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Original Research

Dominant Arm Internal and External Rotation Strength is Related to Arm Pain in Youth Baseball Players

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Background and Purpose

The prevalence of arm pain in youth baseball players is high with approximately half reporting arm pain during the season, and the number of ulnar collateral ligament reconstructions in youth baseball players is increasing. Few studies have examined the relationship between shoulder strength and passive range of motion (ROM) with arm pain (either shoulder or elbow pain) during throwing, especially in athletes in early adolescence. The purpose of this study was to determine the relationship between shoulder ROM and strength and the presence of arm pain during throwing in youth baseball players. It was hypothesized that less internal rotation (IR) ROM, less total rotational ROM, and lower IR and external rotation (ER) strength would be associated with arm pain.

Study Design

Observational cohort study

Methods

Sixty-five youth male baseball players between the ages of 12-15 were enrolled. Shoulder strength (ER, IR, ER/IR strength ratio, scaption) and passive ROM (ER, IR, flexion, horizontal adduction) were collected prior to the start of the spring 2021 baseball season. Players self-reported their arm pain frequency during throwing as never, rarely, sometimes, often, or always. The relationship between reported arm pain frequency during throwing and shoulder ROM and strength measurements was examined.

Results

ER (ρ= -0.289, p=0.020) and IR strength (ρ= -0.262, p=0.035) were weakly and negatively correlated with reports of arm pain during throwing. No other clinical variables were associated with reports of arm pain ($p \geqslant 0.124$)

Conclusion

In youth baseball players, greater IR and ER strength were associated with less arm pain frequency during throwing, while ROM was not associated with arm pain frequency. Future research should explore these variables prospectively to determine if changes in ROM and strength are related to the development of arm pain in youth baseball players.

Level of Evidence

3

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INTRODUCTION

The prevalence of arm pain in youth baseball players is high with approximately half reporting arm pain (either shoulder or elbow pain) during the season.[1,2] In addition, the number of ulnar collateral ligament reconstructions has increased disproportionately in youth baseball players.[3] Several factors related to throwing load (i.e. pitch counts, innings pitched, and pitching greater than 8 months per year) have been identified as potential risk factors for arm pain and injuries.[4,5] However, fewer studies have examined the relationship between arm pain and clinical measures, especially in athletes in early adolescence (<16 y/o). Understanding these relationships could help inform rehabilitation and injury risk reduction for these athletes as these clinical measures are commonly addressed treatment targets in physical therapy.

There is evidence that suggests passive range of motion (ROM) and strength may be factors associated with arm injury and/or arm pain in baseball players. However, the majority of literature examining these factors evaluate high school, collegiate, and professional baseball players.[6-11] Few studies have evaluated the association of these variables in younger baseball players, and conflicting findings are reported among these studies.[12-15]

In youth baseball players, two studies have examined the associations between shoulder internal and external rotator strength and arm injury and/or pain with varying results.[12,13] A large prospective cohort study by Sakata[12] evaluated risk factors for medial elbow injury in 353 youth baseball players (pitchers and nonpitchers) aged 6-12 and used handheld dynamometry of both the dominant and nondominant arms to measure shoulder internal and external rotation (ER) strength and used this strength ratio (dominant arm strength/nondominant arm strength) as the variable characterizing strength in their analysis. These authors characterized medial elbow injury as medial elbow pain during throwing with either an abnormal ultrasonography finding or the presence of pain during the clinical assessment of the elbow. Using these operational definitions, neither shoulder internal rotation (IR) nor shoulder ER strength were identified as risk factors for medial elbow pain. One cross sectional study by Harada[13] evaluated 294 youth baseball players (pitchers and nonpitchers) aged 9-12 and used handheld dynamometry to measure shoulder internal and ER strength. Harada characterized elbow injury as having an ultrasonographic abnormality. They reported that increased shoulder internal and ER strength were each associated with greater odds of elbow injury. Given the variation in methodology and reported findings, it remains unclear if shoulder IR or ER strength are important factors contributing to arm injury in youth baseball players.

Four studies have examined the association of shoulder ROM and arm injury and/or pain.[12-15] Sakata[12] also evaluated risk factors for medial elbow injury in youth baseball players aged 6-12 and used goniometry to measure passive total shoulder IR and ER ROM. These authors characterized medial elbow injury as medial elbow pain during throwing with either an abnormal ultrasonography finding or the presence of pain during the clinical assessment of the elbow. They reported significantly less passive total shoulder rotation ROM in those with medial elbow injury compared to those without shoulder or elbow injury. Another prospective cohort study by Shanley[14] used digital inclinometry to measure glenohumeral horizontal adduction and IR ROM in a cohort of youth baseball pitchers aged 8-12. Shanley[14] reported that side-to-side differences in either measure were associated with increased injury risk, as defined by an upper extremity overuse injury that occurred during any baseball team–sponsored activity (from the beginning of preseason through the last postseason game) to any muscle, joint, tendon, ligament, bone, or nerve. A cross sectional study by Harada[13] evaluated 294 youth baseball players (pitchers and nonpitchers) aged 9-12 by assessing shoulder internal and external ROM using goniometry. These authors characterized elbow injury as ultrasonographic abnormality. They reported that shoulder IR ROM was not significantly associated with greater odds of elbow injury, but players with shoulder ER range motion <130 degrees had significantly greater odds of elbow injury. Another cross-sectional study by Tajika[15] evaluated 229 baseball players (pitchers and nonpitchers) aged 9-14 and used goniometry to measure shoulder external and IR ROM. The authors characterized elbow injury as ultrasonographic abnormality of the elbow but also analyzed whether shoulder ROM was associated with symptoms in those with sonographic abnormalities. They reported that while shoulder IR and ER ROM were not significantly different between those with and without sonographic abnormality, significant decreases in IR compared to the nondominant arm of the players were reported in those with sonographic abnormality. In those with sonographic abnormality, no associations were found between shoulder rotation ROM or side-to-side differences and symptoms.

Given the variation in methodology and reported findings, it remains unclear if shoulder IR or ER ROM are important factors contributing to arm injury in youth baseball players. An important limitation to consider is that two of these studies[13,15] have characterized arm injury with ultrasonographic findings, but it is evident that imaging findings at the shoulder and elbow are not necessarily indicative of symptoms in baseball players.[16-18] When evaluating risk factors for arm injury in baseball players, it is critical to evaluate the associations between potential risk factors and symptoms, because symptoms (pain, instability, etc.) directly contribute to functional limitation and missed baseball participation. Furthermore, it is likely that some degree of pain precedes overuse injuries commonly seen in baseball players, so early detection of arm pain may allow for earlier intervention and may minimize disabling arm injuries.

Therefore, the purpose of this study was to determine the relationship between shoulder ROM and strength and the presence of arm pain during throwing in youth baseball players. . The authors hypothesized that less shoulder IR strength, less ER strength, and decreased ER/IR strength ratio would each be associated with greater arm pain frequency during throwing. It was also hypothesized that less

Figure 1. Shoulder internal rotation strength testing position

Figure 1 legend: Dynamometric assessment of glenohumeral IR strength was performed by a single examiner and with subjects positioned supine.

shoulder IR ROM, ER ROM, total rotational (ER ROM + IR ROM), and horizontal adduction ROM would each be associated with greater arm pain frequency during throwing.

METHODS

SUBJECTS

Sixty-five youth male baseball players between the ages of 12-15 were recruited for this study. Subjects were recruited and enrolled in February 2021 from several local youth baseball leagues, and all provided informed consent to participate in the study prior to data collection. The study was approved by the Arcadia University institutional review board. Height and weight were recorded using a standard balance scale and wall mounted tape measure, respectively.

DATA COLLECTION

Shoulder strength, ROM, height, weight, and reported arm pain during throwing were collected at the time of enrollment, which was in February 2021, prior to the start of the spring 2021 baseball season.

SHOULDER STRENGTH

Measurement of isometric shoulder strength was measured with a hand-held dynamometer (HHD) (Lafayette Instrument, Lafayette, IN) for shoulder ER (ER), IR, and elevation in the scapular plane (scaption). All isometric strength measures were taken in the supine position and all measurements were taken by a single assessor with 20 years of combined clinical and research experience. For shoulder ER and IR strength measures, the shoulder was placed at 90 degrees abduction and in a neutral rotation position with the elbow flexed to 90 degrees. The pad of the HHD was placed at the dorsal surface of the wrist for ER strength measurement, and the volar surface of the wrist for IR measurements (Figure 1).

Shoulder elevation in the scapular plane was measured with the shoulder flexed to 90 degrees and the elbow in full extension with the forearm in neutral pronation and supination. To familiarize the subject with the strength testing procedures one submaximal and one maximal isometric contraction was performed to demonstrate the use of the HHD. Three maximal isometric strength trials were collected, and the ensemble average of the trials was recorded for analysis. Verbal encouragement was provided during the testing.

SHOULDER ROM

Measurement of shoulder passive ROM consisted of goniometric assessment of glenohumeral ER, IR, horizontal adduction, and flexion ROM with each subject in a supine position. Measurements were collected using a two-person method as described previously and using a standard goniometer with attached bubble-level.[9] Glenohumeral ER and IR measurements were performed with the shoulder placed at 90 degrees of abduction and elbow flexed to 90 degrees. Horizontal adduction was measured with the arm placed in 90 degrees of shoulder flexion and neutral shoulder rotation. The participant's shoulder was horizontally adducted and the angle between the humerus and the vertical was measured. Pure glenohumeral flexion ROM measurements were collected by first palpating the lateral bor-

Figure 2. Glenohumeral flexion ROM testing position

Figure 2 legend: Goniometric assessment of glenohumeral flexion passive ROM was performed with two examiners and with subjects positioned supine.

der of the scapula in a neutral position. The shoulder was then flexed until movement of the scapula was noted by the examiner, and pure glenohumeral flexion was measured in this position (Figure 2).

SELF-REPORTED ARM PAIN FREQUENCY DURING THROWING

To characterize arm pain while throwing, all subjects completed a written questionnaire at one timepoint.[19] The questionnaire included the following question that included a Likert based ordinal rating scale, "Does your arm hurt when you throw?" Subjects responded with one of the following options: "never", "rarely", "sometimes", "often", or "always". The questionnaire did not specify any reference time for subjects recall. Answers were recorded and then converted ordinally into a 0-4 scale for statistical analysis.

STATISTICAL ANALYSIS

Spearman correlations were used to examine the relationship between the players self-reported arm pain during throwing and the following clinical measures: height, weight, body mass index, dominant arm flexion ROM, IR ROM, ER ROM, horizontal adduction ROM , total rotational ROM (IR ROM + ER ROM), IR strength, ER strength, ER/IR strength ratio, and scaption strength. Statistical significance was set at $p \leqslant 0.05$.

RESULTS

Demographic information for the participating subjects is provided in Table 1.

Correlations between reported arm pain during throwing and shoulder strength are summarized in Table 2.

Weak negative correlations with reported arm pain frequency were observed for both ER ($r = -0.289$, $p = 0.020$) and IR ($r = -0.262$, $p = 0.035$) strength. No other significant correlations were found between reported arm pain and any other strength variable ($p \geqslant 0.118$).

Correlations between arm pain frequency during throwing and anthropometrics and shoulder ROM are summarized in Table 3.

No significant correlations were observed between any anthropometric or ROM variables ($p \geqslant 0.124$).

DISCUSSION

The purpose of this study was to examine the relationships between reported arm pain frequency, shoulder ROM, and strength in youth baseball players. The hypotheses were partly supported as significant although weak negative correlations were found between ER and IR strength and reported arm pain frequency during throwing. There were no significant correlations between arm pain and any ROM measurements. The negative correlations between arm pain frequency and shoulder strength indicate that greater frequency of arm pain was associated with less shoulder ER and IR strength. These findings suggest that strength of the shoulder internal and external rotators may be relevant modifiable factors that contribute to arm pain during throwing and imply that these factors are treatment targets that should be optimized in youth baseball players.

Future work would be helpful to clarify the mechanisms that explain why increased shoulder rotator strength is associated with less frequent arm pain during throwing. The authors speculate that given the relatively high torques at the shoulder during throwing motions, sufficient dynamic stability that is provided by the shoulder rotators may be necessary to minimize stress on other passive shoulder stabilizers.[20] In addition, higher shoulder rotator strength may reflect superior mechanical, neurophysiological, and vascular qualities of the musculotendinous structures that may be sources of overuse-related arm pain during throwing.[21,22] Despite significant negative correlations between arm pain frequency and shoulder rotator strength, the weak strength of these correlations suggest that other factors apart from strength may also be contributing to arm pain frequency during throwing.

The findings of this investigation somewhat differ from the findings of previously reported studies which have reported associations with shoulder ROM and arm injury or pain. The current findings differ from those of Shanley[14] who reported significantly increased risk of overuse injury sustained during baseball activity in those with limited IR and horizontal adduction ROM, but evaluated only pitchers who were younger than the players (pitchers and nonpitchers) which were evaluated in our study. In addition, shoulder ROM was evaluated using inclinometry, rather than goniometry which was used in the current study. The study by Shanley[14] also evaluated arm injuries prospectively in baseball pitchers throughout the course of a season, whereas as-

Table 1. Demographics

	Mean (SD)
N	65
Age (years)	12.7 (1.3)
Body Mass Index (kg/m^2)	21.4 (4.2)
Number of teams playing with in Spring 2021	1 team = 25, 2 teams = 25, 3 teams = 13, 4 teams = 2
Months of year participating in baseball related activities	10.5 (2.5)
Number of players that stopped participation in other sports to play baseball (yes/no)	yes = 25, no = 40
Frequency of arm pain reported during throwing	Never = 21 (32.3%) Rarely = 21 (32.3%) Sometimes = 20 (30.8%) Often = 2 (3.1%) Always = 1 (1.5%)

SD = standard deviation, kg = kilogram, m = meter

Table 2. Correlations between arm pain and shoulder strength

Variable	Spearman's rho	p-value
Internal Rotation Strength (Dominant Arm)	-0.262	0.035*
External Rotation Strength (Dominant Arm)	-0.289	0.020*
External/Internal Rotation Strength Ratio	-0.071	0.576
Scaption Strength (Dominant Arm)	-0.196	0.118

* indicates statistical significance with significance level of alpha = 0.05

Table 3. Correlations between arm pain and shoulder ROM and player anthropometrics

Variable	Spearman's rho	p-value
Flexion ROM	0.093	0.467
Horizontal adduction ROM	0.048	0.706
IR ROM	-0.008	0.949
ER ROM	0.047	0.714
Total Rotational ROM	0.022	0.865
Body Mass Index (kg/m^2)	-0.201	0.127
Height (m)	-0.185	0.140
Weight (kg)	-0.203	0.124

ROM = range of motion, m = meters, kg = kilogram, , IR = internal rotation, ER = external rotation

sessment of reported arm pain in baseball players was performed only at one time point in the current study. While the findings reported by Shanley[14] that shoulder ROM is associated with higher injury risk may be more specific to pitchers, the findings in the current study that ROM is not significantly associated with arm pain frequency may be more generalizable to nonpitching baseball players. In addition, Sakata[12] found that total passive shoulder rotation ROM was significantly different in those with medial elbow injury. The current study's methodology differs from that of Sakata as older baseball players were included and did not characterize elbow injury using clinical tests nor ultrasonographic findings. Instead, elbow injury was characterized according to arm pain frequency during throwing. The authors believe that classifying arm injury according to reported arm pain frequency during throwing may give additional insight because it takes into account shoulder, elbow, and other arm pain that may contribute to and precede injury. Given the high number of baseball players participating despite arm pain, it is likely that arm pain precedes participation-restricting and otherwise disabling injury.

The current findings somewhat differ from the findings of previous studies which have examined associations with shoulder strength and arm injury or pain in youth baseball players. One large prospective study[12] reported that neither shoulder ER nor IR weakness are risk factors for elbow injury, but they only assessed for medial elbow injuries, and evaluated baseball players that were 6-12 years old, which is younger than the current sample of baseball players which were 12-15 years old. It may be that shoulder strength has less association with medial elbow injury but is more associated with shoulder and other arm injuries. Contrary to the current study which found that increased shoulder IR and ER strength was associated with less frequent arm pain, another cross sectional study[13] reported that increases in shoulder IR and ER strength were associated with elbow injury. However, the prior study used ultrasonography to characterize elbow injury, which may or may not be associated with arm pain which was measured in the current study.

There are limitations to the current study. Correlational analysis was utilized to examine the relationships between clinical measures and arm pain, so causal relationships between these variables cannot be assumed. While causation cannot be established with the current study design, the findings from this study imply that more shoulder rotation strength may be considered positive, because it was related to less frequent arm pain. More research is needed to discern the relationship between shoulder strength and arm pain in youth athletes. Future longitudinal studies may help further clarify the relationship between shoulder ROM and strength and arm pain in youth baseball players. Another limitation to the current study is that shoulder strength measurements were not normalized and thus do not account for confounding anthropometric variables (height and weight) between participants which are thought to correlate with strength.[23] Despite this limitation, associations were found between non-normalized shoulder rotation strength and reported arm pain frequency, but no significant associations between reported arm pain frequency and either height or weight. The current study consisted of a relatively small sample size compared to other studies examining range of motion and strength as risk factors for arm injuries in youth baseball players. Studies with larger samples may be more helpful to confirm whether or not these factors are associated with reported arm pain. Lastly, reliance on self-reported data at one timepoint should be considered a limitation. Given that pain is in part a subjective measure, it may be difficult to characterize pain using strictly objective measures, but more frequent assessment of pain that is consistently measured shortly following throwing may be a more comprehensive method to characterize arm pain frequency which minimizes variability in recall of throwing experiences.

CONCLUSION

In youth baseball players, shoulder ER and IR strength is weakly associated with self-reported arm pain frequency. Non-normalized shoulder ER and IR strength may be more associated with reported arm pain frequency than ER/IR strength ratio or shoulder flexion, ER, IR, or horizontal adduction ROM in youth baseball players. These findings may help guide arm care program development. Future research should prospectively evaluate the relationship between shoulder ROM and strength and the development of arm pain by exploring these measures longitudinally.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest

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