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# COMPARISON OF GLENOHUMERAL INTERNAL ROTATION DEFICIT (GIRD) AND HUMERAL RETROVERSION IN COLLEGE BASEBALL PITCHERS OVER THE COURSE OF A COMPETATIVE SEASON

Shawn T. Huntsman

*Shawn Tyler Huntsman*, [tylerhuntsman1012@gmail.com](mailto:tylerhuntsman1012@gmail.com)

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COMPARISON OF GLENOHUMERAL INTERNAL ROTATION DEFICIT (GIRD) AND  
HUMERAL RETROVERSION IN COLLEGE BASEBALL PITCHERS OVER THE COURSE  
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by

Shawn T. Huntsman

B.A., ATC, Buena Vista University 2013

A Research Paper  
Submitted in Partial Fulfillment of the Requirements for the  
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Department of Kinesiology  
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RESEARCH PAPER APPROVAL

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Approved by:

Juliane P. Wallace

M. Daniel Becque

Graduate School  
Southern Illinois University Carbondale  
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# CHAPTER 1

## INTRODUCTION

Shoulder and elbow injuries are the most common injuries in overhead sports, specifically baseball. Shoulder injuries account for an estimated 22% of all days on the disabled list (DL) for pitchers that play in Major League Baseball (Conte, Requa, & Garrick, 2001). Medical care and attention to fine details regarding pitchers makes all the difference for the longevity of the success throughout a career. Any irritation that a pitcher feels could be the difference in a season ending surgical procedure or an injury free season. Throughout the sports medicine realm there is a vast array of information pertaining to the care and maintenance for pitchers. There is no such thing as knowing too much information about the shoulder. Whether athletes are aiming to prevent shoulder injuries or rehabilitate from a previous surgical procedures; the more information gathered and put to use, the better the outcome and care for the athlete. This research paper will address the Glenohumeral Internal Rotation Deficit and Humeral Retroversion and how the two are related specifically over the course of a competitive season.

To fully understand the forces that the glenohumeral joint undergoes during the throwing motions, first you must understand the biomechanics that the body undergoes during the throwing motion. For starters, the windup phase involves the raising of the stride leg to begin the motion. During this time potential energy is stored within the muscles by contracting both eccentrically and concentrically, this will allow for the rapid acceleration that is needed to be efficient for any overhead athlete. Secondly, the cocking phase, which incorporates abduction and maximal external rotation of the shoulder and ends as the body tilts towards the non-throwing side. During this time, the stress on the anterior capsule of the shoulder is at its highest.

Acceleration at the glenohumeral joint occurs next and begins when the humerus starts internally rotating and adducting from a maximally external rotated position. This phase is intriguing because of the acceleration and deceleration that must occur for the glenohumeral joint to maintain its stability throughout the motion. During this time, the speed of the arm increases significantly from near zero degrees per second to almost 7500 degrees per second until the end of acceleration in a time of 50 msec (Prentice, 2009). Lastly, the follow-through is when the support leg that the pitcher is initially standing on during the windup phase moves forward and contacts the ground to stop the body's motion. During this phase, the musculature must decelerate the arm, most specifically the rotator cuff muscles must prevent the humerus from being distracted to the point of dislocation (Wilk, Reinold, & Andrews, 2009).

Due to the high velocity and forces that the glenohumeral joint must withstand, it is common for the body to adapt the forces that are placed upon it, similar to those explained by Wolff's Law. One of the common adaptations that are seen in baseball pitchers is in the form of humeral retroversion (Hibberd, Oyama, & Myers, 2014). Humeral retroversion is defined by the direction, of torque about the long axis of the humerus, tends to rotate the distal end of the humerus externally relative to the proximal end. This torque therefore causes humeral retroversion over time at the weak proximal humeral epiphyseal cartilage (Wilk et al., 2009). Increased maximal external rotation has been linked with greater retroversion. During the repeated stress of each throw the pull that is created on the proximal head of the humerus creates a torsion of the bone that causes the twisting mechanism that results in humeral retroversion when the bone becomes mature and the growth plates close (Hibberd, et al. 2014). The reason that this occurs is because it allows the articulating surface of the humeral head to remain in contact with the glenoid articulating surfaces while the glenohumeral joint externally rotates to a



higher degree before it is constrained by the anterior capsule (Reagan, Meister, Horodyski, Werner, Carruthers, & Wilk, 2002). This increase in external rotation allows for an increase in velocity when throwing objects, such as a baseball, and why this may be beneficial to an overhead athlete. However, retroversion of the humerus also predisposes the body for injury by placing an increased amount of stress on the shoulder girdle and rotator cuff musculature, due to the lack or decrease in internal rotation.

Several studies have shown a relationship between glenohumeral internal rotation deficit (GIRD) and an increase in shoulder injuries in baseball players (Hibberd, Oyama, & Myers, 2014). GIRD can be defined by a loss of 20 degrees or more of internal rotation as compared bilaterally (Wilk et al., 2009). GIRD is determined by measuring the rotational deficit that is seen when comparing limbs bilaterally in an individual, typically seen in internal rotation and is often exacerbated in professional baseball players. A typical range that is seen in this patient population is anywhere from 10-17 degree difference for the non-dominant limb (Hibberd, et al. 2014). This offset is seen because of an increase in external rotation that is common amongst baseball players due to the repetitive throwing motion, since the constant throwing motion and constant stretch of the supporting musculature along with lack of stretch for the opposing motion. When an increase in external rotation develops a decrease in internal rotation is seen as an offset this adaptation typically in the form of one degree of internal rotation for every degree gained in external rotation, which in turn leads to GIRD in these athletes.

When compared bilaterally, the range of motion of the shoulder is likely to show significant differences due to musculature adaptations as well as bony adaptations (Dwelly, Tripp, B., Tripp, P., Eberman, & Gorin, 2009). In all reality, this statement can be made for any joint or muscle in the body, especially bodies that repetitively produce the same unilateral motion time

after time such as pitching. Dwelly et al. (2009) refers to the adaptations in college pitchers' shoulders due to repetitive pitching at high velocities. Reagan et al. (2002) define these repetitive high velocities as generating 7000 degrees per second of humeral angular velocity while torques exceed 14,000 inch-pound.

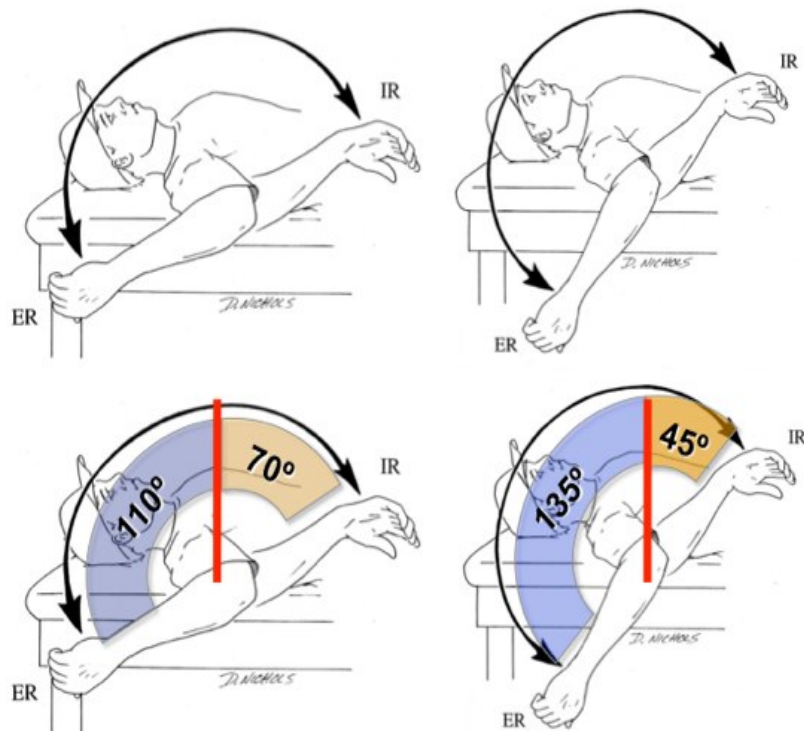
The more external rotation that is available within the glenohumeral joint the more velocity that a pitcher can generate when throwing. However, from a sports medicine realm, this increase in external rotation and a loss of internal rotation does not always mean a positive outcome. Despite the immense number of osseous or soft tissue adaptations that can take place in a pitching arm, glenohumeral retroversion and glenohumeral internal rotation deficit (GIRD) are the two big adaptations worth examining. GIRD is defined as glenohumeral internal rotation deficit, or the decrease in internal rotation (IR) especially when compared bilaterally. Furthermore, when "IR decreases as compared to its bilateral partner and beyond the increase in ROM or gain of ER the condition is considered GIRD," (Dwelly et al. 2009, p. 612). However, there is some controversy over this definition and if it is too "elementary." This would allow for more diagnoses of GIRD than the actual true cases.

Basic goniometer measurements define normal range of motion (ROM) for internal rotation would be approximately 70 degrees (Kevern, Beecher, & Rao, 2014). Based on the very misunderstood definition of GIRD anything less than 70 degrees internal rotation would be considered a case of GIRD. However, Reinold (2013) has helped address what "normal" ROM in overhead athletes actually is. Logistically, all pitchers are different. Their external rotation measurements are all different, which is where velocity is derived from, meaning, not all pitchers can throw 100mph. Reinold (2013) examined 15 years worth of research, which showed that the pitchers dominant arms exhibit an increase in external rotation and subsequent decrease in

internal rotation. So, if we were to use the basic concept definition of GIRD, that would mean there are 15 years worth of GIRD cases in a majority of baseball pitchers of all ages, which is highly unlikely.

Reinold (2013) believes that in order to define or diagnose GIRD, we should not just look at the ROM of internal rotation, but, assess the total arc (Figure 1): external rotation and internal rotation added (normal goniometer says 180 degrees for a full arc). In several publications that Reinold (2013) reviewed, the dominant arm internal rotation was well below the “norm” of 70 degrees and was around 40-60 degrees, but that lack of internal rotation was made up for by an increase in external rotation. This still allowed the arc to be 180 degrees or more.

Figure 1



Humeral retroversion of the humerus is defined by the acute angle, in the medial and posterior directions, between the axis of the elbow joint and the axis through the center of the humeral head (Reagan et al. 2002). Reagan et al. (2002) implies that retroversion is produced as a result from muscular forces about proximal humerus that act in constant opposition. An increase in humeral retroversion allows the articulating surface of the humeral head to remain in contact with the glenoid articulating surfaces while the glenohumeral joint externally rotates to a higher degree before the humeral head is constrained by the anterior capsule. Similarly, “changes in humeral retroversion also may provide an explanation for the decrease in internal rotation characteristic of overhand throwing athletes,” (Reagan et al. 2002, p. 355). It has also been speculated by numerous sources that during youth, humeral retroversion can be manipulated into an increasing fashion. It is assumed that before the epiphyseal plates in the humerus have closed in youth populations, that if they partake in adequate amounts of throwing/pitching they will torque the humerus in an external fashion. Before the epiphyseal plates in the humerus have closed, if youth populations partake in an increased amount of throwing/pitching, they will torque the humerus into an external position. This allows them to have a large amount of humeral retroversion in their dominant throwing arms when compared bilaterally.

Humeral retroversion can be viewed as a positive transformation from the pitchers eyes, as it gives them an increase in external rotation. Reagan et al. (2002, pg. 355) describes an “increase in humeral retroversion allows the articular surface of the humeral head to remain in contact with the glenoid articulating surfaces while the glenohumeral joint externally rotates to a higher degree before the humeral head is constrained by the anterior capsule.” This increase in external rotation can potentially lead to an increase in ball velocity. However, on the down side

an increase in humeral retroversion will decrease internal rotation, which will increase the pitchers susceptibility to injury. Reagan et al. (2002) explains that an increase in humeral retroversion may also provide the explanation for the decrease in internal rotation, due to the restraint of the humeral head by the posterior capsule.

The purpose of this study was to determine the effects that an intercollegiate season has on college pitchers shoulder range of motion. This study takes an in depth look at the change in ROM, specifically internal rotation and if there is any loss compared to pre-season measurements. It is hypothesized that participants will develop GIRD over the course of the season, represented by a decrease in internal rotation. Furthermore, all measurements will portray a negative value over the course of the season.

## CHAPTER 2

### METHOD

#### Participants

Approval from the Human Subject Committee was acquired prior to obtaining university official records from the Sports Medicine department, in which approval from the Head Athletic Trainer was granted. All data were collected from existing, range of motion measurements from the university baseball team. All data entries were recorded in athlete's personal medical files in regard to the health and well-being of the athletes as part of their university athletic participation. Participants consisted of 17 university baseball pitchers ( $M$  age = 19.76 years,  $SD$  = 1.3). Right-handed dominant participants consisted of 13 while four were left hand dominant. All participants were considered highly active individuals. During the time of the first trial measurement (control measurement), all participants were free of all shoulder pain and shoulder injury. Three participants had previous surgical procedures on their elbows prior to all measurements, but had been cleared back to full participation by orthopedic physicians.

#### Apparatus and Task

All measurements were taken using a 12-inch BASELINE™ goniometer. This device measures 360 degrees and calibrated to be used with the IOSM (International Standards of Measurements) system. The BASELINE™ goniometer reads in 1-degree increments and has a single linear arm that reads in inches and centimeters. The BASELINE™ goniometer was used to measure participants shoulder ROM, which consisted of: flexion, external rotation, internal rotation, horizontal abduction, and a clinical version of glenohumeral retroversion (Figure 2). These motions were measured using a protocol similar to Wilk, Reinold, Macrina, Porterfield, Devine, Suarez, & Andrews (2009). Internal and external rotation was measured by stabilizing

the humeral head (placing the palm of the hand over the clavicle, coracoid process, and humeral head). The patient was positioned supine with the shoulder at 90 degrees of abduction and approximately 10 degrees of horizontal adduction (scapular plane). The fulcrum of the goniometer was placed over the olecranon process of the elbow. Flexion allowed for the fulcrum to be placed over the gap between the humeral head and the glenoid fossa while the humeral shaft was placed into full flexion. Lastly, horizontal abduction placed the elbow into 90 degrees with the humerus in 90 degrees flexion. The fulcrum of the goniometer was placed over the acromial process.

Figure 2



## Procedures

The study used a within-participant design to assess differences in shoulder movement throughout a collegiate baseball season. All measurement sessions were held in a controlled private room. All participants went through the same measurements in the same fashion with the same two clinicians. Participants were scheduled for their measurements prior to any baseball related activities for the day, specifically in the morning so that there was no influence of exercise on the measurements.

Measurements were taken on four separate occasions throughout a single competitive season. The first trial was early in the fall season prior to any offseason training from a baseball

related spectrum, this trial served as the control measurement. The second measurement trial was just prior to the opening weekend of the season. The third trial was at the half way mark of the season, while the fourth trial was just after the season had finished.

For all measurement sessions, participants would enter the clinic and lie in a supine position. Participants were then instructed to place feet flat on the table with their knees bent similar to the dorsal recumbent position. This position allows for the lumbar curvature to be decreased, which then allows for the latissimus dorsi to lay flat on the table, thereby decreasing activation in shoulder motion. From here, participants were asked to allow their dominant arm to relax for measurements.

The researchers would then manipulate the participant's dominant arm into shoulder flexion, external rotation, internal rotation, horizontal abduction, and glenohumeral retroversion. The researcher would feel for an end point in the joint, which represented the participant's maximum range of motion for that specific motion. The goniometer measurer would now use the BASELINE™ goniometer to measure the shoulder motion. The fulcrum would constitute where the movement was taking place in the shoulder joint while the movement arm laid across the extremity, which was being manipulated, into the respected motion. After the goniometer measurer found the degrees of motion for the motion, the number was recorded into a coded spreadsheet for that participant. This process was completed for all measurements over the course of all four trials.

Throughout the course of the season, some participants experienced injuries and surgical procedures. The study started with seventeen (N = 17) participants, but ended with fourteen (N = 14) after one shoulder surgical repair and two late season ulnar collateral ligament (UCL) repairs, which placed the participants into motion limited splints. The third measurement trial



saw one participant disqualified after a UCL repair. The fourth trial saw an additional two disqualified; one from a labrum reconstruction and the other from UCL repair. These three participants measurements from the first two trials are represented in the data.

### **Statistical Analyses**

Anthropometric details of the pitchers are presented as means +/- SEM. Analysis of variance (ANOVA) with repeated measures on time (trials) was conducted on the dependent variables of Flexion, External Rotation, Internal Rotation, Total Arc, Horizontal Abduction, and Glenohumeral Retroversion. Where differences in trials were indicated by the repeated measures ANOVA, Tukey post hoc analysis was conducted to determine significant differences between the trials across the baseball season (PASW Statistics 18). All data are presented as means +/- SEM with a significance level of  $p < .05$ .

## CHAPTER 3

### RESULTS

As referred to in Table 1, participants consisted of 17 university baseball pitchers ( $M$  age = 19.76 years,  $SD = 1.3$ ). Right-handed dominant participants consisted of 13 while four were left hand dominant. Participants mean height was 188.26 cm ( $M = 74.12$  in) with a range of 180.34-195.58 cm (71-77 in.), and a mean weight of 92.91 kg ( $M = 204.41$  lbs.) with a range of 72.57-120.2 kg (160-265 lbs.). All participants were considered highly active individuals. During the time of the first trial measurement (control measurement) all participants were free of all shoulder pain and shoulder injury.

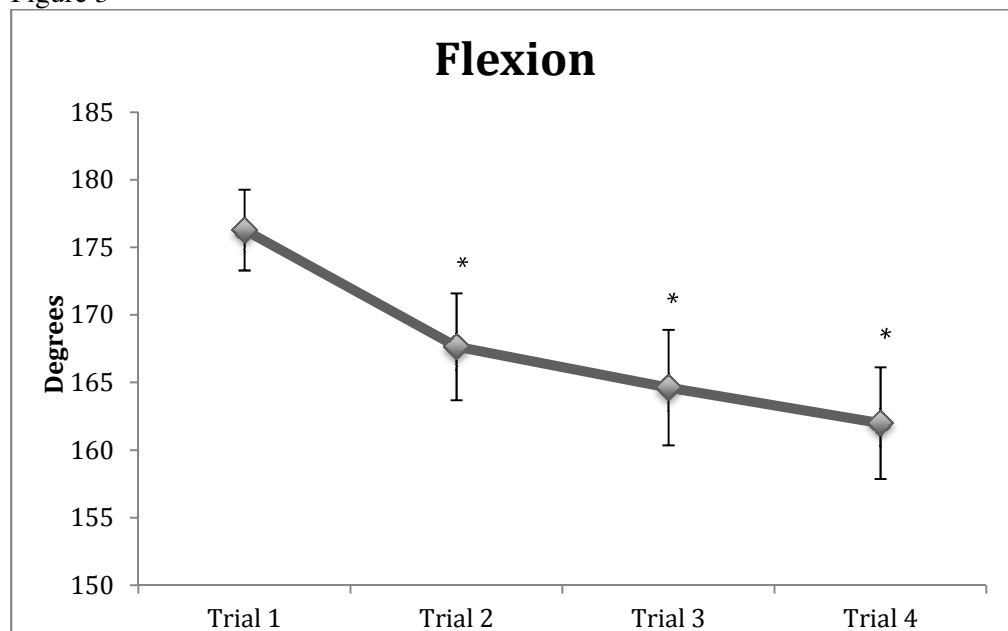
Table 1.

<i>PARTICIPANTS (N=17)</i>				
	<b>Min.</b>	<b>Max.</b>	<b>Mean</b>	<b>Std. Error</b>
<b>Age</b>	18	22	19.76	0.32
<b>Height (cm.)</b>	180.34	195.58	188.26	1.78
<b>Weight (kg.)</b>	72.72	120.45	92.91	3.02
<b>Right-Hand Dominant – N=13</b>			<b>Left-Hand Dominant – N=4</b>	

Figures 3 – 8 show the data for the 14 participants who completed all of the measurements. Figure 3 illustrates flexion trends over the course of the research. Flexion decreased throughout the season compared to the control trial ( $p < .05$ ; Figure 3). External rotation was significantly decreased in trials two and three compared to baseline ( $p < .05$ ), but trial four was not different than baseline assessment (Figure 4.). However, there was a decrease in external rotation in trial four as compared to trial one, there was an increase as compared to other trials. Internal rotation declined significantly across the season compared to baseline ( $p < .05$ ; Figure 5). Internal rotation fell from 59 degrees (trial 1) down to 50 degrees (trial 4) over the course of the season.

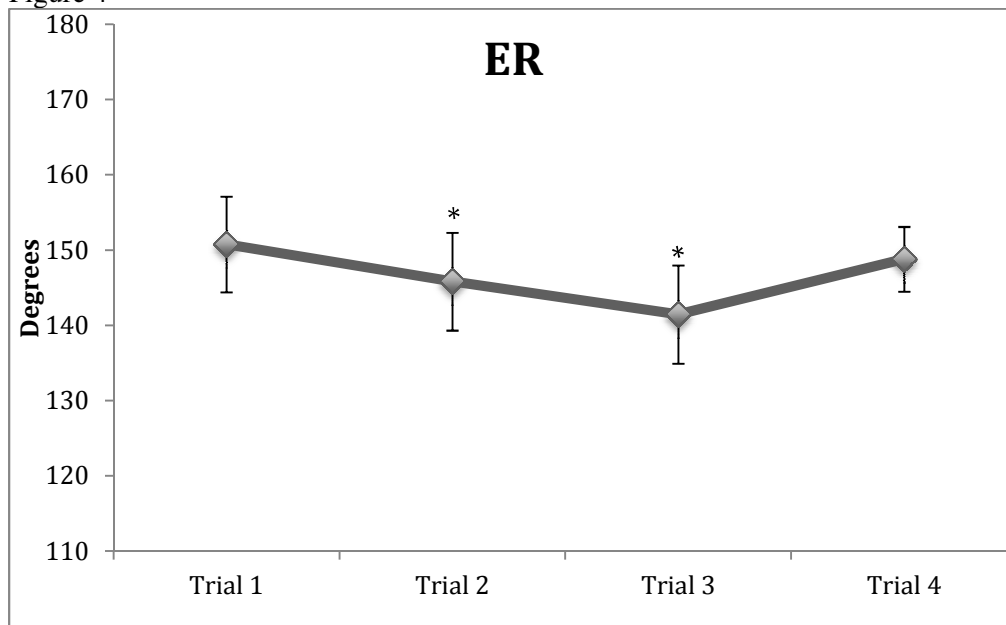
Figure 6 portrays the total arc motion of internal rotation and external rotation added together. Total arc motion decreased significantly from baseline in trials two and three ( $p < .05$ ), but not different from baseline in trial four (Figure 6.). Figure 7 illustrates horizontal abduction over the course of the season, there was no significant change in horizontal abduction across the baseball season. Glenohumeral retroversion did not change significantly over the course of the season (Figure 8).

Figure 3



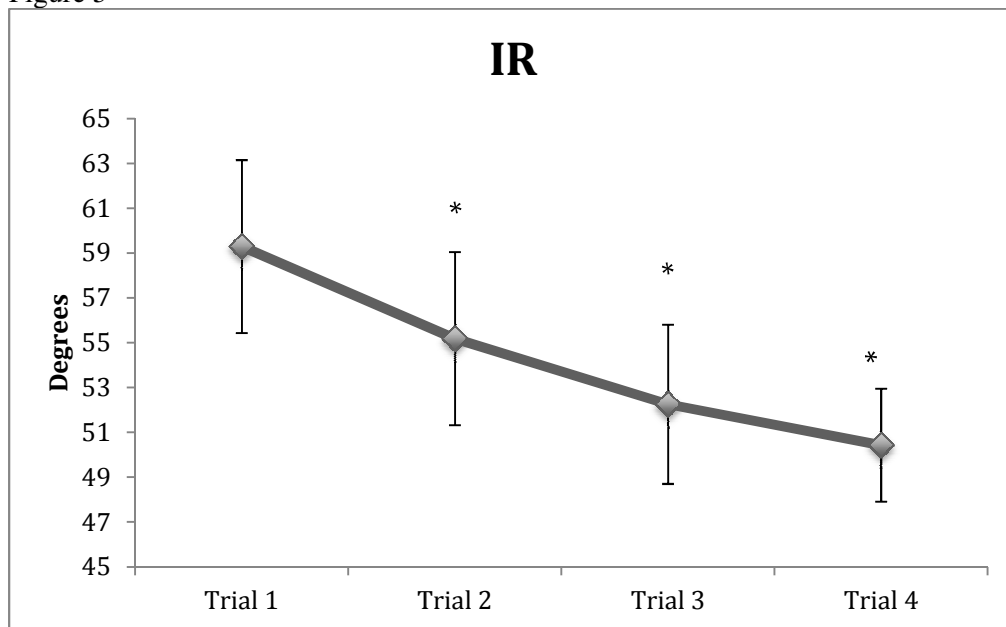
values represent: mean, +/- SEM, statistical significance (\*)

Figure 4



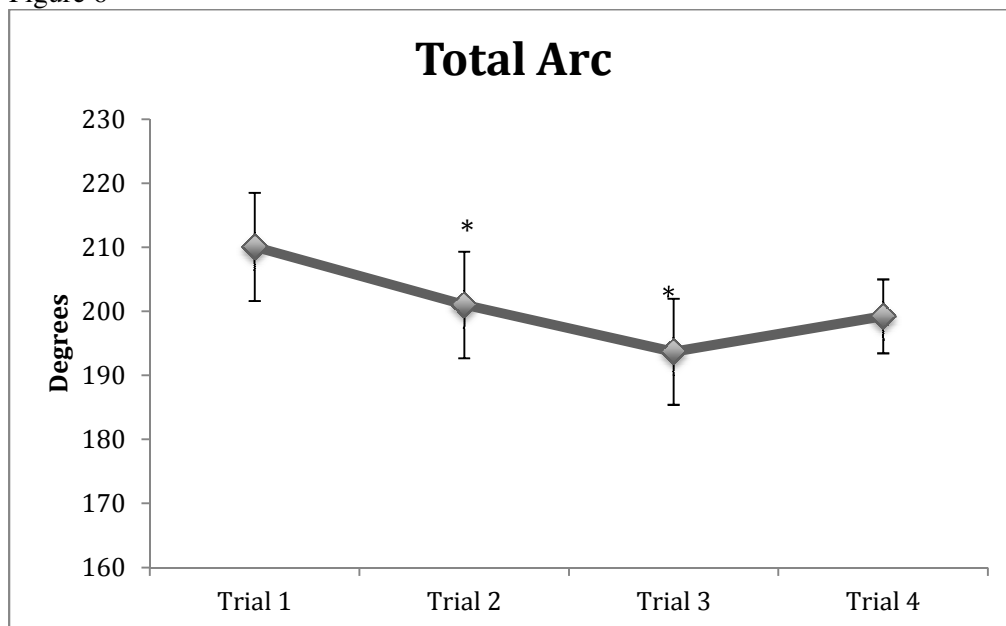
values represent: mean, +/- SEM, statistical significance (\*)

Figure 5



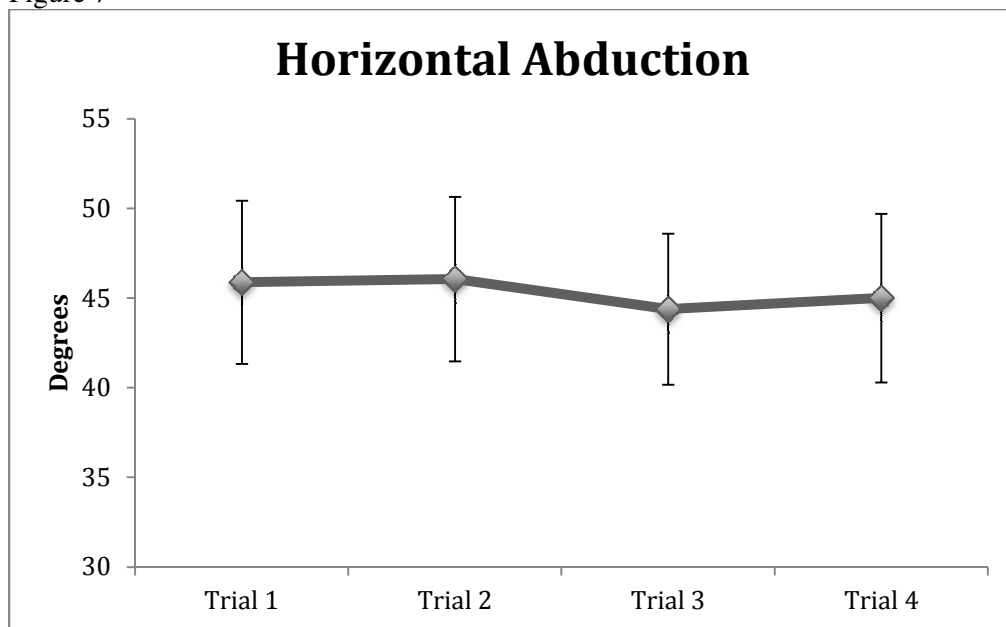
values represent: mean, +/- SEM, statistical significance (\*)

Figure 6



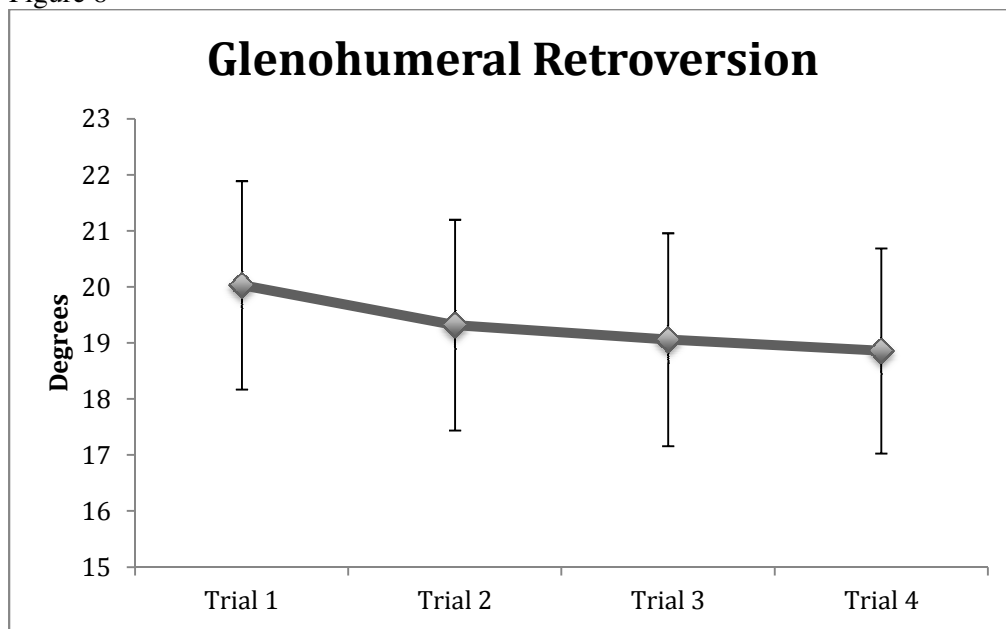
values represent: mean, +/- SEM, statistical significance (\*)

Figure 7



values represent: mean, +/- SEM, statistical significance (\*)

Figure 8



values represent: mean, +/- SEM, statistical significance (\*)

## **CHAPTER 4**

### **DISCUSSION**

The purpose of the current study was to investigate the effects of an intercollegiate baseball season on college pitchers' shoulder range of motion. This study took an in depth look at the change in ROM, specifically internal rotation and if there was any loss compared to pre-season (controlled) measurements. The hypothesis of this study was supported from the findings that pitchers tend to develop GIRD over the course of a season.

It was predicted that throughout the season internal rotation would have a gradual decrease across the trials, while other movements would decrease as compared to control trials.

Shoulder internal rotation during a baseball pitch is the fastest human movement recorded at 7250 degrees per second (Fleisig, Andrews, Dillman, & Escamilla, 1995). The shoulder torque generated is approximately 60 N/m near the instant of maximal external rotation. From the repetitive torques, pitchers exhibit an excessive amount of external rotation of the glenohumeral joint (Wilk, Macrina, Fleisig, Porterfield, Simpson, Harker, & Andrews, 2011). As mentioned earlier by Reinold (2013), this excessive external rotation in pitchers could equate to the decrease in internal rotation when viewed from the total arc. McFarland and Wasik (1998) describe that 69% of time lost from play in college athletics comes from pitchers, specifically shoulder injuries that result from a lack of internal rotation.

Based on the results of this study, the hypotheses were partially supported. Those hypotheses that pitchers would develop GIRD over the course of the season were supported. And although not all measurements (2) showed the hypothesized downward slope the most important did show this change (flexion, internal/external rotation, total rotational arc). Figure 5 shows the gradual decrease in internal rotation over the entire course of the collegiate season.

This is consistent with the findings in previous studies (Wilk et al., 2011; Hibberd et al., 2014; Dwelly et al., 2009), which reported that baseball players will show decreases in internal rotation over the course of a throwing program or season which makes them more susceptible to shoulder injuries.

However, there was a decrease in external rotation in trial four as compared to trial one, and then there was an increase as compared to other trials. Figure 6 shows that from trial three to trial four there was an increase in external rotation, but not an increase that exceeded trial one. The increase in external rotation in trial four, after a gradual decrease during the first three trials, can be explained by a stretch in the anterior capsule. This stretch in the anterior capsule would allow the humeral head to have “free space” within the capsule to allow for external rotation as explained by Gates, Gupta, McGarry, Tibone, & Lee (2012). This increase of space in the anterior capsule or decrease in anterior capsule contracture can be explained by the repetitive “pounding” the capsule takes from the humeral head during glenohumeral internal rotation, especially after the ball is released from the pitcher’s hand and deceleration has been initiated by the supraspinatus (Wilk et al., 2009).

The decrease in flexion seen in the present study (Figure 3) is comparable to the decrease in internal rotation. Gates et al. (2012) explains that posterior glenohumeral capsular contractures are to blame for the decrease in internal rotation after repetitive translation of the anterior capsule from the humeral head. It is also assumed that flexion is affected by the same posterior capsular contracture due to the tracking of the humeral head on the glenoid fossa. Lastly, it was noted in Gates et al. (2012) that the inferior capsule would also develop contracture from the posterior capsular contracture therefore decreasing glenohumeral flexion consistently over all four trials.



Although this study adds to the existing body of research it does have limitations. First, the present study used a very small sample size ( $N = 17$ ) all from the same university. All participants had different throwing mechanics, but were coached and trained by the same individuals who only had one philosophy on baseball pitching. This study should be replicated using a variety of different pitchers from different rosters and from coaches with different pitching philosophies. Lastly, an increase in sample size will also help to provide a broader understanding of the changes that occur over the course of the season.

A second limitation of this study is the fact that humeral retroversion was measured using clinical procedures. The “Gold Standard” of humeral retroversion measurements come from a semiaxial radiograph (x-ray) with lines drawn from (a) orientation of the articular plane of the humeral head, (b) the humeral head neck axis drawn perpendicular to the articular plane, and (c) the condylar axis of the elbow (Reagan et al., 2002). These three lines form a triangle over the semiaxial view of the humeral head in which humeral retroversion would be measured and compared bilaterally. The present study, did not use the “Gold Standard” of humeral retroversion measurement and this likely increased the measurement error of humeral retroversion but not enough to obscure the range of motion changes.

It was assumed that not all participants were affected by the course of a season the same. Also, not all pitchers threw the same number of pitches over the course of the season. It is possible that pitchers who threw more pitches were affected more than those who threw fewer pitches. Lastly, not all pitchers were assumed to have the same pitching history and years of experience, which may not be the case and could correlate with humeral retroversion measurements.

Based on these assumptions, future studies should track pitch count for each participant.

This would help determine the workload of the participants and see if workload affects GIRD. Also, questioning participants about their pitching history could help to determine which participants are more susceptible to humeral retroversion. It may be that pitchers who throw more in their early years are more likely to have increased humeral retroversion. This is based on the idea that the shaft of the humeral head is being drawn into an external torque prior to the growth plates developing and therefore causing a permanent increase in external retroversion of the humeral shaft (Hibberd et al., 2014).

## **CHAPTER 5**

### **CONCLUSION**

In conclusion, this study confirms that over the course of a season pitchers' range of motion will decrease. The results of this study represent similar findings to previous studies. More importantly internal rotation of a pitcher's glenohumeral joint will decrease. This is so important because of the susceptibility that a lack of internal rotation will have on a shoulder injury. It was also noted that pitchers who have larger humeral retroversion are already in danger for a decrease in internal rotation, prior to throwing. It is important to note moving forward that all pitchers need to be treated individually for their unique make up, history, and workload.

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VITA

Graduate School  
Southern Illinois University

Shawn T. Huntsman, ATC

tylerhuntsman1012@gmail.com

Buena Vista University

Bachelor of Arts, Athletic Training, Human Performance, Exercise Science, May 2013

Research Paper Title:

Comparison Of Glenohumeral Internal Rotation Deficit (GIRD) And Humeral  
Retroversion In College Baseball Pitchers Over The Course Of A Competitive Season

Major Professor: Juliane P. Wallace