Evaluation of Hip Characteristics in Baseball and Softball Athletes with and Without Throwing Arm Pain

Authors

Gretchen D Oliver[1], Anthony Fava[1], Billy Lozowski[1], Jason L Zaremski[2], Kaila A Holtz[3], Robert L Bowers[4]

Affiliations

1 School of Kinesiology, Auburn University, Auburn, United States
2 Department of Physical Medicine and Rehabilitation, University of Florida, Gainesville, United States
3 Division of Physical Medicine and Rehabilitation, Department of Medicine, University of British Columbia, Vancouver, Canada
4 Department of Orthopaedics, Emory University School of Medicine, Atlanta, United States

Key words
arm health, injury prevention, range of motion, strength

accepted 09.09.2023
published online 27.10.2023

Bibliography
Int J Sports Med 2024; 45: 71–78
DOI 10.1055/a-2184-5893
ISSN 0172-4622

Georg Thieme Verlag, Rüdigerstraße 14,
70469 Stuttgart, Germany

Correspondence
Dr. Gretchen D Oliver
Auburn University
School of Kinesiology
301 Wire Rd
36849 Auburn
United States
Tel.: 8592004035, Fax: 8592004035
goliver@auburn.edu

ABSTRACT

During throwing, the lower extremity assists in the generation and transfer of momentum. Lower extremity stability assists in this transfer by providing a base for distal mobility of the arm segments. This study aimed to determine differences between hip rotational range of motion and strength based on the presence of throwing-arm pain (yes/no) and throwing sport (baseball/softball). We hypothesized those experiencing pain would display decreases in hip range of motion and strength, and that softball players would display greater range of motion than baseball, but less strength based on sex-specific characteristics. Forty-four baseball (13 ± 2 years, 165.2 ± 13.0 cm, 58.5 ± 13.4 kg) and 50 softball players (13 ± 2 years, 160.9 ± 11.2 cm, 62.7 ± 17.9 kg) participated. Multivariate analysis of variance tests (2 × 2) determined differences in bilateral hip range of motion, total arc of motion, and strength between pain status and sport. There were no significant interactions (> 0.05) for pain status and sport on hip range of motion, total arc of motion, and strength. Furthermore, no significant main effects (> 0.05) were found for pain status or sport alone on range of motion or strength. Future work should be directed at explaining the effects of hip characteristics on the throwing motion and how it equates to throwing-arm health.

Introduction

Youth throwing athletes often participate in their sport while experiencing pain [1, 2]. As pain may be a precursor to acute and/or chronic injury [1], throwing-related upper extremity pain has understandably received considerable attention. Prior research has identified factors such as height, weight/mass, joint range of motion (ROM), throwing workload, balance, and biomechanics as important contributors to upper extremity pain [3–7]. However, an exploration of risk factors associated with pain across throwing sports is still lacking.

The throwing skill is fundamental to baseball and softball athletes and requires precise timing and sequencing of body segments. If motion progresses efficiently from the legs, through the trunk, to the throwing arm and hand before ball release [8], the throwing athlete will then be able to deliver a ball at high speeds without added shear stress on the throwing shoulder girdle and elbow [9]. Moreover, any restrictions along this linked segmental chain, i. e. at the hips, can negatively impact performance [10].

In baseball, decreased hip internal rotation (IR) of the stride leg (front leg) has been associated with elbow and shoulder pain in youth (age: 9–12) players [11]. Further, for adolescent baseball players, limited hip flexion of the stride (front) and stance (back) leg, as well as decreased hip IR ROM (seated 90°) of each leg, was found in a group with pain compared to those who were pain-free [12]. Hamano et al. reported decreased hip external rotation (ER) ROM of the stance leg in high school players who experienced a shoulder or elbow injury in the past 3 years [13], and the authors later reported restrictions in bilateral hip flexion ROM and stance leg hip IR in younger players (age: 7–14) when comparing upper limb injured and non-injured groups [13]. A study by Li et al. reported that professional players who suffered an in-season injury to the hip region had a decreased total hip arc ROM (IR + ER) on both sides compared to non-injured players. Although there are some initial indications in baseball, not all studies have found clinical differences in hip rotational ROM measures between players with and without upper extremity pain [14, 15].

In softball, however, the relationship between hip ROM and pain is less clear. As hip function has been shown to play an important role in throwing mechanics and performance [16–19], numerous studies have been conducted in collegiate [20, 21], high school [21] and youth [22] populations to gain further understanding. However, these studies have only provided descriptive data for hip joint ROM. Whether there are differences in hip ROM between groups of individuals with or without pain has not been fully established. To date, only findings of decreased stance hip ER ROM in a group of collegiate level softball pitchers experiencing upper extremity pain have been reported [23]. Therefore, a comparison of hip ROM measures between different pain status groups is needed.

An alternative way to assess hip function is via strength testing. Harding et al. demonstrated that hip IR and abduction strength were correlated with years of competitive play and number of months played in the last year for baseball pitchers [24]; while Zeppieri et. al. reported decreases in hip abduction strength in baseball pitchers over the course of a season [25]. Furthermore, stance hip extension strength has been positively correlated with hip-shoulder separation angle during the pitch, and both stride and stance hip abduction strength has been positively correlated with elbow valgus torque [26]. Increased rotational forces created by increased hip strength measures may be a risk factor for injury, if the result is increased forces on the upper extremity [27]. An investigation into the effects of hip ROM on the kinetic chain reported an association between increased drive hip ER isometric strength and increased net energy outflow among throwing-arm segments [19].

As literature suggests, factors pertaining to the kinetic chain or kinematic sequencing when throwing can lead to injury [28, 29]. To date, several studies have compared functional differences between baseball and softball, and predictors of injury [30–32]. However, limited data exist evaluating group differences between pain status (upper extremity: pain/no pain), and sport (baseball and softball), for hip rotational ROM and isometric strength. Therefore, the purpose of this study is to investigate stance and stride hip range of motion and isometric strength in youth baseball and softball athletes. Additionally, the authors further sought to explore whether there were any significant differences in stance and stride hip IR and ER ROM and isometric strength measures based on pain status and sport. We hypothesized lower hip ROM and greater strength in baseball and softball players experiencing pain. In regard to sport, we hypothesized that softball players would have greater hip ROM than baseball players but less hip strength.

Materials and Methods

All testing procedures were approved by the University's Institutional Review Board. All consent and assent declarations were obtained prior to any testing. Participants were recruited largely based on the lab's promotion (emails and media) and interaction with parents, players, and coaches among local communities (primarily in the Southeast). Further, interested participants may obtain clinical and biomechanical assessments. In this regard, non-random sampling techniques (convenience/voluntary) were utilized. Study inclusion criteria required participants to be under 18 years of age and actively competing on a team baseball or softball roster at any position (pitcher, catcher, positional). Additionally, participants had to be surgery free for the past six months. A total of 354 throwing athletes [9 to 17 years old] were examined at random times throughout the year. Participants reported to the laboratory, where physical assessments were performed.

Hip ROM and Strength measurements

Hip rotational ROM was measured passively with the participant in a seated position. The participant's knees were flexed to 90° allowing the legs to comfortably hang off the edge of the table with their hands resting comfortably on the table to assist with trunk stabilization [16, 33–35]. The hip was in 90° of flexion and a towel was placed under the femur. A digital inclinometer was aligned along the soft tissue contour of the tibia. The femur was supported by the examiner to eliminate accessory motion. The hip was passively rotated until capsular end-feel was achieved. At the point of a firm capsular end-feel, while not permitting any accessory hip movement (hip hiking), the ROM measurement was recorded [16, 34, 36]. Intra-rater reliability for ROM ($ICC_{(3,k)}$ of 0.92 to 0.95 for all measurements) were reported. Hip total arc ROM was determined as the sum of internal and external ROM respective to each hip. Hip rotational strength was measured with the participant positioned as per the ROM measures. A handheld dynamometer (Lafayette Instruments, Lafayette, IN) was placed three inches proximal to the medial malleolus for ER and three inches proximal to the lateral malleolus for IR. The participant was instructed to maximally internally/externally rotate stance and stride limb hips against the applied resistance of the examiner for 3 seconds. Two maximal effort isometric "make" tests against the dynamometer were performed and the peak value was taken for analysis. The investigator visually monitored the participants for compensations at the trunk or hip. The stance leg hip represented the side ipsilateral to the throwing arm and the stride leg hip represented the side contralateral to the throwing arm.

Based on a health history questionnaire administered to players prior to collection procedures, players were grouped into pain and no-pain groups based on their self-reported responses to the question: "Do you currently experience any pain/discomfort in your upper extremity, specifically your throwing side?" A total of 166 baseball players (upper extremity pain = 23 [13.9 %]; no upper extremity pain = 143 [86.1 %]), and 188 softball players (upper extremity pain = 25 players [13.3 %]; no upper extremity pain = 163

[86.7 %]) comprised the original set of data. Upper extremity pain groups consisted of participants experiencing pain at any of the throwing-arm joints and/or segments. Grouping assignments of participants experiencing upper extremity pain was performed post collection.

Statistical analysis

With randomized controlled trials being the gold standard in testing causal inference and based on the ethical nature of collecting measures on those with UE pain, propensity score matching (PSM) in IBM SPSS (IBM Corp. Released 2021. IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY) was used to create balance between the pain and no pain groups of players for each sport. This removed potential confounders on hip ROM and strength measures, and pain status.[37–39] In order to perform PSM, participants with missing data were removed. This included eight baseball players (pain = 1; no pain = 7) and one softball player (no pain). The remaining 158 baseball players (pain = 22 [13.9 %]; no pain = 136 [86.1 %]) and 187 softball players (pain = 25 [13.4 %]; no pain = 162 [86.6 %]) were matched based on their age, height, mass, and sport using a match tolerance of 0.2, sampling without replacement. A total sample of 94 players was used for analysis, 44 of which were baseball players (age: 13 ± 2 years (range: 9–17 years), height: 165.2 ± 13.0 cm, mass: 58.5 ± 13.4 kg) and 50 who were softball players (age: 13 ± 2 years (range: 10–17 years), height: 160.9 ± 11.2 cm, mass: 62.7 ± 17.9 kg). Participant demographics according to sport and pain status can be found in ▶ **Table 1**.

Three separate two-way multivariate analysis of variance (MANOVA) tests were performed in IBM SPSS (IBM Corp, Version 28.0. Armonk, NY) to determine differences in 1) hip IR/ER ROM, 2) total arc HIP ROM and 3) hip IR/ER strength measures based on pain status and sport. Total arc HIP ROM was tested in a separate analysis due to less theoretical/empirical support than other hip IR/ER ROM measures on upper extremity pain/injury. There was a linear relationship between the dependent variables, as assessed by scatterplots, and no evidence of multicollinearity, as assessed by Pearson correlation ($r < 0.9$). A total of 12 univariate outliers were observed upon inspection of boxplots for ROM and strength data that were grouped according to pain status and sport. The univariate outliers were left in the analysis based on inspection of the data and no reason to reject them.

All hip ROM measures grouped by pain status and sport data were normally distributed as assessed by Shapiro-Wilk's test ($p > 0.05$), except for stride hip IR ROM ($p = .043$) in the baseball no-pain group, which showed negative skewness; stance hip ER ROM ($p = .041$) in the softball pain group, which appeared platykurtic; and stance hip total arc ($p = .033$) in the softball pain group, which showed negative skewness. Hip strength measures grouped by pain status and sport were normally distributed ($p > 0.05$) apart from stride hip ER isometric strength ($p = .015$) in the baseball pain group, which showed positive skewness.

▶ **Table 1** Descriptive statistics.

	Pain Status (n)	Height (cm)	Mass (kg)	Age (y)
BB	No (22)	165.8 ± 14.5	59.7 ± 14.7	13 ± 2
	Yes (22)	164.6 ± 11.7	57.3 ± 12.2	13 ± 2
SB	No (25)	159.1 ± 12.0	62.0 ± 17.0	13 ± 2
	Yes (25)	162.7 ± 10.3	63.4 ± 19.1	14 ± 2

BB = baseball; SB = softball.

Results

A two-way MANOVA was run with two independent variables – pain status and sport – and four dependent hip rotation ROM variables (seated stance leg IR/ER and seated stride leg IR/ER) to understand whether there were differences in throwing athletes' hip ROM based on pain status and sport. Descriptive data for hip ROM by sport and pain status can be found in ▶ **Table 2**.

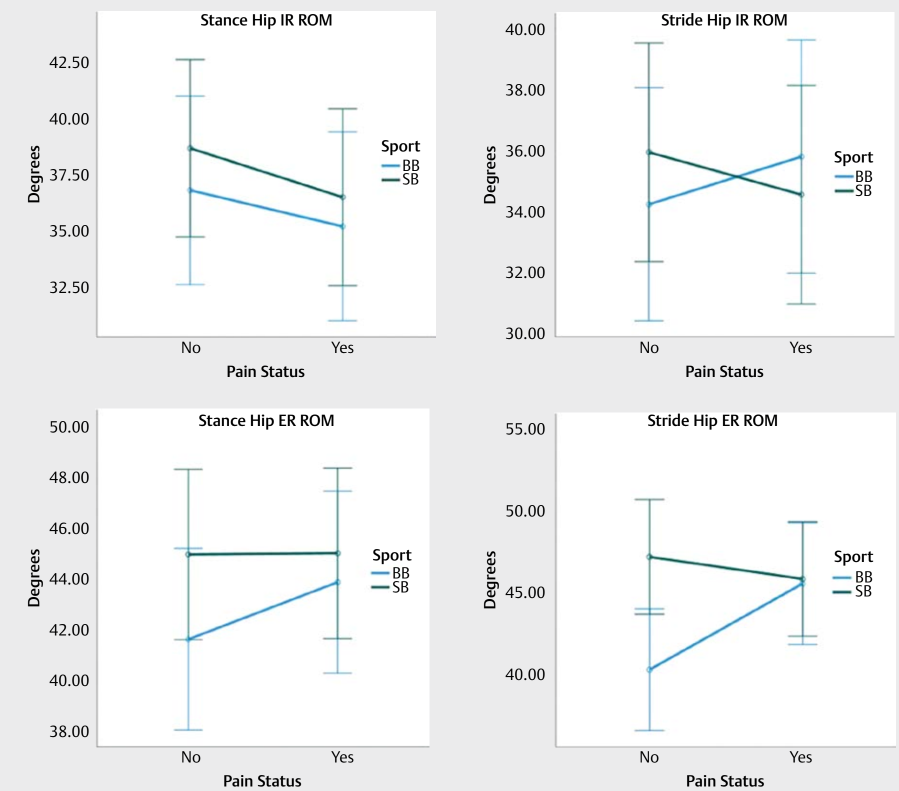
For hip ROM measures there was homogeneity of covariance, as assessed by Box's M test (Box's M = 38.948, $p = .216$). Equal variance was assumed for all ROM measures via Levene's Test of Homogeneity of Variance ($p > 0.05$), aside from stance hip ER ROM ($p < .05$); though group sizes were similar, and adjustment to the alpha level was not implemented based on the reported outcome. The interaction effect between pain status and sport on the combined dependent hip ROM measures was not statistically significant ($F(4, 87) = 2.089$, $p = 0.089$, Wilks' $\Lambda = 0.912$, partial $\eta^2 = 0.088$). The main effect of pain status on the combined dependent hip ROM measures was not statistically significant ($F(4, 87) = 1.470$, $p = 0.218$, Wilks' $\Lambda = 0.937$, partial $\eta^{2=} = 0.063$). The main effect of sport on the combined dependent hip ROM measures was not statistically significant ($F(4, 87) = 0.965$, $p = 0.431$, Wilks' $\Lambda = 0.958$, partial $\eta^{2 = 0.}042$). ▶ **Fig. 1** displays separate plots for each dependent variable based on the two independent variables.

A second two-way MANOVA was run with two independent variables – pain status and sport – and two dependent hip total arc rotation variables (seated stance leg total arc and seated stride leg total arc) to understand whether there were differences in throwing athletes' total hip arc ROM based on pain status and sport. Descriptive data for total hip arc by sport and pain status can be found in ▶ **Table 3**.

For total arc hip ROM measures there was homogeneity of covariance, as assessed by Box's M test (Box's M = 8.243, $p = 0.543$). Equal variance was assumed for all ROM measures via Levene's Test of Homogeneity of Variance ($p > 0.05$). The interaction effect between pain status and sport on the combined dependent total arc

▶ **Table 2** Descriptive statistics for hip range of motion (°) by sport & pain status.

	Pain Status (n)	Stance Hip IR	Stance Hip ER	Stride Hip IR	Stride Hip ER
BB	No (22)	36.8 ± 9.2	41.6 ± 5.8	34.2 ± 9.5	40.3 ± 7.3
	Yes (22)	35.2 ± 9.1	43.9 ± 8.2	35.8 ± 6.6	45.6 ± 8.7
SB	No (25)	38.7 ± 11.3	45.0 ± 8.5	36.0 ± 10.4	47.2 ± 8.3
	Yes (25)	36.5 ± 9.5	45.0 ± 10.3	34.6 ± 9.0	45.9 ± 10.5



▶ **Fig. 1** Estimated marginal means of stance and stride hip internal and external range of motion. Note: Error bars are 95 % confidence intervals. BB = baseball; SB = softball; IR = internal rotation; ER = external rotation.

▶ **Table 3** Descriptive statistics for hip total arc range of motion (°) by sport & pain status.

	Pain Status (n)	Stance Hip Total Arc	Stride Hip Total Arc
BB	No (22)	78.5 ± 12.2	74.6 ± 11.6
	Yes (22)	79.1 ± 15.1	81.4 ± 14.0
SB	No (25)	83.7 ± 14.6	83.2 ± 12.9
	Yes (25)	81.5 ± 16.0	80.4 ± 15.2

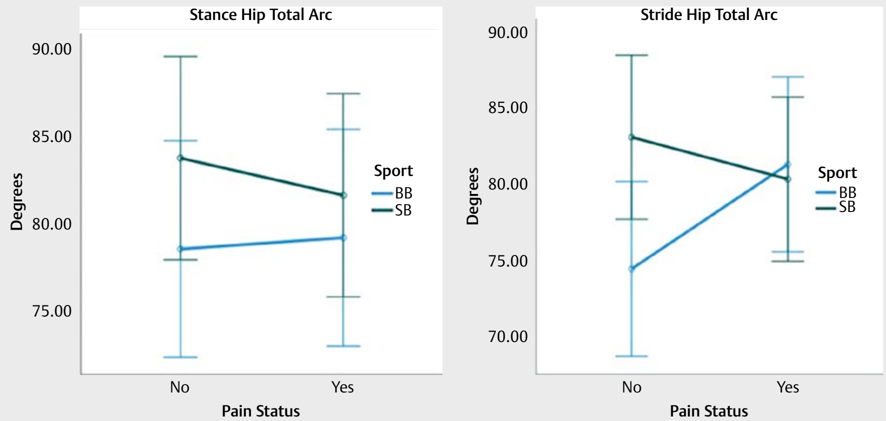
Note: BB = baseball; SB = softball.

hip ROM measures was statistically significant ($F(2, 89) = 4.079$, $p = 0.020$, Wilks' $\Lambda = 0.916$, partial $\eta^2 = 0.084$).

To determine which outcomes differed based on the interaction, we used two factorial ANOVAs. For stance hip total arc ROM there was no statistically significant interaction between pain status and sport ($F(1,90) = 0.210$, $p = 0.648$, partial $\eta^2 = 0.002$. An analysis of main effects revealed no statistically significant main effects for pain status ($F(1,90) = 0.0.60$, $p = .807$, partial $\eta^2 = 0.001$) or sport ($F(1,90) = 1.59$, $p = .210$, partial $\eta^2 = 0.017$) for stance hip total arc ROM. For stride hip total arc ROM there was no statistically significant interaction between pain status and sport ($F(1,90) = 2.942$, $p = 0.09$, partial $\eta^2 = 0.032$. An analysis of main effects revealed no statistically significant main effects for pain status ($F(1,90) = 0.538$, $p = 0.465$, partial $\eta^2 = 0.006$) or sport ($F(1,90) = 1.876$, $p = 0.174$, partial $\eta^2 = 0.020$) for stride hip total arc ROM. ▶ **Fig. 2** displays separate plots for each dependent variable based on the two independent variables.

A third two-way MANOVA was run with the independent variables of pain status and sport and four dependent hip rotation isometric strength variables (seated stance leg IR/ER and seated stride leg IR/ER) to understand if there were differences in throwing athletes' hip rotation isometric strength measures based on pain status and sport. Descriptive data for hip isometric strength by sport and pain status can be found in ▶ **Table 4**.

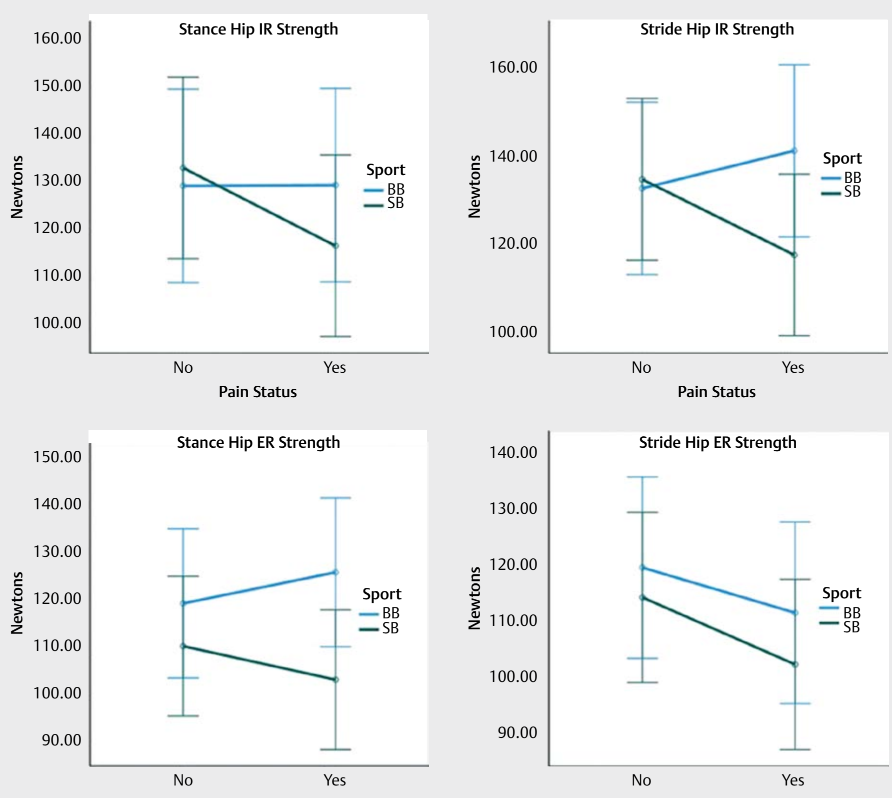
Equal variance was assumed for all ROM measures as assessed by Levene's Test of Homogeneity of Variance ($p > 0.05$) except for stride hip ER strength ($p < 0.05$), though group sizes were again similar, adjustment of the alpha level was not performed based on the reported outcome. The interaction effect between pain status and sport on the combined dependent hip strength measures was not statistically significant ($F(4, 87) = 0.971$, $p = 0.428$, Wilks' $\Lambda = 0.957$, partial $\eta^2 = 0.043$). The main effect of pain status on the combined dependent hip strength measures was not statistically significant ($F(4, 87) = 1.195$, $p = 0.319$, Wilks' $\Lambda = 0.948$, partial $\eta^2 = 0.052$). Similarly, the main effect of sport on the combined dependent hip strength measures was not statistically significant ($F(4, 87) = 1.806$, $p = 0.135$, Wilks' $\Lambda = 0.923$, partial $\eta^2 = 0.077$). ▶ **Fig. 3** displays separate plots for each dependent variable based on the two independent variables.



▶ **Fig. 2** Estimated marginal means of stance and stride hip total arc range of motion, pain status by sport. Note: Error bars are 95 % confidence intervals. BB = baseball; SB = softball; Hip Total Arc = internal rotation + external rotation.

▶ **Table 4** Descriptive statistics for hip isometric strength (N) by sport & pain status.

	Pain Status (N)	Stance Hip IR	Stance Hip ER	Stride Hip IR	Stride Hip ER
BB	No (22)	129.0 ± 56.8	119.0 ± 42.7	132.3 ± 49.4	118.6 ± 50.6
	Yes (22)	129.1 ± 34.4	125.6 ± 33.0	140.8 ± 43.9	110.5 ± 34.9
SB	No (25)	132.8 ± 53.6	110.0 ± 36.3	134.3 ± 48.1	113.3 ± 32.9
	Yes (25)	116.4 ± 42.9	102.9 ± 36.5	117.2 ± 42.7	101.3 ± 33.1



▶ **Fig. 3** Estimated marginal means of stance and stride hip internal and external isometric strength. Note: Error bars are 95 % confidence intervals. BB = baseball; SB = softball; IR = internal rotation; ER = external rotation.

Discussion

We hypothesized lower hip ROM and greater strength in baseball and softball players experiencing pain. Further, we also hypothesized that softball players would have greater hip ROM than baseball players but less hip strength. The current study revealed that there were no significant interactions based on pain status and sport on hip IR/ER ROM measures or significant main effects for pain status or sport on hip measures included in this study when groups were matched for age, height, and mass, and sport. Our hypothesis was not supported by these outcomes which expected hip characteristics to differ between pain status and sport, or at least by pain status or sport alone.

This is the first study to compare hip characteristics of youth throwing athletes' reporting upper extremity pain across throwing sports. A single cross-sectional study has already compared passive hip ROM across multiple sports or sex [40], finding that females had greater hip IR ROM than males, independent of sport. Interestingly, ROM were largely similar across sports, except for cross country athletes whose hip ROM differed from baseball/softball, tennis, basketball, and soccer athletes. While the current study's data agree with the trend of females (softball) having increased mean hip ROM values than men (baseball) – regardless of pain status – no significant differences were found between sports in our study.

The current data also revealed no difference in hip IR ROM for the stride leg in youth baseball throwing athletes reporting pain (pain: 35.8 ± 6.6° vs. no pain, 34.2 ± 9.5°). These findings differ from previously reported findings of internal rotation of the stride hip when flexed 90 degrees between pain and pain-free groups [11]. Sekiguchi and colleagues [11] found that youth baseball players (9 to 12 years old) with elbow or shoulder pain had significant restrictions in hip IR ROM of the stride leg compared to those without pain (35.8° [pain] vs. 43.7 ° [no pain], $p = 0.022$). Saito et al. [12] observed stride leg hip IR values of 36.4° in baseball athletes reporting elbow pain vs. 46.9° in players without pain. Nevertheless, the results of this study do replicate non-significant differences between pain and pain-free groups in drive leg hip IR/ER ROM and stride leg hip ER ROM [11].

It is possible these differences are due to differing ROM measurement techniques used for hip IR and ER between studies. Where hip IR ROM testing in the aforementioned studies was done in a supine position with the hip flexed to 90 degrees – a method that has been shown to have higher inter-rater and intra-rater reliabilities [41] – hip rotational ROM and strength in our study was measured passively with the participant in a seated position, similar to Martin et al., who evaluated youth softball athletes' hip ROM in a seated position and found no difference in hip ROM or strength between athletes reporting upper extremity pain vs. no pain [42]. It may, therefore, be necessary to conduct more research to clarify the relationship of hip measures and upper extremity pain in throwing athletes measured seated vs. supine (or prone).

The repetitive nature of throwing sports can result in hip ROM and strength adaptations [25, 43, 44]. Chan et al. described decreases in hip ROM and increases in shoulder ROM for a professional baseball population over the course of season [44], while others have reported decreases in collegiate baseball players' stance and stride hip passive ROM, and isometric hip abduction strength in the post-season compared to pre-season [25, 43]. Similarly, bilateral decreases of passive hip ROM, and hip abduction strength, were found across a competitive season of softball. Considering these findings and prior work regarding hip tightness [45, 46] limited preseason hip ROM may be considered as a risk factor for shoulder/elbow pain [45, 46]. We did not evaluate for the effect of pre-season vs. in-season timing on hip measures in our study and agree this should be explored further. While not significant at the univariate level of testing, the means for stride hip total arc ROM in softball players without pain ($M \pm SD = 83.2 \pm 12.9$) were relatively higher than baseball players without pain ($M \pm SD = 74.6 \pm 11.6$). These trends in stride hip total arc ROM may be clinically meaningful in athletes without pain as changes in stride hip total arc ROM may occur over the course of season(s), potentially related to arm-pain.

Recent data in both baseball and softball suggest a relationship between hip strength and injury risk in throwing athletes. Albiero et al. [26] reported that elbow varus torque was found to be strongly correlated with both stride and stance hip strength in adolescent baseball pitchers. Additionally, it has been documented that collegiate pitchers reporting upper extremity pain present with decreased hip ER ROM on the throwing side (stance) and reductions in hip IR (throwing side) isometric strength and hip ER (glove side) isometric strength [23]. It is unclear why the current study did not reveal a relationship between pain and isometric hip strength. Hip strength increases with age and it is possible the relationship between strength and upper extremity pain does not reach significance until athletes reach older adolescence.[47]

Considered a strength to the study, propensity score matching was employed to obtain age, height, weight, and sport matched-control groups. Control matching has been used in prior work [48, 49] to account for potential confounders that may be associated with risk factors for pain/injury [7, 50, 51]. As the intention of this study was to investigate the presence of upper extremity pain and sport on hip characteristics, we controlled for age and anthropometric parameters. The pain group comprised athletes experiencing upper extremity pain at the time of testing, which allowed us to compare the presence of pain directly to those without pain. However, pain scales may be a viable method for examining further links between pain and hip characteristics.

Due to the small sample size ($N = 44$ baseball and $N = 50$ softball) we were unable to compare pitchers vs. positional players in our analysis. Though, other work has not identified differences in hip ROM between softball pitchers and positional players [22] or at least players who identified their primary position as a pitcher or positional player. We feel a larger study is needed to determine differences in hip measures that might have been masked by combining positional players, with potentially reduced annual workload, relative to pitchers. Secondly, data were captured in a cross-sectional study design, yet a longitudinal assessment with serial measures may provide a better understanding of the interplay between pain and hip characteristics over time in youth baseball and softball athletes. Lastly, we did not evaluate the differences in other known risk factors for injury like throwing biomechanics, workload, etc. on upper extremity pain in our analysis as this model was utilized to understand how these clinical measures may be useful for interventions directed at injury prevention.

Prior research in baseball and softball indicates various modifiable and non-modifiable intrinsic and extrinsic risk factors for upper extremity injuries. When controlling for age, height and body mass, rotational hip measures were similar between baseball and softball athletes. Moreover, there was no relationship between sport, hip ROM, hip strength, and pain in our model. More research is needed to determine the interrelatedness between hip ROM, hip strength, and upper extremity pain in a larger cohort of throwing athletes. Further, identifying sex- and sport-specific differences in hip ROM in throwing athletes with upper extremity pain in baseball and softball may be useful for player assessment and injury prevention.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

[1] Yang JS, Stepan JG, D'voracek L et al. Fast-pitch softball pitchers experience a significant increase in pain and fatigue during a single high school season. HSS J 2016; 12: 111–118

[2] Lyman S, Fleisig GS, Andrews JR et al. Effect of pitch type, pitch count, and pitching mechanics on risk of elbow and shoulder pain in youth baseball pitchers. Am J Sports Med 2002; 30: 463–468

[3] Dowling B, McNally MP, Chaudhari AM et al. A review of workload-monitoring considerations for baseball pitchers. J Athl Train 2020; 55: 911–917

[4] Keeley DW, Oliver GD, Dougherty CP. A biomechanical model correlating shoulder kinetics to pain in young baseball pitchers. J Human Kinet 2012; 34: 15–20

[5] Oliver GD, Friesen K, Barfield J et al. Association of upper extremity pain with softball pitching kinematics and kinetics. Orthop J Sports Med 2019; 7:

[6] Nakase K, Shitara H, Tajika T et al. The relationship between dynamic balance ability and shoulder pain in high school baseball pitchers. Sports Health 2022; 14: 397–403

[7] Tajika T, Oya N, Kuboi T et al. Risk factors for throwing-related shoulder and elbow pain in adolescent baseball players: A prospective study of physical and developmental factors. Orthop J Sports Med 2021; 9: 23259671211017129

[8] Fleisig GS, Barrentine SW, Zheng N et al. Kinematic and kinetic comparison of baseball pitching among various levels of development. J Biomech 1999; 32: 1371–1375

[9] Davis JT, Limpisvasti O, Fluhme D et al. The effect of pitching biomechanics on the upper extremity in youth and adolescent baseball pitchers. Am J Sports Med 2009; 37: 1484–1491

[10] Albiero ML, Kokott W, Dziuk C et al. Hip flexibility and pitching biomechanics in adolescent baseball pitchers. J Athl Train 2022; 57: 704–710

[11] Sekiguchi T, Hagiwara Y, Yabe Y et al. Restriction in the hip internal rotation of the stride leg is associated with elbow and shoulder pain in elite young baseball players. J Shoulder Elbow Surg 2020; 29: 139–145

[12] Saito M, Kenmoku T, Kameyama K et al. Relationship between tightness of the hip joint and elbow pain in adolescent baseball players. Orthop J Sports Med 2014; 2: 2325967114532424

[13] Hamano N, Shitara H, Tajika T et al. Relationship between upper limb injuries and hip range of motion and strength in high school baseball pitchers. J Orthop Surg 2021; 29:

[14] Garrison JC, Hannon J, Conway JE. No differences in hip range of motion exists between baseball players with an ulnar collateral ligament tear and healthy baseball players. Int J Sports Phys Ther 2019; 14: 920–926

[15] Kim Y, Jo Y, Kim S et al. Shoulder pain and rotational range of motion of the trunk, shoulder, and hip in baseball players. J Athl Train 2019; 54: 1149–1155

[16] Robb AJ, Fleisig G, Wilk K et al. Passive ranges of motion of the hips and their relationship with pitching biomechanics and ball velocity in professional baseball pitchers. Am J Sports Med 2010; 38: 2487–2493

[17] Plummer H, Bordelon N, Wasserberger KW et al. Association between passive hip range of motion and pitching kinematics in high school baseball pitchers. Int J Sports Phys Ther 2021; 16: 1323–1329

[18] Gilmer GG, Washington JK, Dugas J et al. The role of lumbopelvic-hip complex stability in softball throwing mechanics. J Sport Rehab 2019; 28: 196–204

[19] Oliver GD, Wasserberger KW, de Swart A et al. Hip range of motion and strength and energy flow during windmill softball pitching. J Athl Train 2021; 56: 280–285

[20] Oliver GD, Plummer H, Brambeck A. Hip and glenohumeral passive range of motion in collegiate softball players. Int J Sports Phys Ther 2016; 11: 738–745

[21] West AM, Scarborough DM, McInnis KC et al. Strength and motion in the shoulder, elbow, and hip in softball windmill pitchers. PM & R 2019; 11: 1302–1311

[22] Friesen K, Downs JL, Wasserberger KW et al. Glenohumeral and hip range of motion in youth softball athletes. Int J Sports Med 2020; 41: 59–64

[23] Oliver GD, Gilmer GG, Friesen K et al. Functional differences in softball pitchers with and without upper extremity pain. J Sci Med Sport 2019; 22: 1079–1083

[24] Harding JL, Picha KJ, Bliven KCH. Pitch volume and glenohumeral and hip motion and strength in youth baseball pitchers. J Athl Train 2018; 53: 60–65

[25] Zeppieri G, Lentz TA, Moser MW et al. Changes in hip range of motion and strength in collegiate baseball pitchers over the course of a competitive season: A pilot study. Int J Sports Phys Ther 2015; 10: 505–513

[26] Albiero ML, Kokott W, Dziuk C et al. Relationships between hip strength and pitching biomechanics in adolescent baseball pitchers. J Athl Train 2022. DOI: 10.4085/1062-6050-0074.22

[27] Luera MJ, Dowling B, Magrini MA et al. Role of rotational kinematics in minimizing elbow varus torques for professional versus high school pitchers. Orthop J Sports Med 2018; 6: 2325967118760780

[28] Burkhart SS, Morgan CD, Kibler WB. The disabled throwing shoulder: spectrum of pathology Part I: Pathoanatomy and biomechanics. Arthroscopy 2003; 19: 404–420

[29] Chaudhari AM, McKenzie CS, Pan X et al. Lumbopelvis control and days missed because of injury in professional baseball pitchers. Am J Sports Med 2014; 42: 2734–2740

[30] Hibberd EE, Oyama S, Tatman J et al. Dominant-limb range-of-motion and humeral-retrotorsion adaptation in collegiate baseball and softball position players. J Athl Train 2014; 49: 507–513

[31] Butler RJ, Myers HS, Black D et al. Bilateral differences in the upper quarter function of high school aged baseball and softball players. Int J Sports Phys Ther 2014; 9: 518

[32] Shanley E, Rauh MJ, Michener LA et al. Shoulder range of motion measures as risk factors for shoulder and elbow injuries in high school softball and baseball players. Am J Sports Med 2011; 39: 1997–2006

[33] Ellenbecker TS, Ellenbecker GA, Roetert EP et al. Descriptive profile of hip rotation range of motion in elite tennis players and professional baseball pitchers. Am J Sports Med 2007; 35: 1371–1376

[34] Sauers EL, Huxel Bliven KC, Johnson MP et al. Hip and glenohumeral rotational range of motion in healthy professional baseball pitchers and position players. Am J Sports Med 2013. DOI: 10.1177/0363546513508537

[35] Scher S, Anderson K, Weber N et al. Associations among hip and shoulder range of motion and shoulder injury in professional baseball players. J Athl Train 2010; 45: 191–197

[36] Laudner KG, Moore SD, Sipes RC et al. Functional hip characteristics of baseball pitchers and position players. Am J Sports Med 2010; 38: 383–387

[37] Norton R, Honstand C, Joshi R et al. Risk factors for elbow and shoulder injuries in adolescent baseball players: A systematic review. Am J Sports Med 2019; 47: 982–990

[38] Hill JL, Humphries B, Weidner T et al. Female collegiate windmill pitchers: Influences to injury incidence. J Strength Cond Res 2004; 18: 426–431

[39] Friesen KB, Anz AW, Dugas JR et al. The effects of body mass index on softball pitchers' hip and shoulder range of motion. Sports Med Int Open 2021; 5: E8–E13

[40] Hogg JA, Schmitz RJ, Nguyen AD et al. Passive hip range of motion values across sex and sport. J Athl Train 2018; 53: 560–567

[41] Gradoz MC, Bauer LE, Grindstaff TL et al. Reliability of hip rotation range of motion in supine and seated positions. J Sport Rehab 2018; 27:

[42] Martin CL, Pobocik K, Hannah M et al. Clinical Measures of Adolescent Softball Players With and Without Upper-Extremity Pain: A Preliminary Study. J Sport Rehab 2022; 1: 1–7

[43] Guy CR, Zeppieri G, Bruner ML et al. Shoulder and hip range of motion and strength changes throughout a season in college softball players. Int J Sports Phys Ther 2021; 16: 1492–1503

[44] Chan JM, Zajac J, Erickson BJ et al. Upper extremity and hip range of motion changes throughout a season in professional baseball players. Am J Sports Med 2020; 48: 481–487

[45] Endo Y, Sakamoto M. Correlation of shoulder and elbow injuries with muscle tightness, core stability, and balance by longitudinal measurements in junior high school baseball players. J Phys Ther Sci 2014; 26: 689–693

[46] Hamano N, Shitara H, Tajika T et al. Relationship between tightness of the hip joint and shoulder/elbow injury in high school baseball pitchers: a prospective study. Sci Rep 2020; 10: 1–4

[47] Picha KJ, Harding JL, Bliven KC. Glenohumeral and hip range-of-motion and strength measures in youth baseball athletes. J Athl Train 2016; 51: 466–473

[48] Manzi JE, Kunze KN, Meza B et al. Decreased trunk rotation at foot contact in professional baseball pitchers with prior conservatively managed SLAP tears: A propensity score–matched analysis. Arthroscopy 2022; 38: 1066–1074

[49] Manzi JE, Dennis E, Black GG et al. Kinematic and kinetic analyses of professional pitchers with history of core or groin injuries: A propen. J Orthop 2022; 30: 108–114

[50] Jayanthi N, LaBella CR, Fischer D et al. Sports-specialization intensive training and the risk of injury in young athletes: A clinical case-control study. Am J Sports Med 2015; 43: 794–801

[51] Chalmers PN, Sgroi T, Riff AJ et al. Correlates with history of injury in youth and adolescent pitchers. Arthroscopy 2015; 31: 1349–1357

