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ORIGINAL RESEARCH

HIP AND GLENOHUMERAL PASSIVE RANGE OF MOTION IN COLLEGIATE SOFTBALL PLAYERS

Gretchen D. Oliver, PhD, FACSM, ATC, LAT, CES[1]
Hillary Plummer, PhD, ATC, LAT, CES[2]
Allison Brambeck, MS[1]

ABSTRACT

Background and Purpose: Range of motion deficits at the hip and glenohumeral joint (GHJ) may contribute to the incidence of injury in softball players. With injury in softball players on the rise, softball related studies in the literature are important. The purpose of this study was to examine hip and GHJ passive range of motion (PROM) patterns in collegiate softball players.

Hypothesis: It was hypothesized that the position players would exhibit significantly different PROM patterns than pitchers. Additionally, position players would exhibit significantly different side-to-side differences in PROM for both the hip and GHJ compared to pitchers.

Study Design: Prospective cohort study.

Methods: Forty-nine collegiate softball players (19.63 $\pm$ 1.15 years; 170.88 $\pm$ 8.08 cm; 72.96 $\pm$ 19.41 kg) participated. Passive hip and GHJ internal (IR) and external rotation (ER) measures were assessed. Glenohumeral PROM was measured with the participants supine with the arm abducted to 90°. The measurements were recorded when the scapula began to move or a firm capsular end-feel was achieved. The hip was positioned in 90° of flexion and passively rotated until a capsular end-feel was achieved. Total PROM was calculated by taking the sum of IR and ER for both the hip and GHJ.

Results: No significant side-to-side PROM differences were observed in pitchers, at the GHJ or hip joint. Position players throwing side hip IR was significantly greater than the non-throwing side hip ($p = 0.002$). The non-throwing side hip had significantly greater ER compared to the throwing side hip ($p = 0.002$). When examining side-to-side differences at the GHJ, IR was significantly greater in the non-throwing shoulder ($p = 0.047$). No significant differences in total range of motion of the hip and GHJ were observed.

Conclusion: In the current study, position players displayed side-to-side differences in hip and GHJ IR PROM while no statistically significant differences were observed in the softball pitchers. The findings of the current study add to the body of literature related to PROM in throwing athletes, additionally these are the first hip IR and ER PROM data presented in softball players.

Level of Evidence: Level 3

Key Words: pitchers; position players; throwing; upper extremity.

CORRESPONDING AUTHOR
Gretchen D. Oliver, PhD, FACSM, ATC, LAT, CES
School of Kinesiology
301 Wire Rd
Auburn AL 36849
859-200-4035
E-mail: goliver@auburn.edu
sportsmedicineandmovement.com

[1] School of Kinesiology, Auburn University, Auburn AL, USA
[2] Division of Biokinesiology and Physical Therapy, University of Southern California, Los Angeles, CA, USA

INTRODUCTION

Throwing a softball overhead requires efficient coordination of both the lower and upper extremity for effective ball release.[1] Fleisig[2] describes the beginning of the throwing motion as the stride phase in which the non-throwing side or stride foot is pointed in the direction of the desired target. During the stride phase, the non-throwing side leg must have adequate hip external rotation (ER) in order to position the foot directly in line with the target. Proper non-throwing side leg (non-throwing side) positioning allows for optimal hip, pelvis and trunk position, for effective utilization of the kinetic chain to accelerate the ball during throwing.[3] In addition, proper non-throwing side leg positioning also requires adequate hip internal rotation (IR) of the throwing side leg. Following the stride phase, the motion progresses into the cocking phase where the throwing arm must reach a position of maximum shoulder external rotation. The final two phases of the throwing motion include arm acceleration (from maximum shoulder ER to ball release) and follow-through (ball release to maximum shoulder IR) phases. As the movement progresses into arm acceleration, hip ER of the throwing side leg is required to drive the body forward towards the target.[4] After ball release, the body must decelerate the arm and this is best accomplished from the body rotating around the non-throwing leg, causing hip IR.

Due to the repetitive nature of overhead throwing, athletes participating in throwing sports often develop adaptive changes. An increase in ER and decrease in IR compared to the non-throwing arm is customary in baseball players.[5-11] In addition, GHJ adaptive changes have been speculated to be due to a contracture of the posterior capsule and the inferior glenohumeral ligaments [11-15] as well as retroversion of the humeral head.[6,8-11,16,17] These adaptive changes reported in baseball players have also been documented in collegiate softball players.[18,19] However, in addition to examining the repetitive nature of overhead throwing in softball players, it is important to acknowledge that softball pitchers perform a unique underhand throw during the windmill softball pitch. The windmill softball pitch, just as the overhead throw requires both coordination and adequate range of motion (ROM) of both the lower and upper extremity for efficient ball release.[20]

While it is evident that adaptations at the GHJ occur with repetitive throwing there is a lack of evidence on the adaptations that may occur at the hip, particularly in softball players. However, alterations in hip passive range of motion (PROM) have also been reported to be associated with upper extremity injury in throwing athletes.[21,22] Reduced hip PROM throughout the throwing motion could result in alterations up the kinetic chain in effort to impart the same ball velocity at ball release. Deviations in hip PROM resulting in either throwing across the body (non-throwing side foot closed or directed more to the right for a right handed athlete) or opening up too early in the throw (non-throwing side foot directed more to the left of the desired target for a right handed athlete) will cause increased stress to not only the hip but also more distally in the upper extremity at the shoulder and elbow.[23] Because these adaptations are not well understood, it is critical that research be conducted to describe both normal and abnormal hip PROM patterns.

The importance of PROM in throwing has been thoroughly examined in the sport of baseball [1,24-30] however only a few studies have examined softball athletes.[18,19,31] Of the aforementioned studies examining PROM in throwing athletes, only the baseball literature has focused on both the hip and GHJ, with the softball literature limited to only reports on glenohumeral PROM.[19,31] As the number of injuries in softball players is on the rise, it is important to better understand GHJ and hip range of motion in these players. Therefore the purpose of this study was threefold: (1) to assess hip and GHJ PROM and total arc of motion in National Collegiate Athletic Association (NCAA) Division I softball players, (2) describe side-to-side differences in PROM of the hip and GHJ, and (3) compare hip and GHJ PROM between position players and pitchers.

METHODS

Participants

Participants were recruited from Auburn University's softball team and were examined prior to beginning fall practice. Forty-nine NCAA Division I softball players (19.63 ± 1.15 years; 170.88 ± 8.08 cm; 72.96 ± 19.41 kg) participated. Participants included both pitchers (N = 10; 19.60 ± 0.97 years; 174.19 ± 9.97

cm; 84.01 ± 10.34 kg) and position players (N = 39; 19.64 ± 1.20 years; 170.35 ± 7.30 cm; 70.13 ± 20.25 kg). Participant selection criteria included freedom from injury within the prior six months and being active on the playing roster. Auburn University's Institutional Review Board approved all testing protocols. Prior to data collection all testing procedures were explained to each participant informed consent and participant assent was obtained.

Procedures

All participants were tested prior to the beginning of fall practices and had not thrown on the testing day, prior to their PROM measurements. A trained examiner, with clinical background as a certified athletic trainer, conducted all measurements. Bilateral hip and GHJ rotational PROM were measured using a Baseline Digital Inclinometer (Medline Industries, Mundelein, Illinois) (Figure 1 and 2). The average of three trials for each PROM measurement was used for analysis.

Hip rotational PROM (IR and ER) was measured with the participant in a seated position, knees flexed to

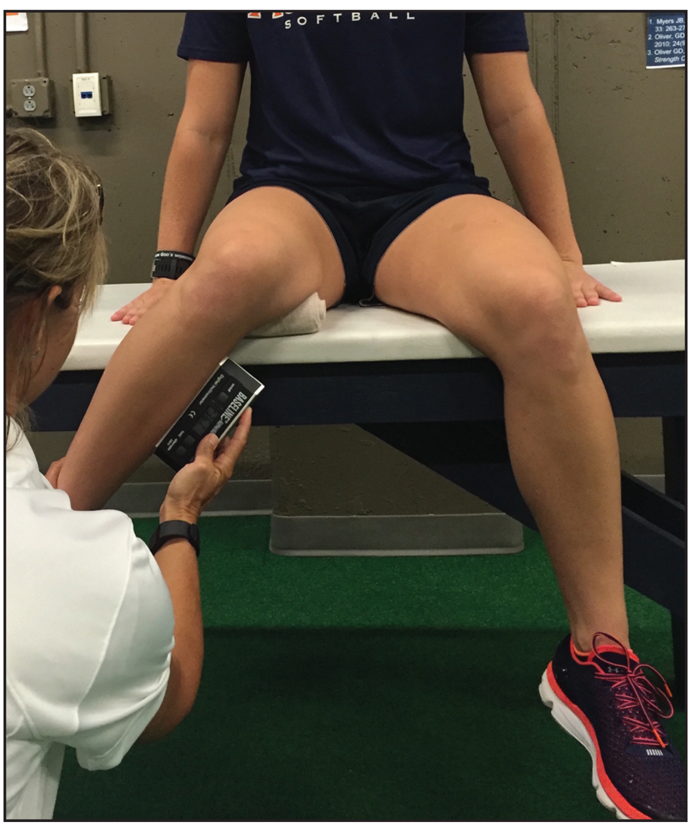

Figure 1. *Hip passive range of motion.*

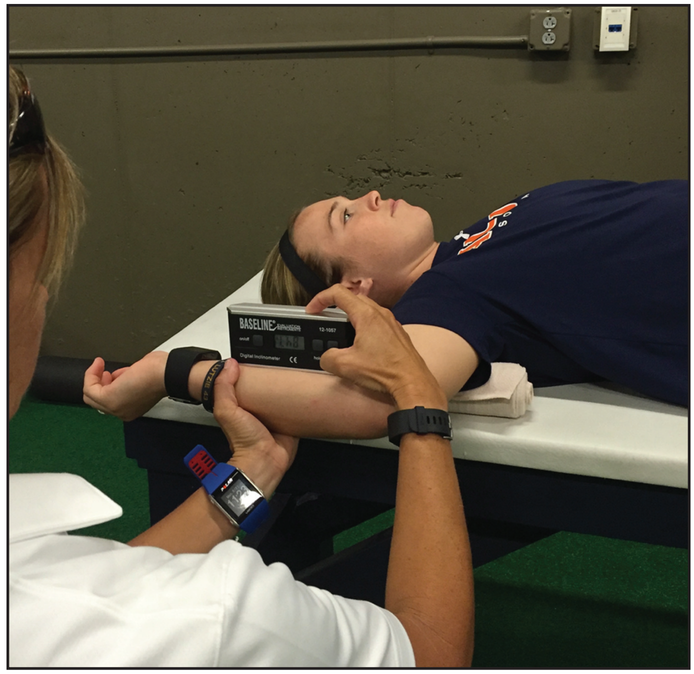

Figure 2. *Glenohumeral passive range of motion.*

90° allowing the legs to comfortably hang off the edge of the table (standard athletic training treatment table) with their hands resting on the table to assist with trunk stabilization.[25,28-30] The hip was positioned in 90° of flexion, by placing a towel under the femur and the digital inclinometer was aligned along the soft tissue contour of the participant's tibia (Figure 1). The examiner supported the femur, to eliminate accessory motion, and passively rotated the hip until a capsular end-feel was achieved. At the point of a firm capsular end-feel without the production of accessory hip movement (hip hiking), the PROM measurement was recorded.[27-29] The throwing side hip was defined as the ipsilateral hip to the throwing arm and the non-throwing side hip was contralateral to the throwing arm.

Glenohumeral IR and ER PROM measurements were performed with the participant supine. For the purposes of this study isolated GHJ motion was of main intrest, therefore standard PROM techniques[32] as well as a visual inspection technique to control for scapulothoracic movement[33,34] were utilized. The visual inspection technique has been indicated to yield reliable measures for isolated glenohumeral motion.[33,34] It is important to note that this method of measurement may result in lower observed PROM values than some previously published values in which researchers do not limit scapulothoracic movement. To perform the PROM measurements, participants were supine on the athletic training table with the arm elevated to 90° of abduction in the coronal plane and proximal humerus was supported with a towel to ensure neutral abduction/adduction in the transverse plane.[25,29] For both IR and ER measurements, the digital inclinometer was supported against the soft tissue contour of the forearm between the olecranon process and the styloid process of the ulna. The examiner passively rotated the humerus in either IR or ER with one hand. The measurement was recorded when the scapula began to move (acromion process began to rise off of the table) or at a firm capsular end-feel.

The examiner reported excellent intra-rater reliability for both hip and GHJ in a pilot study of seven collegiate softball players ($ICC_{(3,k)}$ of 0.92 to 0.95 for all measurements). Minimal detectable change (MDC) values were calculated based on these pilot data in order to determine clinical significance for the measures. Any differences that are observed in the data must exceed the MDC to indicate a clinically significant change. Hip IR and ER PROM, MDC_{95} was 5.6° and 4.7°, respectively while glenohumeral joint IR and ER MDC_{95} values were 6.8° and 9.7°, respectively.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics 20 (IBM corp., Armonk, NY).

A 2 (Throwing/Non-throwing) x 2 (IR/ER) x 2 (Hip/Shoulder) x 2 (Position/Pitcher) ANOVA was performed to examine differences in PROM between position players and pitchers. Total arc of motion measures, for the hip and GHJ, were calculated by summing the measurements for IR and ER. Separate paired samples t-tests were performed to evaluate IR, ER, and total arc of motion differences between the throwing and non-throwing side hip and GHJ in position players and pitchers. An alpha level of $p < 0.05$ was used to signal statistical significance.

RESULTS

Descriptive data for both hip and GHJ PROM are presented in Table 1. No significant differences in total arc ROM of the hip and glenohumeral joint were observed. The ANOVA revealed no significant interactions between pitchers and position players ($F_{(1,47)} = 3.705$, $p = 0.06$). The paired samples t-tests revealed no significant side-to-side difference in hip and GHJ PROM in the pitchers, however there were significant side-to-side differences in the position players. In the sample of position players throwing side hip IR was significantly greater than the values observed for the non-throwing side hip ($p = 0.002$). For external rotation, the throwing side hip was significantly greater than the non-throwing side hip ($p = 0.002$). When examining side-to-side differences at the glenohumeral joint, IR was significantly greater in the non-throwing shoulder ($p = 0.047$) in this sample of position players.

Irrespective of the few statistically significant side-to-side differences that were observed, the current study also examined how many players had PROM differences greater than the MDC between the

Table 1. *Descriptive data of hip and shoulder ROM means and standard deviations.*

Measurement	Pitchers Throwing Side	Pitchers Non-Throwing Side	Position Throwing Side	Position Non-Throwing Side	Combined Pitchers & Position Players Throwing Side	Combined Pitchers & Position Players Non-Throwing Side
Hip IR	29.9 ± 7.8	31.5 ± 7.0+	35.7 ± 6.7	32.9 ± 7.4+	34.5 ± 7.3	32.6 ± 7.3
Hip ER	37.6 ± 10.2	38.2 ± 7.3	39.7 ± 8.0	42.1 ± 8.1	39.3 ± 8.4	41.3 ± 8.0
Hip Total PROM	67.5 ± 16.5	69.7 ± 11.3	75.4 ± 11.7	75.0 ± 13.7	73.8 ± 13.0	73.9 ± 13.3
Glenohumeral IR	39.3 ± 9.0	38.3 ± 11.2	33.9 ± 9.6*	36.7 ± 8.2*	35.0 ± 9.6	37.0 ± 8.8
Glenohumeral ER	100.7 ± 8.9	100.0 ± 10.3	98.9 ± 12.6	97.5 ± 8.6	99.3 ± 11.9	98.0 ± 8.9
Glenohumeral Total PROM	140.0 ± 9.7	138.2 ± 9.8	132.9 ± 15.4	134.2 ± 12.5	134.3 ± 14.6	135.0 ± 12.0

+ = significant difference between positions at $p \leq 0.05$.
* = significant side to side difference at $p \leq 0.05$.

Table 2. *Number of position players and pitchers exceeding the minimal detectable change for each range of motion measure.*

Measurement	MDC_{95} Indicating Clinical Significance	Position Players Exceeding MDC_{95}	Pitchers Exceeding MDC_{95}
Hip IR	5.6°	16/39 (41.0%)	2/10 (20.0%)
Hip External	4.7°	8/39 (20.5%)	5/10 (50.0%)
Glenohumeral IR	6.8°	12/39 (30.8%)	2/10 (20.0%)
Glenohumeral ER	9.7°	11/30 (36.7%)	4/10 (40.0%)

dominant and non-dominant sides (Table 2). This was examined in order to look for clinically significant differences.

DISCUSSION

The current study examined hip and GHJ rotational PROM in NCAA Division I softball pitchers and position players to determine if side-to-side differences were present. With the increase in injuries in softball players, descriptions of PROM in collegiate softball players are needed to allow clinicians working with these athletes to better understand potential motion restrictions that these players may have. Understanding PROM deficits could potentially lead to enhanced training and rehabilitation protocols that address these deficiencies. Side-to-side differences were not observed in the pitchers which may may have been due to the small portion of the sample comprised of pitchers. When examining the position players, side-to-side differences were observed at the shoulder, with greater IR in the non-throwing arm compared to throwing arm. Despite the statistically significant differences found in the current study, these differences were small and failed to surpass the calculated MDC_{95} value of 6.8˚. These results are in partial agreement with those of Shanley et al[19,30] who did not observe any significant differences in PROM in the high school softball players that they studied. However the data presented by Shanley et al.[19,30] likely included some of the players that had asymmetric PROM differences that when grouped in a larger sample were not statistically different.

Further expanding on the analyses, the number of players with side-to-side differences exceeding the MDC for glenohumeral IR were examined in attempt to identify those lacking symmetry and thus possible candidates for intervention programs. Some position players (12/39) and pitchers (2/10) had side-to-side differences in GHJ IR that were clinically significant. The results of this study are a valuable reminder to sports medicine clinicians working with softball players when examining PROM that some players may not have side-to-side patterns consistent with that reported in the literature.[19,31] It has been speculated in that baseball players with deficits in GHJ internal rotation deficits may be at greater risk for upper extremity injury and it is possible that this may also be true for softball. Each player's PROM deficit should be addressed and some players may warrant targeted mobility interventions.

Irrespective of the significant IR side-to-side difference, there was no total arc of motion difference between the throwing and non-throwing arm. The lack of significant change in total arc of motion indicates that while GHJ IR may have decreased there was a concomitant increase in ER leading to similar total arc of motion between sides. This may be supported by the current results that some position players and pitchers had side-to-side differences in GHJ ER that surpassed the MDC (9.7˚). These GHJ PROM data for the position players are consistent with those values from both the baseball and softball literature (Table 3).[6,29,31,35,36] Previous literature has postulated that this shift in arc of motion may be a protective mechanism.[37,38] When there is a shift in the total arc of motion, there is a minimization of humeral head translation within the glenoid and thus maximizes the concavity compression.[39] The symmetrical shift in ROM could potentially alleviate stress on the anterior-inferior GHJ capsule as well as maximize throwing velocity.[37,38]

In addition to the GHJ PROM, this study also examined PROM profiles of the hip in both softball pitchers and position players. The importance of hip PROM and strength in overhead throwers has previously been established.[1,25,27-29,40,41] For efficient

Table 3. *Means and standard deviations of previous softball literature shoulder ROM.*

	Throwing Side ER	Non-Throwing Side ER
Current Study (n = 49)	99.3 ± 11.9	98.0 ± 8.9
Shanley et al., 2012 (n = 12)	119.1 ± 12.9	119.5 ± 12.8
Shanley et al., 2011 (n = 219)	124.0 ± 2.2	121 ± 12.3
Werner et al., 2005 (n = 23)	129 ± 19	123 ± 19
	Throwing Side IR	**Non-Throwing Side IR**
Current Study	35.0 ± 9.6	37.0 ± 8.8
Shanley et al., 2012	60.6 ± 8.3	62.9 ± 12.9
Shanley et al., 2011	59.2 ± 11.5	65.8 ± 9.9
Werner et al., 2005	57 ± 13	61 ± 11

energy generation and transfer from the lower extremity to the upper extremity in overhead throwing, the lower extremity should supply 50% of the total kinetic energy during the throw.[23,42] The more efficient the body can work as a kinetic chain from the lower extremity to the upper extremity, the more optimal the outcome. In overhead throwing, proper hip and pelvis orientation at foot contact requires adequate IR of the throwing side hip and ER of the non-throwing side hip for the trunk to square to the target.[1,27-29,38,41] Then after ball release, to dissipate energy, the body should rotate around the non-throwing side hip resulting in throwing side hip IR.[1,27,28,40,41]

Asymmetric hip loading patterns are present in baseball pitching and it is expected that sport-specific and extremity-specific range of motion adaptations are likely to occur in all overhead throwing motions.[25] Ellenbecker et al.[25] previously examined hip IR and ER ROM in professional baseball pitchers. Internal rotation in the pitchers throwing hip was 23 ± 8.3° and 22 ± 8.9° in the non-throwing hip. IR of the throwing hip is necessary to position the non-throwing stride leg.[27] Limited IR of the throwing hip may lead to a player throwing across their body while limiting the use of energy from the lower extremity.[27,43] In the current study, greater throwing side hip IR was observed in position players but this difference was not clinically significant. Therefore, we also examined the number of players with side-to-side differences that were clinically significant. Forty-one percent (41%) of position players had clinically significant IR differences between their throwing and non-throwing side hips and 21% had clinically significant differences in hip ER.

The results of this study provide valuable data on hip and GHJ PROM rotational profiles in NCAA Division I softball players, which have not been previously reported. While this study provides valuable descriptive glenohumeral and hip PROM values it is important to note that limitations do exist. The data for this study were collected on players from only one NCAA Division I Softball Team. It is possible that these data are not generalizable to PROM in other teams and in larger samples of softball pitchers. There are many factors that must be accounted for when examining PROM data such as previous injury, team and individual training and rehabilitation programs, and pre-competition warm-up routines. Some softball programs may place greater emphasis on thorough pre and post throwing stretching protocols than other programs thereby greatly influencing the players' PROM. In effort to account for this the researchers collected data at the beginning of the fall academic semester prior to any individual or team training that may have occurred. Furthermore, it is important to note that the small sample size of pitchers may have contributed to the lack of significant differences in range of motion. Future research should examine hip and GHJ PROM in a larger number of NCAA Division I softball players across multiple teams to determine if these values are similar. Additionally, in depth analysis of the effects of PROM on throwing kinematics in softball players should also be examined to better understand the role hip PROM has on the efficiency of the kinetic chain.

CONCLUSIONS

The results of this study demonstrated statistically significant PROM differences in hip IR between pitchers and position players and side-to-side differences in GHJ IR in position players. However these differences were small and did not achieve the minimal detectable change threshold for clinical significance.

Regardless of statistical or clinical significance the descriptive data presented in this study can serve as a baseline for future research. The amount of shoulder and hip PROM in softball players likely has a major role in their ability to maximize throwing and pitching velocity through sequential kinetic chain sequencing. Examining these measures in softball players and subsequently monitoring these data longitudinally can allow for individual training programs to be created based on PROM limitations.

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