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Research Article

The Effects of a Pre-Throwing Program on Collegiate NCAA Division I Softball Pitchers' Biomechanical Measures of Hip and Shoulder Range of Motion

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Abstract

The purpose of the study was to examine the effects of a pre-throwing program on softball pitchers' passive rotational hip and shoulder range of motion and isometric strength. Four female fast-pitch softball pitchers (20.6 + 1.4 yrs, 174.0 + 6.7 cm, 82.6 + 6.6 kg) completed a pre-throwing program one hour prior to the start of every game. Data were collected pre-game, post-game, and 24-hours post game at three time periods: pre-season, mid-season, and post-season. Data were analyzed using a repeated-measures analysis of variance with an alpha level of $p < 0.05$. Statistical analysis revealed a significant decrease in throwing shoulder internal rotation from pre-season to mid-season (Mean Difference (MD) = -8.692, p=0.001) and from pre-season to post-season (MD= -12.617, p=0.002) in addition to a significant decrease in non-throwing shoulder internal rotation from pre-season to mid-season (MD= -9.542, p=0.012) and from pre-season to post-season (MD= -12.792, p=0.003). Additionally, a significant increase was revealed in external rotation strength of the non-throwing shoulder from pre-game to 24 hours post-game (MD = 0.925, p=0.043) as well as a significant increase in post-game external rotation strength of the back hip from pre-season to post-season (MD = 1.375, p=0.003). No significant differences were found in rotational hip range of motion, suggesting the pre-throwing program helped maintain the necessary kinematics to aid proper pitching mechanics. These data support the continual implementation of a pre-throwing program as well as biomechanical monitoring of passive range of motion in addition, the need of further research aiming to enroll additional teams into the pre-throwing program. Recruitment of additional teams both to the pre-throwing program as well as serving as a control would allow for more definitive conclusions of the program's effectiveness.

Keywords: Injury Prevention; Performance; Windmill Softball Pitching

Introduction

In 2014, the United States Department of Education reported that 23,488 individuals participated in all competition levels (NCAA Divisions I-III, NAIA, and NJCAA) of collegiate softball [1]. Of these individuals, 2,369 participated in the highest level of collegiate competition (NCAA Division I). Furthermore, more than 2 million females ages 12-18 play softball competitively each year [2-5]. Softball is considered one of the fastest growing and most popular female sports in the United States, and injury rates have recently been comparable to or exceed that of baseball [4,6-9]. In 2004, it was reported that 73% of collegiate fastpitch softball pitchers are injured each year [10]; however, cause of increase in injury have not been determined.

Range of motion (ROM) profiles have been examined in both softball and baseball pitchers, as injury of the throwing shoulder has been attributed to insufficient ROM in recent literature, specifically concerning glenohumeral internal rotation deficit (GIRD) and impingement [11]. When examining hip ROM in throwing athletes, it has been found that following extended bouts of throwing internal and external passive range of motion (pROM) was decreased [12,13], which was hypothesized to occur due to repeated muscular contractions. Altered ROM patterns at the hip have been shown to affect upper extremity throwing kinematics, as the total arc of motion of the non-dominant hip is directly correlated to trunk separation velocity and the total arc of motion of the dominant hip is directly correlated with pelvic positioning [13]. Therefore, these factors inevitably alter dissipation of energy and forces through the kinetic chain to the upper extremity during the overhead throw. Additionally, reduction in strength of the glenohumeral external rotators, specifically the supraspinatus, has also been associated with injury in highly skilled baseball pitchers [14], therefore, examination of these biomechanical measures is warranted in providing potential injury risk factors for softball pitchers. To the authors' knowledge, there is only one study that has examined the effects of high pitch volume in softball pitchers [15], and it was found that following a bout of high pitch volume, bilateral hip and scapular muscle fatigue was observed. Thus, these results reiterate the need to more thoroughly examine softball pitching volume as well as biomechanical measures.

While exact injury mechanisms have yet to be established in softball athletes, specifically pitchers, insufficient warm-up routines are of concern for injury prevention [16]. Several programs have been established for both pre-throwing and post-injury rehabilitation. Traditional warm-up routines such as the Thrower's Ten program primarily target the rotator cuff, biceps, triceps, and the wrist flexors, extensors, pronators, and supinators [17, 18] in addition to non-traditional routines, such as the sling exercise, which also targets the shoulder [19]. These exercises are executed in attempt to strengthen specific muscle groups and combat injury susceptibility of the throwing athlete; however, the primary focus lies solely on stabilizing muscular of the upper extremity. Research has shown the critical role of proximal musculature in force generation and injury prevention of the shoulder, specifically, sufficient strength in pelvis and scapular stabilization musculature has been reported to allow for more efficient and proper throwing mechanics [20-22]. As such, implementation of a pre-throwing program with an emphasis on proximal stabilization in addition to the upper extremity, rather than upper extremity strength alone, could further assist in combatting fatigue and injury of pitching athletes.

Authors have proposed the utilization of pitch count regulations, most importantly to reduce the total number of pitches thrown by softball pitchers, as well as optimization of pitch mechanics to enable a more efficient usage of the lower extremity [3,15,23-25]. However, there are no data to support these claims. Thus, the purpose of this pilot study was to investigate the effects of a pre-throwing program on passive ROM and strength measures of the hip and shoulder in collegiate softball pitchers over the course of an NCAA Division I softball season.

Methods

Experimental Approach to the Problem

The aim of this study was to investigate the effects of a pre-throwing program on bilateral hip and shoulder passive ROM and isometric strength (ISO) across a competitive season. Range of motion and ISO measures were taken pre-game, post-game, and 24 hours post-game at three-time points during the season: pre-season, mid-season, and post-season.

Subjects

Four female fast-pitch softball pitchers (20.6 ± 1.4 yrs, 174.0 ± 6.7 cm, 82.6 ± 6.6 kg) of a Division I NCAA softball team ranked in the top five National Rankings at the beginning of the testing season, agreed to participate. Institutional Review Board from Auburn University (Auburn, AL) approved all testing protocols and informed consent was obtained. All pitchers were on the active playing roster and reported no upper or lower extremity injuries in the past 12 months. Over a four-month study period, data were collected on the four pitchers pre-game, post-game, and 24-hours post game during pre-season, mid-season, and post-season. Average pitches thrown were 168 ± 40, 162 ± 37, and 162 ± 32 for pre-season, mid-season and post-season, respectively. Pitch counts included game pitches, as well as, bull-pen pitches.

Data Collection

Subjects were assessed for bilateral hip and shoulder rotational ISO and ROM four hours prior to the game, immediately following the game, and 24-hours following the game. All measurements were collected prior to the subject performing any type of therapeutic rehabilitation or modality. One hour prior to the start of the game, the pre-throwing program was implemented for approximately fifteen minutes. The same investigator who performed the pre-and post-game measurements, directed the pre-throwing program.

Testing Protocol

The throwing shoulder was defined as the arm used to pitch, while the non-throwing shoulder was defined as the shoulder contralateral to the pitching shoulder. The back hip was defined as the hip ipsilateral to the throwing shoulder, and the lead hip was the hip ipsilateral to the non-throwing shoulder. The ROM variable was determined as the change in degrees from pre-to post-to 24-hours post game testing, while strength measurements were determined as the change in percentage of kilogram of force (kgf) from pre-to post-to 24hours post game testing.

Range of Motion

Intra-rater reliability was determined during the pilot study of 7 collegiate softball players. The examiner reported an excellent intra-rater reliability using the technique described below, of an $ICC_{(3,k)}$ of 0.92 to 0.95 for all measurements. Minimal detectable Cange (MDC) values for the 95% confidence interval were calculated based on these pilot data in order to determine clinical significance for the measures. Any differences that were observed in the data must have exceeded the MDC to be a clinically significant change. Glenohumeral joint internal rotation (IR) and external rotation (ER) MDCs were 6.8° and 9.7°, respectively. Hip IR and ER MDC was 5.6° and 4.7°, respectively.

Range of motion measurements were taken using a digital inclinometer (Fabrication Enterprises, Inc., White Plains, NY). Glenohumeral ROM was performed using standard passive ROM techniques as well as the visual inspection technique in order to isolate glenohumeral movement and control for scapulothoracic movement during assessment [26,27] (Figure 1).

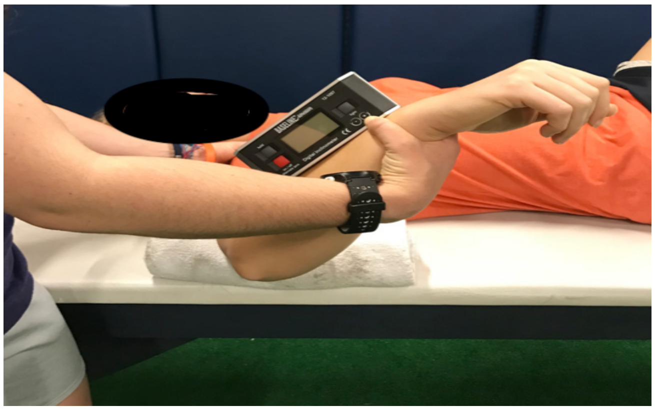

Figure 1: Inclinometer placement for shoulder ROM measurement.

Subjects were supine in 90˚ of shoulder abduction and 90˚ of elbow flexion with a rolled towel placed under the distal humerus. The digital inclinometer was placed on the soft tissue contour of the forearm between the olecranon process and the styloid process of the ulna. Measurements were recorded at scapulothoracic movement during IR and firm capsular end-feel during ER [26,27].

Internal and ER ROM measurements of the hip were conducted with the subjects in a seated position, knees flexed to 90˚ and a rolled towel placed under the distal femur [13,27,28] (Figure 2).

Figure 2: Inclinometer placement for hip ROM measurement.

The digital inclinometer was placed on the shaft of the fibula just proximal to the lateral malleolus for IR and on the shaft of the tibia just proximal to the medial malleolus for ER. Each measurement was recorded when firm capsular end-feel was reached [13,27,28].

Isometric Strength

High intraclass correlation coefficients were reported for all isometric strength measurement tests ($ICC_{(3,k)}$ of 0.86 to 0.99 for all measurements). Glenohumeral joint IR and ER MDC was 4.0 kgf and 3.1 kgf, respectively, while hip IR and ER MDC was 3.1 kgf and 3.0 kgf, respectively. Isometric strength measurements were assessed using a handheld dynamometer (Lafayette Instruments, Lafayette, IN). Measurements were performed for bilateral hip and shoulder IR and ER.

Glenohumeral isometric strength was performed while the subjects were supine, shoulder positioned at 90˚ of abduction and the elbow flexed to 90˚. A rolled towel was placed under the distal humerus to prevent horizontal adduction [26,27] (Figure 3).

Figure 3: Dynamometer placement for shoulder ISO measurement.

The handheld dynamometer was positioned three inches proximal to the wrist, on the volar side of the forearm for IR and the dorsal side for ER [15,29]. Subjects were instructed to perform maximal IR, followed by maximal ER. Subjects were asked to push with maximal effort against resistance from the investigator, for three seconds [15,29].

Internal and ER ISO of the hip was conducted with the subjects in a seated position, knees flexed to 90°, and a rolled towel placed under the distal femur [15,29] (Figure 4).

Figure 4: Dynamometer placement for hip ISO measurement.

The dynamometer was positioned three inches proximal to the medial malleolus for ER and three inches proximal to the lateral malleolus for IR [15,29]. Subjects were instructed to execute maximal IR followed by maximal ER. Subjects were asked to push with maximal effort against resistance from the investigator for three seconds.

Pre-Throwing Protocol

One hour prior to competition, all subjects reported to the pitchers' bullpen for the pre-throwing protocol. Exercise selection and order was randomized for each session. Total total time of the pre-throwing protocol was 15 minutes. Five to eight exercises were implemented during this time, equally targeting pelvic and scapular stabilizing musculature. All exercises completed throughout the competitive season are listed in Table 1. Exercises were randomly chosen by the primary investigator and exercise selection was based on pre-game ROM and ISO measures.

Table 1. Pre-throwing program exercises.

Exercise	Description
Single Leg Stance	Non-weight bearing hip is flexed to 90 degrees with arms in the position of a W, pulling elbows to opposite back pockets.
Lunge: without knee touching ground	Arms remain in the W position, elbows to the opposite back pocket.
Airplane	Body parallel to the ground, weight bearing leg straight and fully flexed at the hip.
Deep Squat	Arms overhead in line with the ears.
Single Leg Standing Hip Abduction	Leg moving does not rest on the ground. Try to balance the whole time on standing leg and try not to lean forward or to the weight bearing side.
Single Leg Standing Hip Extension	Leg moving should not allow foot to rest on the ground throughout the exercise and try not to allow the trunk to lean forward.
Side Lying Clams	Position the body where hips, shoulder and knees are in a straight line, with knees bent and feet stacked.
Basic Plank	Maintain tight core and do not let butt rise into the air.
Plank with Shoulder Taps	Maintain tight core and do not let butt rise and do not rotate body when tapping.
Basic Plank with Hip Abduction	Maintain tight core and do not let butt rise into the air, try to keep abduction leg/foot off the ground the whole time.
Pelvic Bridge	Core tight, straight line from shoulders to hip with feet Together.
Pelvic Bridge with Bands and Clams	Core tight, straight line from shoulders to hip with feet together.
Single Leg Standing Hip Diagonal Abduction Pumps	Take the leg out and back diagonally to the end range of motion and then pump. Keep moving foot off the ground.
Single Leg Standing Hip Extension Pumps	Extend the leg back to the end range of motion and then pump. Keep moving foot off the ground.
Single Leg Backward Kirsty Lunge with Single Leg Hold	Lunge backward across body to get a stretch then bring lunge leg back up to single leg stance with hip flexed at 90 degrees and hold for a count of 3.
Single Leg Pelvic Bridge with Leg Extended	Keep butt level with torso as the right leg extends at the knee.

Statistical Design

All statistical procedures were executed using IBM SPSS Statistics 23 (SPSS, Chicago, IL, USA). A 3 (pre-, mid-, and post-season) x 3 (pre-, post-, and 24 hours post-game) repeated-measures analysis of variance (ANOVA) was used to determine differences in ROM and ISO measures of the shoulders and hips throughout the competitive season. Post-hoc simple effects tests were executed for all statistically significant interactions and main effects that included time within the competitive season and within one game. The alpha level was set a priori $p < 0.05$.

Results

Range of Motion

A 3 x 3 repeated measures ANOVA statistical analysis revealed a statistically significant main effect of season for IR ROM of the throwing shoulder ($F_{2,6}$=57.255, p<0.001). Post-hoc simple effects tests showed a significant decrease in throwing shoulder IR from pre-season to mid-season (mean difference= -8.692, p=0.001) and from pre-season to post-season (mean difference= -12.617, p=0.002). No significant main effect of game ($F_{2,6}$=1.076, p=0.399) or interaction of season x game ($F_{4,12}$=0.707, p=0.602) was found in IR. For the throwing shoulder ER ROM, no significant main effects of season ($F_{2,6}$=2.877, p=0.133), game ($F_{2,6}$=1.510, p=0.294), or interaction of season x game ($F_{4,12}$=1.160, p=0.376) were found.

A significant main effect of season was revealed for IR of the non-throwing shoulder ($F_{2,6}$=34.768, p=0.001). Post-hoc simple effects tests showed a significant decrease in IR from pre-season to mid-season (mean difference= -9.542, p=0.012) and from pre-season to post-season (mean difference= -12.792, p=0.003). No significant main effect of game ($F_{2,6}$=3.797, p=0.086) or interaction of season x game ($F_{4,12}$=2.233, p=0.126) was found in IR ROM. For non-throwing shoulder ER ROM, no significant main effects of season ($F_{2,6}$=2.755, p=0.142), game ($F_{2,6}$=0.173, p=0.845), or interaction of season x game ($F_{4,12}$=0.563, p=0.694) were found. Neither back hip IR nor ER were found to have a significant main effect of season (IR: $F_{2,6}$=3.222, p=0.112; ER: $F_{2,6}$=4.090, p=0.076), game (IR: $F_{2,6}$=0.272, p=0.771; ER: $F_{2,6}$=0.127, p=0.883), or interaction of season x game (IR: $F_{4,12}$=0.774, p=0.563; ER: $F_{4,12}$=1.310, p=0.321). No significant findings were revealed for IR or ER of the lead hip in main effect of season (IR: $F_{2,6}$=1.103, p=0.391; ER: $F_{2,6}$=4.947, p=0.054), game (IR: $F_{2,6}$=0.103, p=0.904; ER: $F_{2,6}$=0.479, p=0.641), or interaction of season x game (IR: $F_{4,12}$=2.616, p=0.088; ER: $F_{4,12}$=0.792, p=0.553). Means and standard deviations of all ROM measurements are presented in Table 2.

Isometric Strength

A 3 x 3 repeated measures ANOVA statistical analysis revealed no significant main effect of season ($F_{2,6}$=0.301, p=0.751), game ($F_{2,6}$=4.570, p=0.062), or interaction of season x game ($F_{4,12}$=2.539, p=0.095) in IR ISO strength of the throwing shoulder. Additionally, no significant main effect of season ($F_{2,6}$=1.118, p=0.387), game ($F_{2,6}$=0.103, p=0.903), or interaction of season x game ($F_{4,12}$=1.801, p=0.194) in ER ISO of the throwing shoulder was found. No significant main effect of season ($F_{2,6}$=1.091, p=0.394), game ($F_{2,6}$=0.627, p=0.566), or interaction of season x game ($F_{4,12}$=0.733, p=0.587) in IR ISO of the non-throwing shoulder was found. However, a significant main effect was revealed of game for ER ISO of the non-throwing shoulder ($F_{2,6}$=8.001, p=0.020). Post-hoc simple effects tests showed a significant increase in ER ISO from pre-game to 24 hours post-game (mean difference = 0.925, p=0.043). No significant main effect of season ($F_{2,6}$=0.016, p=0.984) or interaction of season x game ($F_{4,12}$=0.707, p=0.602) was found in ER ISO of the non-throwing shoulder.

No significant main effect of season ($F_{2,6}$=2.663, p=0.149), game ($F_{2,6}$=1.595, p=0.278), or interaction of season x game ($F_{4,12}$=0.402, p=0.804) was found in IR ISO of the back hip. However, a significant interaction was revealed of season x game for ER ISO of the back hip ($F_{4,12}$=4.291, p=0.022). Post-hoc simple effects tests showed a significant increase in post-game ER ISO from pre-season to post-season (mean difference = 1.375, p=0.003). No significant main effects of season ($F_{2,6}$=0.292, p=0.757) or game ($F_{2,6}$=1.252, p=0.351) were found in ER ISO of the back hip. No significant main effect was found of season ($F_{2,6}$=1.367, p=0.324), game ($F_{2,6}$=0.343, p=0.723), or interaction of season x game ($F_{4,12}$=0.572, p=0.688) in IR ISO of the lead hip. Additionally, no significant main effect of season ($F_{2,6}$=1.170, p=0.372), game ($F_{2,6}$=0.451, p=0.657), or interaction of season x game ($F_{4,12}$=2.256, p=0.124) in ER ISO of the lead hip was found. Means and standard deviations of ISO measurements are presented in Table 3.

Table 2. Range of motion comparisons between Pre, Post, 24-hours following game at the time events of pre-season, mid-season, and post-season.

	Pre-Season	**Mid-Season**	**Post-Season**	**Average**
	Mean, SD	Mean, SD	Mean, SD	Mean, SD
Back Hip IR (°)				
Pre	29.50±11.28	26.35±6.11	26.08±7.28	27.31±8.22
Post	31.05±7.05	24.20±4.87	30.75±7.25	28.67±6.39
24-Hrs	29.25±12.27	27.40±7.09	28.20±9.37	28.28±9.58
Average	29.93±10.2	25.98±6.02	28.34±7.97	-
Back Hip ER (°)				
Pre	34.40±4.18	28.05±9.60	27.58±9.29	30.01±7.69
Post	29.58±7.24	28.55±3.55	30.80±6.35	29.64±5.71
24-Hrs	32.60±8.27	28.80±3.50	30.15±7.05	30.52±6.27
Average	32.19±6.56	28.47±5.55	29.51±7.56	-
Lead Hip IR (°)				
Pre	27.95±4.30	22.95±7.26	21.55±2.36	24.15±4.64
Post	24.13±3.20	22.30±4.41	24.40±3.12	23.61±3.58
24-Hrs	24.95±2.93	24.75±5.02	22.2±1.39	23.97±3.11
Average	25.68±3.48	23.33±5.56	22.72±2.29	-
Lead Hip ER (°)				
Pre	35.95±11.71	30.65±6.88	29.05±7.58	31.88±8.72
Post	34.38±4.75	31.93±6.56	31.45±9.15	32.58±6.82
24-Hrs	32.98±5.67	29.73±6.65	32.18±10.40	31.63±7.57
Average	34.43±7.38	30.77±6.70	30.89±9.04	-
T Shoulder IR (°)				
Pre	42.63±3.69	32.50±0.62	29.38±5.99	34.83±3.43
Post	43.60±2.56	34.35±3.85	30.95±3.70	36.30±3.37
24-Hrs	39.80±2.53	33.10±2.01	27.85±1.68	33.58±2.07
Average	**42.01±2.93*†**	**33.32±2.16***	**29.39±3.79†**	-
T Shoulder ER (°)				
Pre	110.85±7.10	103.15±11.35	100.75±12.47	104.92±10.31
Post	105.98±8.61	91.03±16.58	105.63±11.27	100.88±12.15
24-Hrs	111.18±8.16	105.75±8.26	99.50±5.00	105.48±7.14
Average	109.33±7.96	99.98±12.06	101.96±9.58	-
NT Shoulder IR (°)				
Pre	48.68±7.99	36.10±2.42	32.83±2.22	39.20±4.21
Post	47.08±6.66	33.80±1.72	31.83±2.51	37.57±3.63
24-Hrs	38.55±2.57	35.78±4.03	31.28±2.26	35.20±2.95
Average	**44.77±5.74*†**	**35.23±2.72***	**31.98±2.33†**	-
NT Shoulder ER (°)				
Pre	106.775±8.90	103.30±16.46	94.28±7.22	101.45±10.86
Post	105.63±12.02	95.75±15.72	102.30±10.58	101.23±12.77
24-Hrs	103.50±7.17	95.55±14.22	96.65±15.75	98.57±12.38
Average	105.30±9.36	98.20±15.47	97.74±11.18	-

IR = Internal Rotation, ER = External Rotation, T = Throwing, NT = Non-throwing.
*difference between pre-season and mid-season at significance level $p < 0.05$
†difference between pre-season and post-season at significance level $p < 0.05$

Table 3. Isometric strength comparisons between Pre, Post, 24-hours following game at the time events of pre-season, mid-season, and post-season.

	Pre-Season	**Mid-Season**	**Post-Season**	**Average**
	Mean, SD	Mean, SD	Mean, SD	Mean, SD
Back Hip IR (kgf)				
Pre	11.55±0.90	14.13±4.14	14.65±1.18	13.44±2.07
Post	11.20±1.25	13.10±1.59	13.35±2.32	12.55±1.72
24-Hrs	11.58±1.13	12.73±4.33	14.25±0.57	12.85±2.01
Average	11.44±1.09	13.32±3.53	14.08±1.36	-
Back Hip ER(kgf)				
Pre	11.28±1.31	11.70±2.22	11.40±1.28	11.46±1.60
Post	**9.58±1.48***	11.43±2.78	**10.95±1.69***	10.65±1.98
24-Hrs	11.53±1.44	10.05±2.83	12.58±1.79	11.38±2.02
Average	10.79±1.41	11.06±2.61	11.64±1.59	-
Lead Hip IR (kgf)				
Pre	12.15±1.21	13.25±3.15	13.88±2.81	13.09±2.39
Post	11.03±2.02	13.95±2.49	13.03±3.55	12.67±2.69
24-Hrs	11.70±1.35	12.78±3.02	13.93±2.84	12.80±2.40
Average	11.63±1.53	13.33±2.89	13.61±3.07	-
Lead Hip ER (kgf)				
Pre	11.55±1.44	10.45±2.45	12.10±2.49	11.37±2.13
Post	9.90±1.94	11.93±2.07	11.23±2.39	11.02±2.13
24-Hrs	10.68±0.59	10.75±1.80	12.95±2.32	11.46±1.57
Average	10.71±1.32	11.04±2.11	12.09±2.40	-
T Shoulder IR (kgf)				
Pre	11.00±1.44	12.10±1.96	11.03±0.97	11.38±1.46
Post	10.38±1.40	10.43±2.16	11.93±1.19	10.91±1.58
24-Hrs	10.58±0.79	10.90±1.86	11.15±1.35	10.88±1.33
Average	10.65±1.21	11.14±1.99	11.37±1.17	-
T Shoulder ER (kgf)				
Pre	10.85±1.76	11.13±0.90	10.30±0.79	10.76±1.15
Post	10.20±0.87	10.75±0.26	10.95±1.31	10.63±0.81
24-Hrs	10.05±1.10	11.00±1.41	11.10±1.25	10.72±1.25
Average	10.37±1.24	10.96±0.86	10.78±1.12	-
NT Shoulder IR (kgf)				
Pre	9.73±1.13	11.08±1.48	10.60±1.07	10.47±1.23
Post	10.18±1.81	10.73±1.88	10.93±0.87	10.61±1.52
24-Hrs	10.28±1.28	10.75±1.95	11.73±1.11	10.92±1.45
Average	10.06±1.41	10.85±1.77	11.08±1.02	-
NT Shoulder ER (kgf)				
Pre	9.93±2.05	10.60±1.54	10.25±2.44	**10.26±2.01***
Post	10.38±1.79	10.43±1.47	10.90±1.62	10.57±1.63
24-Hrs	11.75±1.71	11.15±0.73	10.65±1.91	**11.18±1.45***
Average	10.68±1.85	10.73±1.25	10.60±1.99	-

IR = Internal Rotation, ER = External Rotation, T = Throwing, NT = Non-throwing.
*significance level $p < 0.05$

Discussion

The current study examined the effects of a pre-throwing program on ROM and ISO measures of the hip and shoulder in collegiate softball pitchers over the course of an NCAA Division I softball season. Results revealed decreases in throwing shoulder and non-throwing shoulder IR ROM from pre-season to mid-season and from pre-season to post-season. While the quantifiable injury risk from GIRD has not been investigated in female, softball pitchers, evidence is available that suggests the presence of GIRD in the throwing athlete does significantly increase one's susceptibility to shoulder and elbow injury [30,31]. It has been suggested that decreases in IR, specifically of the throwing shoulder, are normal in the overhead throwing athlete when in conjunction with a substantial increase in ER [32]. However, the softball pitchers in this study pitched underhanded versus previous documentation of overhand throwing athletes; as well as the fact that the shoulder IR values still fell within the range previously reported in softball pitchers [33]. Additionally, the pitchers in the current study did not display significant increases in ER ROM. Thus, further investigation into ROM and injury propensity within windmill softball pitching is obligatory. Aside from the decrease in shoulder ROM, alterations in ISO at the shoulder were not observed. These findings could be a result of strength and conditioning performed throughout the season, but also could be attributed to the pre-throwing program emphasizing primarily hip, pelvis, and scapular stabilization with minimal focus on ROM.

Although there are concerning deficits in shoulder ROM, no changes were seen in the hip ROM. This finding is of high importance, as it is known that substantial decreases in hip ROM can ultimately alter upper extremity mechanics in throwing and lead to habitual pathomechanics [13,34-37]. It can only be postulated that the lack of changes in hip ROM was, to some degree, a product of the pre-throwing program, emphasizing hip and pelvic muscular stabilization and activation, that was implemented throughout the season. Because the program emphasized stability of the proximal segments, namely the lumbopelvic-hip complex, deficits in hip ROM could have been negated by the specific exercises within the pre-throwing program. The increase in ER ISO of the back hip is also of crucial importance as this muscle group is necessary in the push-off motion of the pitch. As the pitcher begins to generate momentum towards the catcher, she must push forward onto single-leg support while externally rotating the back hip. This phase of the pitch can ultimately influence the outcome of the pitch and the susceptibility to injury because energy and forces are generated and transferred up the kinetic chain for efficient energy for ball release.

The more efficient the body can work as a kinetic chain from the lower extremity to the upper extremity, the more optimal the outcome, and the less susceptibility of injury [38]. In overhead throwing, proper hip and pelvis orientation at foot contact requires adequate IR ROM of the throwing side hip and ER ROM of the non-throwing side hip for the trunk to square to the target [13,27,28,39,40,41]. Then after ball release, to dissipate energy, the body should rotate around the non-throwing side hip resulting in throwing side hip IR [13,28,39,40,42]. In softball pitching the lead hip must have adequate ER for foot contact and then sufficient strength to IR and pull the body forward for ball release. While the back hip must possess appropriate rotational ROM as well as IR strength to push the body into a power balanced position to allow for max utilization of the lead hip. The current study's lack of significant differences in ROM and ISO of the hip is in agreement with the notion of utilizing the lower half to propel the upper half and that the implementation of the pre-throwing program possibly could have assisted in these results.

These data support the continual implementation of a pre-throwing program, as well as, biomechanical monitoring of passive range of motion. Recruitment of additional teams both to the pre-throwing program as well as serving as a control would allow for more definitive conclusions of the program's effectiveness. It is difficult to ascertain the association of the pre-throwing program and biomechanical measures over the course of a softball pitcher's career. As a pitching coach, strength and conditioning coach and athletic trainer, the primary goal is to prevent injury and optimize performance. From the current pilot study, we cannot determine what particular ROM and ISO is optimal for injury prevention and performance as each athlete's individual differences and mechanics have to be taken into consideration. Additionally, we cannot definitely state that it was because of the pre-throwing program we were able to obtain such positive results because of the lack of a control group. Though, the only study to the authors' knowledge to examine ROM and ISO of pitchers found that after a bout of pitching they reported fatigue and decreased strength [15]. However, we can state that the pitchers in the current study had minimal losses in ROM and ISO within 24hrs of competition and none sustained a time loss injury or any injury that required rehabilitation. Though we cannot state that it was the pre-throwing program that allowed for these results, we can say that the pre-throwing did not cause any detriments in these pitchers' biomechanical measures nor were the pitchers injured. The fact that none of the pitchers sustained a time loss injury is promising in regard to further investigation into the effectiveness of the pre-throwing program, as numerous studies have reported increased injury rates in softball pitchers [5,9,10,15, 43].

It should be noted that this case only included four collegiate softball pitchers, which limits the applicability of the results to other collegiate pitchers. Only one pre-throwing program was tested and there was no control group. However, none of these limitations underscore the study's attempt to investigate if monitoring mechanics and implementing a pre-throwing program can decrease recovery time and possibly curtail injury susceptibility. This study was performed with minimal equipment and minimal time constraint on the athlete. Further research is needed to apply similar pre-throwing programs to a larger population/cohort of softball pitchers with longer follow-up in order to make stronger inferences. Other suggestions include measuring the muscle mass and girth of the upper body surrounding the shoulder to better understand reasoning for differences in shoulder ROM throughout the season.

The pre-throwing program was designed to focus on pitchers' hip, pelvis, and scapular muscle activations in response to the bilateral hip and scapular muscle fatigue that has been reported to occur during game-situation pitching [15]. In order to for a team to rely on pitchers as many tend to (favoring one of the few pitchers on the staff), the limited time allotment for recovery is of concern, while also vital to the success of the pitcher in games to follow. The pre-throwing program showed results beneficial to the pitcher as recovery time from post-game back to pre-pitching biomechanical measures was less than 24 hours. This is ideal for teams who compete in three game series, one game per day on three consecutive days. There were also no time loss injuries or any injury requiring rehabilitation while on the program, proving advantageous especially to a team with limited pitching staff.

Practical Applications

While a baseball team carries 10+ pitchers on a roster, softball teams are much more conservative in numbers due to NCAA team roster restrictions. As with the current sample size, it is normal for a collegiate softball team to carry no more than five pitchers. With the collegiate season schedule allowing for near 60 regular and pre-season games, a team's bull pen pitching staff needs to be able to handle the longevity of the season, maintaining and even increasing performance as the season progresses. It is for this reason that prevention strategies be put in place to alleviate the high-prevalence of injury among inter-collegiate athletes. For performance reasons and durability of optimal pitching ability, coaches can implement a pre-throwing program that will assist in keeping the core of their defensive scheme properly functioning throughout the entire season. Especially as post-season dawns on the collegiate teams, coaches will want the necessary measures taken earlier in the season to ensure their pitchers are reaching their peak performance and optimal health status as post-season approaches.

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