

Shoulder Pain and Rotational Range of Motion of the Trunk, Shoulder, and Hip in Baseball Players

Yeol-oh Kim, BHSc, PT*; Yoon-ju Jo, BHSc, PT*; Si-hyun Kim, PhD, PT†; Kyue-nam Park, PhD, PT*

*Department of Physical Therapy, College of Medical Sciences, Jeonju University, South Korea; †Department of Physical Therapy, Sangji University, Wonju, South Korea

Context: Deficient glenohumeral rotational range of motion (ROM) is a risk factor for shoulder pain. Adapted ROM of the trunk and hip in response to loss of glenohumeral ROM has been suggested, as the nature of baseball leads to ROM adaptations.

Objective: To compare the bilateral rotational ROM values of the trunk and glenohumeral and hip joints in adolescent baseball players with or without shoulder pain and to measure the correlation between shoulder-pain intensity and bilateral rotational ROM values for each body area.

Design: Cross-sectional study.

Setting: Research laboratory.

Patients or Other Participants: Ninety-five adolescent baseball players (60 with shoulder pain, 35 without shoulder pain).

Main Outcome Measure(s): Bilateral trunk rotation and internal rotation, external rotation, and total rotation of the dominant and nondominant glenohumeral and hip joints.

Results: Glenohumeral and hip ROM did not differ between groups, and pain intensity and rotational ROM were not related in either joint. Trunk rotational ROM was greater in the pain group than in the control group (dominant side = $48.8^\circ \pm 14.2^\circ$ versus $41.8^\circ \pm 11.9^\circ$, respectively; nondominant side = $45.1^\circ \pm 14.2^\circ$ versus $38.9^\circ \pm 7.7^\circ$, respectively; P values < .05), although the difference was clinically small (mean differences = $7.0^\circ \pm 2.7^\circ$ [95% confidence interval = 1.7, 12.4] on the dominant side, $P = .01$, and $6.1^\circ \pm 2.7^\circ$ [95% confidence interval = 0.8, 11.5] on the nondominant side, $P = .03$). Positive but low correlations in all players ($\rho = 0.27$, $P = .01$) and in those with shoulder pain ($\rho = 0.36$, $P = .001$) were present between shoulder-pain intensity and trunk rotational ROM toward the dominant side.

Conclusions: We found no clinical relationship between shoulder pain and rotational ROM and no clinical differences in rotational ROM values between players with and those without shoulder pain.

Key Words: correlation, pain, joint flexibility

Key Points

- No clinically meaningful differences were apparent in the rotational range of the trunk and glenohumeral and hip joints between players with and those without shoulder pain.
- No clinical correlations were demonstrated between shoulder-pain intensity and the rotational ranges of the trunk and glenohumeral and hip joints.
- Authors of future studies should investigate the factors influencing shoulder pain, such as pathologic restriction, competition level, pitch volume, and throwing frequency, rather than range-of-motion variables, in baseball players.

The glenohumeral internal-rotation (IR) deficit and adaptive range-of-motion (ROM) gain in external rotation (ER) of the throwing shoulder is normal in baseball throwers and is characterized by an IR loss of $<18^\circ$ to 20° on the basis of normative data.¹ Loss of glenohumeral IR ROM may be caused by osseous adaptation and posterior shoulder tightness (16° greater humeral retrotorsion on the throwing side than on the nonthrowing side).^{2–4} The total rotational ROM deficit (2.5-fold higher risk) is more predictive of a throwing-related shoulder injury than is IR ROM loss (1.9-fold higher risk).⁵ However, recent researchers⁶ determined that preseason screening of glenohumeral rotational ROM or humeral retrotorsion may not effectively identify the risk of shoulder injury in high school baseball players. Thus, the association between shoulder pain and glenohumeral IR deficit remains unclear.

Repetitive throwing volume may lead to an increase in glenohumeral rotational ROM and in hip IR ROM in the lead (nondominant) leg.⁷ During throwing, the lead leg moves the body forward, which requires more hip IR ROM; thus, the lead leg has greater hip IR ROM than the stance leg.⁷ However, studies of the effects of increased hip IR ROM on shoulder pain are lacking. Throwing a baseball involves trunk rotation in the transverse plane.⁸ Insufficient trunk rotation may result in excessive lateral leaning of the trunk during a throw, increasing stress on the glenohumeral joint.⁹ Adaptive changes in trunk rotational ROM may occur because of ROM losses or gains in the shoulder and hip.¹⁰ Healthy pitchers may show increased trunk ROM toward the nonthrowing side, which could represent compensation for a dominant-side glenohumeral IR deficit.¹⁰

No authors have examined the correlations between shoulder pain and rotational ROM of the trunk and

glenohumeral and hip joints in baseball players. Previous researchers^{11–15} have assessed healthy baseball players without shoulder pain and those who had a history of shoulder injury but were healthy at the time of testing. Therefore, the aims of our study were to (1) investigate the association between shoulder-pain intensity and rotational ROM of the trunk and glenohumeral and hip joints and (2) compare the differences in rotational ROM among these 3 body areas between baseball players with and those without shoulder pain.

METHODS

Participants

A total of 95 adolescent male baseball players (31 pitchers, 64 position players; age = 16.9 ± 1.5 years, height = 173.8 ± 7.9 cm, weight = 68.5 ± 10.9 kg) were recruited. All players belonged to 3 middle or high school baseball teams and were tested during spring training. They were instructed not to exercise the day before the evaluation and were assessed before practice. The participants were divided into groups with or without shoulder pain according to the inclusion and exclusion criteria.^{16,17} The inclusion criteria for the group with shoulder pain (26 pitchers, 34 position players; age = 16.7 ± 0.9 years, height = 173.5 ± 7.4 cm, weight = 68.2 ± 10.3 kg; 54 were right-hand dominant and 6 were left-hand dominant) were as follows: reproducible shoulder pain in the throwing arm >1 on a visual analog scale (VAS) with scores ranging from 0 to 10, report of pain for >1 month, a minimum of 2 years' experience practicing baseball with a practice routine of at least 4 h/d and 3 d/wk, and currently belonging to an organized baseball team. To differentiate between shoulder pain and muscle soreness, participants were instructed to determine the intensity of pain within the joint, not the muscles, because muscle soreness is a normal part of pitcher development, whereas joint pain is not.¹⁸ The mean VAS score in the pain group was 3.9 ± 2.3 cm. The nonpain group (5 pitchers, 30 position players; age = 16.9 ± 1.5 years, height = 173.8 ± 8.0 cm, weight = 68.5 ± 10.9 kg; 33 were right-hand dominant and 2 were left-hand dominant) was selected according to the same criteria as those for the pain group, except that the players had no history of shoulder pain during the previous 6 months and reported a VAS of 0 during and after baseball. The exclusion criteria for both groups were a history of shoulder surgery, pain in the spine or either or both hip joints, and continuous (>6 months') use of muscle relaxants and analgesics. This study was approved by the Institutional Review Board of Jeonju University. All participants, or their guardians, provided written informed consent.

Procedures

Before measuring ROM, examiner A (a physical therapist), who was blinded to the other examiners, administered a questionnaire addressing shoulder-pain intensity during throwing using VAS scores, anthropometric characteristics, and the dominant arm and leg. The *dominant arm* was defined as the arm the player used predominantly for throwing a ball, and the ipsilateral leg was defined as the *dominant leg* (stance leg).

Examiners B, C, and D (ROM examiners, all physical therapists) were blinded to each other's results, to the group assignment (shoulder pain or no shoulder pain), and to each player's dominant arm. They measured the rotational ROM of the trunk, glenohumeral joint, and hip joint. All examiners had at least 3 years' experience with physical assessments and were educated on ROM measurement techniques for 1 month to improve intrarater test-retest reliability. All active rotational ROMs were measured using a standard goniometer ($\pm 1^\circ$ precision) and reliable methods.^{19–21} During pilot testing, we confirmed good to high intrarater test-retest reliability for all active rotational ROM values (intraclass correlation coefficient [ICC] = 0.85–0.98; standard error of measurement = 1.0° – 5.0° ; minimal detectable change [MDC] 90% confidence interval [CI] = 2.3° , 11.6°). Five active rotational ROM values were measured bilaterally: trunk rotation, glenohumeral IR, glenohumeral ER, hip IR, and hip ER. The order of measurements was randomly selected for the dominant versus nondominant sides and each rotational ROM evaluation using Excel (version 2016; Microsoft Corp, Redmond, WA).

Trunk rotational ROM was measured in the lunge position, which helps restrict the compensatory motion of the lumbar spine and hip during trunk rotation. It also requires stability and balance of the lower extremities during trunk rotation to remain upright, similar to that needed when throwing a ball. To measure the ROM of trunk rotation toward the dominant side, the player positioned the dominant leg forward and the nondominant leg behind the trunk with both legs in a straight line on the floor to minimize pelvic rotation.²² To measure the ROM of trunk rotation toward the nondominant side, the player moved the nondominant leg forward and the dominant leg behind the trunk. Next, the participant placed his front foot on the ground with the contralateral knee, tibia, and toe in contact with the floor. Previous authors^{20,22} have demonstrated that the half-kneeling trunk-rotation test with the bar in both the front and back has good reliability. The bar-in-front position was more reliable than the bar-in-back position.²⁰ However, it is possible to protract the scapula during active trunk rotation, in which case the measurement reflects combined trunk rotation and scapular motion. To prevent compensatory scapular protraction, the participant crossed both arms over a bar in front of the chest and placed both hands on the anterior shoulder region over the bar to prevent scapular protraction during trunk rotation. The participants were asked not to compensate (ie, bend laterally and lean the trunk forward). The examiner monitored contact with the bar, the bar's parallel position to the ground, head and neck rotation, and knee and foot shifting during rotation to prevent compensation. When compensation occurred, the trial was considered a failure and repeated.²⁰ The goniometer was aligned parallel to the floor, and its axis was at the midpoint between the T1 and T2 spinous processes. The T1 and T2 spinous processes were identified by inferior palpation from the C7 spinous process, the most prominent vertebra. The location of the C7 spinous process was confirmed using the flexion-extension test, which identifies the freely moving spinous process as C6 and the stationary spinous process as C7 during active-assisted cervical flexion and extension.²³ The goniometer's stationary arm was placed parallel between

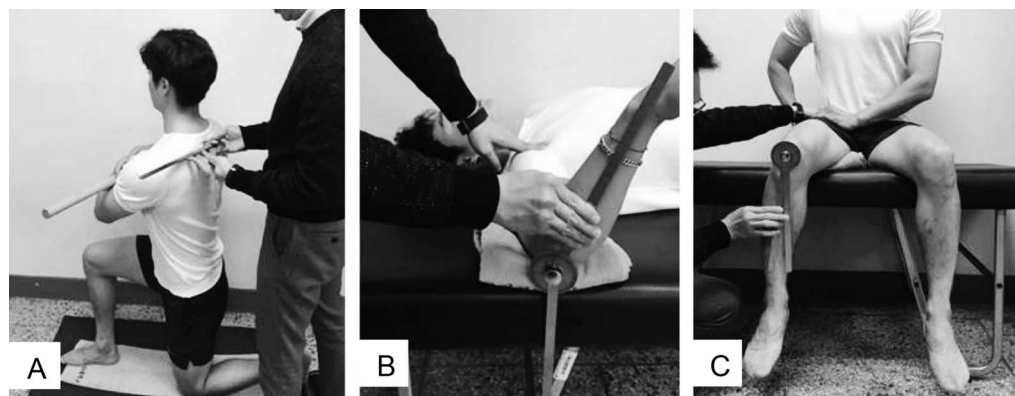


Figure 1. Measurement of rotational ranges of motion of the A, trunk, B, glenohumeral joint, and C, hip joint.

the T1 and T2 spinous processes and the scapular spine opposite the rotational side. During trunk rotation, the stationary arm was held in the starting position, and the moveable arm of the goniometer followed the spine of the scapula of the opposite side from the rotational side. The player rotated his trunk toward the forward leg as much as possible while maintaining an upright posture in the lunge position and without losing his balance. He was also asked to continue looking forward at an eye-level line on the wall without holding the head and neck in the starting position while performing maximal trunk rotation.²⁴ The trunk-rotation values were then noted (Figure 1A). The average of 3 trials for each rotational ROM was used in the data analysis. The same measurement procedures were used for the dominant and nondominant sides.

The examiner stabilized the scapula while assessing humeral rotational ROM on the glenoid because an isolated assessment of glenohumeral ROM (instead of the total shoulder complex) can better reflect a shoulder injury.^{25,26} The procedures for active glenohumeral joint IR and ER ROM measurements were as follows. The player was asked to flex his hips and knees in a hook-lying position on the treatment table. The arm was elevated to 90° abduction in the frontal plane, and the humerus was supported with a towel to maintain neutral horizontal abduction-adduction in the transverse plane. To measure both IR and ER, the examiner placed the axis of the goniometer on the center of the olecranon and the stationary arm perpendicular to the floor and aligned the moving arm between the styloid process of the ulna and the center of the olecranon. The player then moved his humerus into either IR or ER until anterior or superior motion of the scapula was initiated, and the ROM result were recorded (Figure 1B).¹⁵ The same measurement procedures were used for the dominant and nondominant sides. The average of 3 trials for each rotational ROM was used in the data analysis. Total rotational ROM (IR + ER) of the glenohumeral joint was calculated from the sum of IR and ER ROM.

To measure the IR and ER ROM of the hip, the player sat on the edge of a table with his knees flexed to 90°. The axis of the goniometer was placed on the top of the patella, its stationary arm was aligned vertically to the floor, and its moveable arm was aligned with the tibial shaft. While the examiner stabilized the pelvis, the player performed hip IR or ER until the earliest lateral tilting of the pelvis was detected, and the value was recorded (Figure 1C).^{27,28} The

average of 3 trials for each rotational ROM was used in the data analysis. The same measurement procedures were used for the dominant and nondominant sides. Total rotational ROM of the hip joint was calculated from the sum of IR and ER ROM.

Data Analysis

To determine the sample size, we performed an a priori power analysis using 80% power, an α level of .05, and an effect size of 0.38 (version 3.0.10; GPOWER, Franz Faul, Universität Kiel, Germany), which was established from the group mean and standard deviation of the preliminary data. The required sample size was 30 participants. The Kolmogorov-Smirnov test was conducted to confirm normal distribution of the dependent variables. Two-way analysis of variance with 1 interparticipant factor (pain versus no-pain group) and 1 intraparticipant factor (dominant versus nondominant side) was used to compare the parametric variables (trunk rotational ROM, glenohumeral IR ROM, glenohumeral total rotational ROM, hip IR ROM, and hip ER ROM). In the absence of a normal distribution (pain intensity, glenohumeral ER ROM, and hip total rotational ROM), the Kruskal-Wallis and Mann-Whitney *U* tests were used to compare nonparametric variables.

Correlation analyses between the pain intensity of the shoulder and the rotational ROM of each body area were performed under 2 conditions and evaluated using Spearman correlation coefficients. Condition 1 involved all players (pain and no-pain groups), whereas condition 2 involved only the pain group. Correlation analyses between glenohumeral ROM and trunk or hip rotational ROM in the shoulder-pain group were also evaluated using Pearson or Spearman correlation coefficients.

Correlation coefficients of 0.00 to 0.25 were interpreted as *weak*, 0.26 to 0.49 as *low*, 0.50 to 0.69 as *moderate*, 0.70 to 0.89 as *strong*, and 0.90 to 1.00 as *very strong*. The analyses were performed using SPSS (version 18.0.1; IBM Corp, Armonk, NY). The α level for statistical significance was set at .05.

RESULTS

The rotational ROM data are presented in Table 1. Trunk rotational ROM values were greater in the pain group than in the control groups (mean differences = $7.0^\circ \pm 2.7^\circ$ [95%

Table 1. Rotational Range of Motion (ROM) Measurements of Glenohumeral Joint, Trunk, and Hip Joint, Mean \pm SD^a

ROM, °	Shoulder-Pain Group	No-Pain Group
Trunk rotation		
Dominant	48.8 \pm 14.2 ^b	41.8 \pm 11.9
Nondominant	45.1 \pm 14.2 ^b	38.9 \pm 7.7
Glenohumeral IR		
Dominant	43.9 \pm 12.4 ^c	46.0 \pm 8.8 ^c
Nondominant	51.5 \pm 11.7	52.6 \pm 12.2
Glenohumeral ER		
Dominant	92.6 \pm 9.1	87.7 \pm 13.9
Nondominant	87.8 \pm 11.7	87.6 \pm 8.3
Glenohumeral total		
Dominant	136.5 \pm 12.8	133.7 \pm 16.2
Nondominant	139.3 \pm 14.7	140.2 \pm 13.0
Hip IR		
Dominant	24.4 \pm 6.4 ^c	24.5 \pm 7.8
Nondominant	27.4 \pm 7.4	26.0 \pm 7.4
Hip ER		
Dominant	22.1 \pm 6.5	21.1 \pm 6.1
Nondominant	19.1 \pm 6.8	20.2 \pm 5.8
Hip total		
Dominant	46.5 \pm 10.7	45.6 \pm 10.7
Nondominant	46.5 \pm 12.3	46.1 \pm 10.3

Abbreviations: ER, external rotation; IR, internal rotation.

^a Dominant, throwing arm (trunk rotational ROM or glenohumeral IR or ER) or stance leg (hip ROM); nondominant, nonthrowing arm (trunk rotational ROM or glenohumeral IR or ER) or lead leg (hip ROM).^b Difference between shoulder-pain group and no-pain group ($P < .05$).^c Difference between sides ($P < .05$).

CI = 1.7, 12.4] on the dominant side, $P = .01$, and $6.1^\circ \pm 2.7^\circ$ [95% CI = 0.8, 11.5] on the nondominant side, $P = .03$). However, trunk ROM between the dominant and nondominant sides ($P = .09$) did not differ and there was no interaction of side \times group ($P = .82$). Glenohumeral IR ROM values were lower on the dominant side than the nondominant side (mean differences = $-7.9^\circ \pm 2.2^\circ$ [95% CI = -12.3, -3.7] in the pain group, $P = .01$, and $-6.4^\circ \pm 2.7^\circ$ [95% CI = -11.7, -1.2] in the no-pain group, $P = .02$). Glenohumeral IR between the pain and no-pain groups did not differ ($P = .35$), and the interaction of side \times group was not significant ($P = .76$). No differences were present in glenohumeral ER between the dominant and nondominant sides ($P = .13$) or groups ($P = .12$). Total rotational ROM between the dominant and nondominant sides ($P = .06$) and groups ($P = .88$) was not different. Hip IR ROM in the pain group was less on the dominant side than on the nondominant side, whereas no difference was demonstrated in the no-pain group (mean differences = $-2.9^\circ \pm 1.3^\circ$ [95% CI = -5.5, -0.3] in the pain group, $P = .03$, and $-1.5^\circ \pm 1.7^\circ$ [95% CI = -4.8, 1.9] in the no-pain group, $P = .40$). Hip IR between groups ($P = .55$) did not differ, and the interaction of side \times group was not significant ($P = .50$). No difference was present in hip ER between the dominant and nondominant sides ($P = .05$) or groups ($P = .97$). Finally, total hip ROM did not differ between sides ($P = .87$) or groups ($P = .72$).

Table 2. Spearman Correlations Between Shoulder-Pain Intensity and Rotational Range of Motion (ROM) in All Players and in Shoulder-Pain Group Only^a

ROM	All Players ^b	Pain Group Only ^b
Trunk rotation		
Dominant ^b	0.27 ^c	0.36 ^c
Nondominant	0.18	0.20
Glenohumeral IR		
Dominant	-0.08	-0.10
Nondominant	-0.04	-0.06
Glenohumeral ER		
Dominant	-0.01	-0.12
Nondominant	0.03	0.11
Glenohumeral total		
Dominant	-0.07	-0.21
Nondominant	-0.04	-0.04
Hip IR		
Dominant	-0.07	-0.24
Nondominant	0.03	0.01
Hip ER		
Dominant	-0.03	-0.09
Nondominant	-0.09	-0.14
Hip total		
Dominant	-0.06	-0.20
Nondominant	-0.06	-0.11

Abbreviations: ER, external rotation; IR, internal rotation.

^a Dominant, throwing arm (trunk rotational ROM or glenohumeral IR or ER) or stance leg (hip ROM); nondominant, nonthrowing arm (trunk rotational ROM or glenohumeral IR or ER) or lead leg (hip ROM).^b Correlation (ρ) values are reported. Pain was measured according to a visual analog scale with scores ranging from 0 to 10.^c Significant correlation ($P < .05$).

The correlations between shoulder-pain intensity and rotational ROM for condition 1 (all players) ranged from $\rho = -0.09$ to $\rho = 0.27$ (P values = .01–.76). A significant low correlation was present between shoulder-pain intensity and trunk rotational ROM toward the dominant side ($\rho = 0.27$, $P = .01$; Table 2). The correlations between shoulder-pain intensity and rotational ROM for condition 2 (pain group only) ranged from $\rho = -0.24$ to $\rho = 0.36$ (P values = .001–.097). A significant low correlation occurred between shoulder-pain intensity and trunk rotational ROM toward the dominant side ($\rho = 0.36$, $P = .001$; Table 2).

The correlations between each glenohumeral ROM (IR, ER, or total rotational ROM) and trunk or hip ROM in the shoulder-pain group ranged from ρ or $r = -0.24$ to 0.25 (P values = .10–.97), indicating no significant relationship (Table 3).

DISCUSSION

The purposes of our study were to investigate the relationship between shoulder pain and rotational ROM and compare the differences in rotational ROM values of the trunk and glenohumeral and hip joints between baseball players with and those without shoulder pain. However, we found no relationship between shoulder pain and rotational ROM except for a low correlation with trunk rotational ROM toward the dominant side. Additionally, no differ-

Table 3. Correlations Between Glenohumeral Rotational Range of Motion (ROM) and Trunk or Hip Rotational ROM in the Shoulder-Pain Group^a

ROM	Glenohumeral ROM					
	IR		ER		Total Rotational	
	Dominant Side	Nondominant Side	Dominant Side	Nondominant Side	Dominant Side	Nondominant Side
Trunk rotation						
Dominant side	−0.01 ^b	0.10 ^b	−0.03 ^c	0.11 ^c	−0.04 ^b	0.18 ^b
Nondominant side	0.15 ^b	0.09 ^b	−0.24 ^c	−0.05 ^c	0.01 ^b	0.04 ^b
Hip IR						
Dominant side	0.19 ^b	0.10 ^b	0.04 ^c	0.07 ^c	0.24 ^b	0.22 ^b
Nondominant side	0.10 ^b	0.17 ^b	0.14 ^c	−0.08 ^c	0.14 ^b	0.25 ^b
Hip ER						
Dominant side	0.17 ^b	0.10 ^b	0.02 ^c	−0.14 ^c	0.25 ^b	0.07 ^b
Nondominant side	0.13 ^b	−0.01 ^b	−0.04 ^c	−0.06 ^c	0.22 ^b	0.02 ^b
Hip total						
Dominant side	0.22 ^c	0.09 ^c	0.01 ^c	−0.05 ^c	0.25 ^c	0.15 ^c
Nondominant side	0.19 ^c	0.16 ^c	0.07 ^c	−0.07 ^c	0.25 ^c	0.20 ^c

Abbreviations: ER, external rotation; IR, internal rotation.

^a Dominant, throwing arm (trunk rotational ROM or glenohumeral IR or ER) or stance leg (hip ROM); nondominant, nonthrowing arm (trunk rotational ROM or glenohumeral IR or ER) or lead leg (hip ROM).

^b Pearson correlation values are reported.

^c Spearman correlation values are reported.

ences were evident between the rotational ROM values of players with and those without shoulder pain, except in trunk ROM toward the dominant and nondominant sides, and the differences were clinically small. Clinicians commonly use the kinetic chain theory of energy exchange from the proximal to distal joints during assessment of ball throwing to evaluate or treat baseball players.²⁹ We noted no changes in the rotational ROM of the hip or trunk in response to glenohumeral ROM loss in adolescent players with shoulder pain; we believe ours is the first study to demonstrate this.

Although the rotational ROM values of the glenohumeral and hip joints did not differ between groups, the trunk ROM values toward the dominant and nondominant side were greater in the pain group than in the no-pain group. In addition, a significant low correlation was present between shoulder-pain intensity and trunk rotational ROM toward the dominant side ($\rho = 0.27$, $P = .01$), indicating that more trunk rotation can induce greater shoulder pain and vice versa (Figure 2). Previous authors³⁰ showed that the rotational angular velocity of the humerus was approximately 5 times that of the trunk during throwing. The greater angular acceleration of the trunk in conjunction with greater trunk ROM may result in shoulder stress.³⁰

From an injury-development perspective, a higher magnitude of trunk rotation would increase tensile loading on the soft tissues around the shoulder, such as the rotator cuff, biceps-labral complex, and joint capsule.³¹ These observations suggest that trunk rotational hypermobility may put baseball players at an increased risk of shoulder pain. However, clinicians should be cautious when interpreting the clinical relationship between shoulder-pain intensity and trunk rotational ROM, despite the differences between the shoulder-pain and no-pain groups. In our study, bilateral trunk rotational ROM values were approximately 7° higher in the pain group than in the no-pain group. This difference was higher than the MDC of half-kneeling trunk rotation at 3.82° in healthy participants based on previous data.²⁰ Yet another researcher³² reported an MDC of 10.2° in the half-kneeling position among softball players with a history of shoulder or elbow injury. Despite its statistical significance, our 7° difference failed to surpass the threshold for clinical meaningfulness (10.2°). In addition, a significant but low correlation occurred between shoulder-pain intensity and trunk rotational ROM toward the dominant side.

We detected no side-to-side differences in trunk rotational ROM in either group. Contrary to our findings, earlier investigators¹⁰ described such differences in healthy

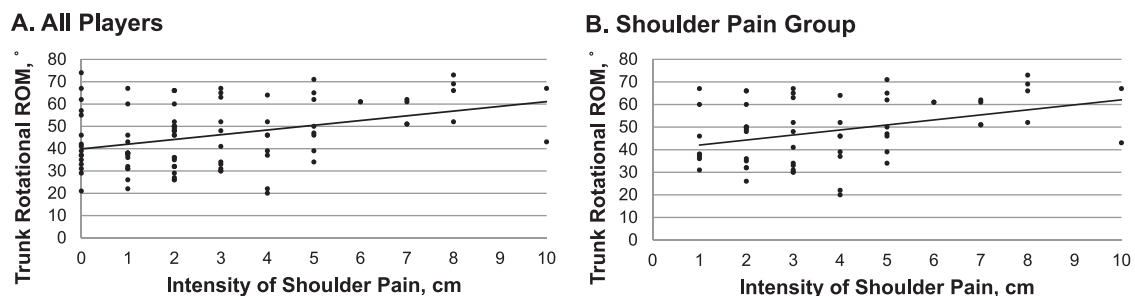


Figure 2. Significant low correlations between shoulder-pain intensity and trunk rotational range of motion on the dominant side were noted, A, in all players ($\rho = 0.27$, $P = .01$), as well as B, in the shoulder-pain group ($\rho = 0.36$, $P = .001$).

baseball players: specifically, pitchers had increased trunk rotational ROM toward the nondominant side. Test position is one potential explanation for the inconsistent results between studies. The previous authors¹⁰ tested trunk rotational ROM with participants in a standing position with the trunk flexed to 90°, whereas we tested it in the lunge position. The lunge position is more similar to the position used when throwing a ball than standing with the trunk flexed and requires stability and balance in the lower extremities during trunk rotation.²⁶

Our results are consistent with those of earlier researchers^{4,15,19,33–35} who demonstrated side-to-side differences in glenohumeral IR ROM values only in healthy baseball players. Both groups showed side-to-side differences in glenohumeral IR ROM but no differences were demonstrated between groups. In addition, the side-to-side differences in our study were clinically minor (7.9° in the pain group and 6.4° in the no-pain group) compared with previous normative data on baseball throwers, which suggested that the side-to-side differences were 18° to 20°.¹ Baseball players are known to have a loss of glenohumeral IR ROM on the dominant side of 18° to 20° due to humeral retrorsion and posterior shoulder tightness, which is not pathologic.¹ For hip IR ROM, the side-to-side difference was 2.9° in the pain group, which is not clinically important.¹⁵ Hence, we suggest that side-to-side differences in these body areas may not be associated with shoulder pain but rather may be characteristic of all baseball players, regardless of shoulder pain.

Previous authors¹⁵ suggested the need for further studies to evaluate the relationship between glenohumeral IR and trunk and hip ROM in players with shoulder pain. However, based on our results, we found no relationship between glenohumeral and trunk or hip ROM in the shoulder-pain group (Table 3). Thus, we suggest that no clinical association exists between glenohumeral IR deficit and hip ROM change, regardless of shoulder pain in baseball players.

CLINICAL IMPLICATIONS

We observed no clinical correlations between shoulder-pain intensity and the rotational ROM values of the trunk and glenohumeral and hip joints. These findings do not mean that baseball players do not have a pathologic restriction of the trunk or hips, because we did not differentiate whether ROM restrictions were less than normal limits. Therefore, pathologic restriction of the trunk and hip may still cause shoulder ROM restriction and pain. When developing management plans for baseball players with shoulder pain, sports clinicians should consider multidirectional factors that may contribute to shoulder pain in baseball players, such as pathologic restriction, competition level, pitch volume, and throwing frequency rather than evaluating only joint ROM.

LIMITATIONS

The first limitation of this study is that our players were adolescents; as a result, it is difficult to generalize our results to professional baseball players. Second, we did not subdivide the groups according to specific shoulder injuries, such as rotator cuff tears or superior-labrum anterior and posterior lesions. A third limitation was the unbalanced

numbers of participants in each group. More players were in the pain group (60 players) than in the no-pain group (35 players). With regard to the statistical analysis, we could not fully compare ROM differences between groups because of the unbalanced number of participants. Thus, a future comparison study with equal distributions of participants in the pain and no-pain groups is needed. And finally, when measuring thoracic rotational ROM, it is difficult to maintain the goniometer's stationary arm while correctly placing the moveable arm. Earlier investigators²⁰ described good reliability using this method to measure thoracic rotational ROM (within-session interrater reliability ICC = 0.94, within-day intrarater reliability ICC = 0.92). However, no researchers have demonstrated the validity of radiography for this purpose. Further studies are needed to determine the validity of thoracic rotational ROM measured using a goniometer versus radiography.

CONCLUSIONS

The purposes of our study were to investigate the association between shoulder-pain intensity and rotational ROM of the trunk and glenohumeral and hip joints and compare the differences in rotational ROM values of these 3 body areas between baseball players with and those without shoulder pain. However, no clinical correlations were noted between shoulder-pain intensity and the ROM of each body area. Additionally, no clinically meaningful differences were present in the ROM values of these body areas between players with and those without shoulder pain. Thus, we did not find rotational ROM changes of the hip and trunk in response to a loss of glenohumeral ROM in adolescent players with shoulder pain.

REFERENCES

1. Manske R, Wilk KE, Davies G, Ellenbecker T, Reinold M. Glenohumeral motion deficits: friend or foe? *Int J Sports Phys Ther*. 2013;8(5):537–553.
2. Crockett HC, Gross LB, Wilk KE, et al. Osseous adaptation and range of motion at the glenohumeral joint in professional baseball pitchers. *Am J Sports Med*. 2002;30(1):20–26.
3. Oyama S, Hibberd EE, Myers JB. Changes in humeral torsion and shoulder rotation range of motion in high school baseball players over a 1-year period. *Clin Biomech (Bristol, Avon)*. 2013;28(3):268–272.
4. Wilk KE, Macrina LC, Fleisig GS, et al. Deficits in glenohumeral passive range of motion increase risk of shoulder injury in professional baseball pitchers: a prospective study. *Am J Sports Med*. 2015;43(10):2379–2385.
5. Wilk KE, Macrina LC, Fleisig GS, et al. Correlation of glenohumeral internal rotation deficit and total rotational motion to shoulder injuries in professional baseball pitchers. *Am J Sports Med*. 2011;39(2):329–335.
6. Oyama S, Hibberd EE, Myers JB. Preseason screening of shoulder range of motion and humeral retrorsion does not predict injury in high school baseball players. *J Shoulder Elbow Surg*. 2017;26(7):1182–1189.
7. Picha KJ, Harding JL, Bliven KC. Glenohumeral and hip range-of-motion and strength measures in youth baseball athletes. *J Athl Train*. 2016;51(6):466–473.
8. Aguinaldo AL, Buttermore J, Chambers H. Effects of upper trunk rotation on shoulder joint torque among baseball pitchers of various levels. *J Appl Biomech*. 2007;23(1):42–51.

9. Oyama S, Yu B, Blackburn JT, Padua DA, Li L, Myers JB. Effect of excessive contralateral trunk tilt on pitching biomechanics and performance in high school baseball pitchers. *Am J Sports Med.* 2013;41(10):2430–2438.
10. Laudner K, Lynall R, Williams JG, Wong R, Onuki T, Meister K. Thoracolumbar range of motion in baseball pitchers and position players. *Int J Sports Phys Ther.* 2013;8(6):777–783.
11. Oliver GD, Weimar WH. Hip and shoulder range of motion in youth baseball pitchers. *J Strength Cond Res.* 2016;30(10):2823–2827.
12. Shanley E, Kissenberth MJ, Thigpen CA, et al. Preseason shoulder range of motion screening as a predictor of injury among youth and adolescent baseball pitchers. *J Shoulder Elbow Surg.* 2015;24(7):1005–1013.
13. Levine WN, Brandon ML, Shubin Stein BE, Gardner TR, Bigliani LU, Ahmad CS. Shoulder adaptive changes in youth baseball players. *J Shoulder Elbow Surg.* 2006;15(5):562–566.
14. Scher S, Anderson K, Weber N, Bajorek J, Rand K, Bey MJ. Associations among hip and shoulder range of motion and shoulder injury in professional baseball players. *J Athl Train.* 2010;45(2):191–197.
15. Sauers EL, Huxel Bliven KC, Johnson MP, Falsone S, Walters S. Hip and glenohumeral rotational range of motion in healthy professional baseball pitchers and position players. *Am J Sports Med.* 2014;42(2):430–436.
16. Leigh RJ, Osis ST, Ferber R. Kinematic gait patterns and their relationship to pain in mild-to-moderate hip osteoarthritis. *Clin Biomech (Bristol, Avon).* 2016;34:12–17.
17. Almeida GP, Silveira PF, Rosseto NP, Barbosa G, Ejnisman B, Cohen M. Glenohumeral range of motion in handball players with and without throwing-related shoulder pain. *J Shoulder Elbow Surg.* 2013;22(5):602–607.
18. Lyman S, Fleisig GS, Andrews JR, Osinski ED. 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(4):463–468.
19. Ellenbecker TS, Ellenbecker GA, Roetert EP, Silva RT, Keuter G, Sperling F. Descriptive profile of hip rotation range of motion in elite tennis players and professional baseball pitchers. *Am J Sports Med.* 2007;35(8):1371–1376.
20. Johnson KD, Kim KM, Yu BK, Saliba SA, Grindstaff TL. Reliability of thoracic spine rotation range-of-motion measurements in healthy adults. *J Athl Train.* 2012;47(1):52–60.
21. Walker H, Pizzari T, Wajswelner H, et al. The reliability of shoulder range of motion measures in competitive swimmers. *Phys Ther Sport.* 2016;21:26–30.
22. Aragon VJ, Oyama S, Oliaro SM, Padua DA, Myers JB. Trunk-rotation flexibility in collegiate softball players with or without a history of shoulder or elbow injury. *J Athl Train.* 2012;47(5):507–513.
23. Shin S, Yoon DM, Yoon KB. Identification of the correct cervical level by palpation of spinous processes. *Anesth Analg.* 2011;112(5):1232–1235.
24. Johnson KD, Grindstaff TL. Thoracic rotation measurement techniques: clinical commentary. *N Am J Sports Phys Ther.* 2010;5(4):252–256.
25. Awan R, Smith J, Boon AJ. Measuring shoulder internal rotation range of motion: a comparison of 3 techniques. *Arch Phys Med Rehabil.* 2002;83(9):1229–1234.
26. Boon AJ, Smith J. Manual scapular stabilization: its effect on shoulder rotational range of motion. *Arch Phys Med Rehabil.* 2000;81(7):978–983.
27. Nussbaumer S, Leunig M, Glatthorn JF, Stauffacher S, Gerber H, Maffiuletti NA. Validity and test-retest reliability of manual goniometers for measuring passive hip range of motion in femoroacetabular impingement patients. *BMC Musculoskeletal Disord.* 2010;11:194.
28. Tak I, Glasgow P, Langhout R, Weir A, Kerkhoffs G, Agricola R. Hip range of motion is lower in professional soccer players with hip and groin symptoms or previous injuries, independent of cam deformities. *Am J Sports Med.* 2016;44(3):682–688.
29. Kibler WB. Pathophysiology of overload injuries around the elbow. *Clin Sports Med.* 1995;14(2):447–457.
30. Fleisig GS, Barrentine SW, Escamilla RF, Andrews JR. Biomechanics of overhand throwing with implications for injuries. *Sports Med.* 1996;21(6):421–437.
31. Oyama S, Yu B, Blackburn JT, Padua DA, Li L, Myers JB. Improper trunk rotation sequence is associated with increased maximal shoulder external rotation angle and shoulder joint force in high school baseball pitchers. *Am J Sports Med.* 2014;42(9):2089–2094.
32. Brindle TJ. Commentary: trunk-rotation flexibility in collegiate softball players with or without a history of shoulder or elbow injury. *J Athl Train.* 2012;47(5):513–515.
33. Downar JM, Sauers EL. Clinical measures of shoulder mobility in the professional baseball player. *J Athl Train.* 2005;40(1):23–29.
34. Shanley E, Rauh MJ, Michener LA, Ellenbecker TS, Garrison JC, Thigpen CA. 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(9):1997–2006.
35. Laudner KG, Moore SD, Sipes RC, Meister K. Functional hip characteristics of baseball pitchers and position players. *Am J Sports Med.* 2010;38(2):383–387.

Address correspondence to Kyue-nam Park, PhD, PT, Department of Physical Therapy, College of Medical Sciences, Jeonju University, 1200 Hyoja-dong, Wansan-gu, Jeonju, Jeollabuk-do 560-759, South Korea. Address e-mail to knpark@jj.ac.kr.