	5.7	5.7	5.7
Player 9	4.3	4.4	4.2	4.3
Player 10	5.4	5.2	5	5.2

Table 4. Humeroulnar Joint Width – Measurement 3

	Measurement 1	Measurement 2	Measurement 3	Mean Score
Player 1	8.8	8.8	8.6	8.7
Player 2	5.3	5.2	5.4	5.3
Player 3	7	7.1	6.9	7
Player 4	4.8	4.7	4.7	4.7
Player 5	5.3	5.2	5.4	5.4
Player 6	5.2	5.4	5.2	5.2
Player 7	6	6.1	6.2	6.2
Player 8	6	6.3	6.2	6.2
Player 9	6.2	6.1	6	6
Player 10	5.7	5.4	5.6	5.6

Table 5 contains descriptive statistical analysis of the measures taken.

Table 5. Protocol Group Descriptive Statistics

	N	Mean	Std. Dev.	Min	Max
Measurement 1	10	4.25	1.21	3.2	7.2
Measurement 2	10	5.01	1.22	3.5	7.8
Measurement 3	10	6.04	1.10	4.7	8.7

The Friedman Test determined that there was a statistically significant difference in joint width (Chi square = 20.00, $p < .001$, df = 2) found among the three measurements. Wilcoxon

Signed-Rank tests then were used to identify which group differed significantly from one another. The Wilcoxon Signed-Rank Tests demonstrated that there was a statistically significant increase in humeroulnar joint space with a gravity applied valgus force compared to rest Z = -2.807, p < .00501. There was also a statistically significant increase in humeroulnar joint space with a manually applied valgus force compared to gravity applied valgus force Z = -2.805, p < .00503. Finally, there was a statistically significant increase in humeroulnar joint space with a manually applied valgus force compared the same position without stress Z = -2.81 p < .00495.

Table 6. Friedman Test

	N	Chi square	df	Asymp. Sig.
Joint Width	10	20.0	2	.000

Table 7. Wilcoxon Signed-Rank Tests

		Mean	Std. Dev.	Std. Error Mean	Test Statistic	Asymp. Sig. (2 tailed)
Pair 1	Measurement 1 & Measurement 2	4.63	1.25	.28	-2.807	.00501
Pair 2	Measurement 2 & Measurement 3	5.53	1.27	.28	-2.805	.00503
Pair 3	Measurement 1 & Measurement 3	5.15	1.47	.33	-2.81	.00495

DISCUSSION

Prior to this study, there had been no studies that assessed HJG with gravity and manually applied valgus stress compared to rest under the conditions described in this study. A previous study by Ciccotti et al[5] involving 368 professional baseball pitchers demonstrated similar humeroulnar joint width with manual valgus force compared to this study, but did not assess gapping with gravity.[5] This current study observed a statistically significant ~18% increase in HJG compared to rest and the manual force causing a statistically significant ~21 increase in HJG compared to gravity force. This suggests a linear relationship between joint width and valgus stress. Other important differences between this study and the prior one are that the study made no specific mention of the position shoulder during imaging and only states the elbow was placed at 30 degrees of flexion.[5] The study also utilized 150 N of force directly proximal to the humeroulnar joint as opposed to the 5.9 N utilized in this study. There was no mention of why 150 N of force was used. The level of force used in this study was selected as a previous study determined this protocol to be reliably performed by a novice clinician as was the case in the current study.[9]

This study demonstrated a statistically significant increase in HJG exists with a gravity applied valgus stress compared to at rest. The most common method of diagnosing a ligamentous laxity in baseball players is a comparison of laxity between the throwing and non-throwing arm.[4,5,15] Other studies have shown a greater amount HJG occurs in the throwing arm of baseball players compared to their non-throwing arm with a manually applied valgus force.[4,5] This study suggests gravity alone would result in increased joint space opening in normal subjects, but further joint space opening can be attained by applying an external stress force.

Gravity Stress UI protocols would be quicker and less provocative for players, and would also forgo the need for additional equipment in order to apply a specific manual force. It is unclear if the amount of joint opening obtained under gravity is sufficient to identify ligamentous laxity, therefore future studies should include subjects with known ligament laxity or disrupted ligament integrity.

There are a number of limitations with this current study. The application of 3 kg of force with a handheld digital dynamometer can be difficult to maintain throughout the image recording process. Another limitation is the small sample size as well as the inclusion of two non-pitcher players. Future studies with larger sample sizes shoulder separate players based on position to see whether the results of this study apply to a broader population. There was also the potential that the gravity induced valgus stress prior to manually applied stress could have caused an increase in HJG, but that would not influence the results compared joint width at rest versus a gravity applied force. The order of protocols was chosen to minimize this risk as well as reduce the risk of pain provocation in the subjects. There was also no control for pre-imaging activities of the subjects. The majority of images were taken as the players returned from practice, which may acutely influence the gathered results. It is thought that any acute changes caused by practice would manifest uniformly in the amount of joint gapping during the three protocols and thus not affect the results. Future studies should perform assessment of both throwing and non-throwing elbows to determine if the results from this study apply to the non-throwing arm. The current studies primary focus was the throwing arm of players so images of the non-throwing arm were not taken.

CONCLUSION

Several studies have suggested that the amount of ligamentous laxity of the UCL can be assessed using a valgus stress compared to rest.[4,5,7] This study demonstrated that a gravity applied valgus force can provide a statistically significant amount of HJG in the throwing arm of collegiate baseball players compared to rest. A protocol using only gravity applied force would be easier, potentially cheaper, and less provocative allowing examination in acute injuries where additional stress cannot be tolerated, however it is unknown if the amount of joint space opening attained via gravity stress is sufficient to identify ligament laxity or disruption. Future should include larger sample sizes, subjects with known ligament laxity, and analysis to assess whether the amount of HJG that occurs with gravity applied force is a predictor for future UCL injuries.

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