

Upper Extremity Range of Motion and Pitching Profile of Baseball Pitchers in Japan

Ted Sueyoshi,^{*†} ATC, PES, Takuya Nakatani,[‡] PT, Takashi Tsuruta,[§] PT, and Gen Emoto,[‡] MD
Investigation was performed at Emoto Knee and Sport Clinic and Minamikawa Orthopedic Hospital, Fukuoka, Japan

Background: Shoulder range of motion and pitch count in baseball pitchers have been linked to pitching-related upper extremity injury.

Purpose: To investigate upper extremity range of motion and pitching profiles in baseball pitchers in Japan as well as to make a comparison between injured and noninjured pitchers.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Forty-one Little League to college-level baseball pitchers were measured for bilateral shoulder and elbow range of motion, including shoulder internal rotation (IR), external rotation (ER), shoulder horizontal adduction (HAD), and elbow extension (EXT). They were also asked to answer a simple questionnaire regarding their past pitching-related medical history and pitching profile. Additionally, 28 participants with baseball-related upper extremity injuries (injury group) were compared with 13 participants without injury (no-injury group) for the same parameters. Collected data were analyzed using analysis of variance.

Results: Significant limb differences (dominant vs nondominant side) were noted for ER (117.2° vs 109.8°, $P = .02$), IR (53.5° vs 61.9°, $P = .007$), HAD (28.3° vs 32.8°, $P = .03$), and EXT (1.0° vs 4.6°, $P = .01$). A significant between-group difference (injury vs no-injury group) was observed for IR in both the dominant (55.4° vs 45.6°, $P = .03$) and nondominant shoulder (65.3° vs 55.0°, $P = .01$). Participants in the injury group pitched more games in a season and more innings per game started.

Conclusion: Japanese baseball pitchers displayed adaptive changes in upper extremity range of motion similar to American pitchers when compared bilaterally. Injured pitchers exhibited greater IR range of motion in their pitching arm compared with noninjured pitchers.

Keywords: baseball pitching; glenohumeral range of motion; shoulder; pitch count; baseball injury

The baseball pitching motion places a great deal of stress in the upper extremity,^{1,2} and pitching-related arm pain is very common among baseball pitchers.^{16,19} Pitching is also a common cause of injury in baseball players.¹⁶

Pitching mechanics have been extensively studied by investigators as a potential risk of a pitching-related injury.^{1,20,22,24} Aguinaldo et al¹ investigated the effects of trunk rotation on shoulder joint torque and concluded that early trunk rotation at foot contact placed increased load on the shoulder. A similar study done by Aguinaldo and

Chambers² found that early trunk rotation resulted in an increased elbow valgus load in baseball pitchers. Takagi et al²⁸ studied horizontal abduction range of motion (ROM) during baseball pitching and concluded that an increase in horizontal abduction ROM resulted in increased shoulder joint load.

Glenohumeral (GH) ROM and its relationship to an injury is another area that has been studied extensively in baseball pitchers.^{15,26,27} It has been reported that baseball pitchers demonstrate increased GH external rotation (ER) ROM and decreased GH internal rotation (IR); however, total rotation ROM (ER + IR) is not significantly different when compared with the nonpitching shoulder.^{15,29} Also, a decrease in shoulder horizontal adduction (HAD) has been reported in the pitching shoulder of baseball pitchers.^{27,32} Wilk et al³³ investigated shoulder ROM in professional baseball pitchers and found that pitchers with a more than 5° deficit in total shoulder rotation ROM in their pitching shoulder had a 2.6 times greater risk of an injury.

It has been suggested that changes in shoulder ROM as a result of pitching are due to bony and soft tissue adaptations.^{4,6,23,34} Past studies have suggested that

*Address correspondence to Ted Sueyoshi, ATC, PES, Physiotherapy Associates, 9917 North 95th Street, Scottsdale, AZ 85258, USA (email: pennstlions@hotmail.com).

†Physiotherapy Associates, Scottsdale, Arizona, USA.

‡Emoto Knee and Sport Clinic, Fukuoka, Japan.

§Minamikawa Orthopedics, Fukuoka, Japan.

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changes in shoulder ROM are a result of humeral head torsion and glenoid retroversion and that those bony adaptations are protective mechanisms of the shoulder.^{6,21,23,34} Bailey et al⁴ conducted a study on posterior soft tissue stiffness of baseball players' shoulders and found that ROM deficits were due to muscle stiffness.

The short-term effect of pitching on shoulders has also been studied, and past research has suggested that ROM of the pitching shoulder might not be affected over the course of a single season.^{14,17} Interestingly, Laudner et al¹⁷ investigated shoulder ROM in a single season and found no changes; however, they did find a change in scapular motion in position players during the course of the season.¹⁷ In contrast to these studies, Oyama et al²¹ found a significant change in shoulder ROM in high school baseball players over the course of a single season and suggested that the short-term change in shoulder ROM was due to soft tissue change and not bony adaptation.

The ROM changes and adaptations seen in baseball pitchers and their role in pitching-related injuries have been studied extensively in the American population. However, there has not been a study conducted in Japanese pitchers. Thus, we decided to conduct the current study in the Japanese population. This is the first such investigation performed on this particular population to our knowledge.

The purpose of our investigation was to (1) study upper extremity ROM in the pitching arm and nonpitching arm of baseball pitchers in Japan and (2) make a comparison between injured pitchers and noninjured pitchers. We hypothesized that (1) ER ROM in the pitching arm would be significantly greater than in the nonpitching arm and IR, HAD, and elbow extension (EXT) ROMs in the pitching arm would be significantly less than in the nonpitching arm, but there would be no significant limb difference in total shoulder ROM; (2) injured pitchers would exhibit significantly less IR and HAD ROM in the pitching arm when compared with noninjured pitchers; and (3) injured pitchers would have an increased pitching frequency and more innings pitched a year when compared with noninjured pitchers.

METHODS

Forty-one male Little League to college-level baseball pitchers who were being treated at Emoto Knee and Sport Clinic and Minamikawa Orthopedic Hospital participated in this study. All provided a signed informed consent prior to data collection (signed by a parent/legal guardian if a participant was a minor). The participants were measured for shoulder and elbow ROM and also asked to answer a questionnaire regarding their past and current medical history and pitching profile (Table 1). They were asked to only include an injury that required an orthopaedic office visit and when a diagnosis was provided. The participants were assigned to either the injury group or the no-injury group based on the presence of current and past history of pitching-related upper extremity injury, which was defined as an injury to the pitching arm that happened while pitching or the onset of symptoms while pitching that led to a hospital visit.

TABLE 1
Questionnaire

Q1. What sport(s) other than baseball do you play?
Q2. How old were you when you started playing baseball?
Q3. How old were you when you started pitching?
Q4. List any position(s) that you play other than pitching.
Q5. How many years have you been pitching?
Q6. How many months out of a year do you pitch on average?
Q7. How many games do you pitch in a single season on average?
Q8. How many innings per game do you pitch on average?
Q9. What is your average pitch count in a game?
Q10. What is the average number of games in a year that you have missed due to an injury?
Q11. What is the average number of games in a year that you pitch with shoulder or/and elbow pain?

For data analysis, single-factor analysis of variance was used between dominant arm and nondominant arm in the entire sample for each measured variable. It was also used between the injury and no-injury groups to determine whether there was a statistical significance in each measured dependent variable. Alpha (α) was set at .05. This study was approved by the institutional review board of Emoto Knee and Sport Clinic or Minamikawa Orthopedic Hospital.

Range of Motion Measurement

ROM was assessed bilaterally by 2 authors (T.T., T.N.), who measured shoulder IR, shoulder ER, shoulder HAD, and elbow EXT. All ROM measurements were done using a standard goniometer.³² ER was measured with a participant in a supine position on a treatment table with his shoulder abducted at 90°. The tester then took the shoulder into ER endpoint to measure the ROM. IR was also measured in a supine position with 90° shoulder abduction. The tester passively moved the shoulder into IR with the scapula stabilized until the scapula started to move, at which point IR ROM was measured. HAD was measured by the tester taking the participant's shoulder into HAD with his scapula stabilized on a treatment table. The HAD ROM was measured from an imaginary vertical line to the upper arm. Elbow EXT was measured with the participant standing while elbows were extended with the shoulders flexed at 90°.

RESULTS

Of the 41 study participants, 13 were being treated for lower extremity injuries and did not have a history of pitching-related upper extremity injuries (the no-injury group). This group consisted of 1 Little League, 6 junior high school, 5 high school, and 1 college-level player. The remaining 28 participants had a current and/or past history of pitching-related shoulder or elbow injuries (the injury group) and included 5 Little League, 10 junior high, 11 high school, and 2 college-level pitchers. All participants except for the Little League pitchers played on the varsity team of a school that they belonged to at the time of data collection.

TABLE 2
Range of Motion Profile of All Participants^a

	Dominant Arm		Nondominant Arm		P
	ROM (SD)	95% CI	ROM (SD)	95% CI	
ER	117.2 (12.0)	±3.6	109.8 (19.1)	±5.8	.02 ^b
IR	53.5 (17.0)	±5.2	61.9 (11.9)	±3.6	.007 ^b
ER + IR	169.0 (18.0)	±5.5	173.6 (18.1)	±5.5	.1
HAD	28.3 (9.1)	±2.7	32.8 (11.0)	±3.3	.03 ^b
EXT	1.0 (8.2)	±2.5	4.6 (5.1)	±1.5	.01 ^b

^aAll ROM values are expressed in degrees. ER, shoulder external rotation; EXT, elbow extension; HAD, shoulder horizontal adduction; IR, shoulder internal rotation; ROM, range of motion.

^bDenotes statistically significant limb difference ($P < .05$).

TABLE 3
Additional Positions Played by Participants
Other Than Pitching^a

Position	Catcher	1B	2B	3B	SS	OF	IF
Number	6	6	3	6	5	11	1

^a1B, first baseman; 2B, second baseman; 3B, third baseman; IF, infield; OF, outfield; SS, shortstop.

The mean age of the participants was 14.9 years (SD, 2.6). The mean height and weight were 166.5 cm (SD, 11.6) and 57.8 kg (SD, 13.2). There was a significant difference between dominant arm and nondominant arm (mean ± SD) in ER ($117.2^\circ \pm 12.0^\circ$ vs $109.8^\circ \pm 19.1^\circ$, $P = .02$), IR ($53.5^\circ \pm 17.0^\circ$ vs $61.9^\circ \pm 11.9^\circ$, $P = .007$), HAD ($28.3^\circ \pm 9.1^\circ$ vs $32.8^\circ \pm 11.0^\circ$, $P = .03$), and EXT ($1.0^\circ \pm 8.2^\circ$ vs $4.6^\circ \pm 5.1^\circ$, $P = .01$); however, there was no significant difference in total shoulder ROM (TROM = ER + IR) (Table 2). All but 1 participant played baseball only. One participant ran track in addition to playing baseball. Twelve athletes only pitched, and 29 other athletes played multiple positions in addition to pitching (Table 3). Nine out of the 29 athletes played more than 1 position in addition to pitching. Nine out of 28 players in the injury group had suffered multiple injuries. Types of injuries suffered by participants are described in Table 4.

Injury Versus No-Injury Group

In the injury and no-injury groups, the mean age of the participants was 14.9 (SD, 2.8) and 15.0 years (SD, 2.1), respectively ($P = .8$); the mean height was 164.3 cm (SD, 12.7) and 171.1 cm (SD, 7.5) ($P = .04$); and the mean weight was 56.4 kg (SD, 14.3) and 60.6 kg (SD, 10.7) ($P = .3$). There was a significant between-group difference in IR in both dominant and nondominant shoulders, the age when players started pitching, the average number of games pitched in a season, and the average innings pitched per game (Table 5).

The injury group had significantly greater IR ROM (55.4° ; SD, 18.1) compared with the no-injury group

TABLE 4
Types of Injuries Suffered by Players^a

Injury	LLE	LLS	OCD	UCL	Stress Fx	Impingement ^b
Occurrence	25	4	5	1	1	1

^aAll injuries were diagnosed by an orthopaedic surgeon. The injury types are listed as the diagnoses given by the medical doctor. None of these injuries required surgical intervention. LLE, Little League elbow; LLS, Little League shoulder; OCD, osteochondritis dissecans of elbow; Stress Fx, stress fracture of elbow; UCL, ulnar collateral ligament sprain of elbow.

^bShoulder impingement.

TABLE 5
Profile of Injury Versus No-Injury Group^a

	Injury Group		No-Injury Group		P
	Mean (SD)	95% CI	Mean (SD)	95% CI	
Age, y	14.9 (2.8)	±1.0	15.0 (2.1)	±1.1	.8
Height, cm	164.3 (12.7)	±4.7	171.1 (7.5)	±4.0	.04 ^b
Weight, kg	56.4 (14.3)	±5.2	60.6 (10.7)	±5.8	.3
ROM, deg					
ER D	117.4 (12.0)	±4.4	116.7 (12.5)	±6.8	.4
ER ND	108.8 (21.1)	±7.8	112.0 (14.8)	±8.0	.2
IR D	55.4 (18.1)	±6.7	45.6 (19.0)	±10.3	.03 ^b
IR ND	65.3 (9.5)	±3.5	55.0 (13.7)	±7.4	.01 ^b
TROM D	172.3 (16.0)	±5.9	162.3 (20.4)	±11.1	.07
TROM ND	176.9 (15.5)	±5.7	167.0 (21.7)	±11.7	.08
HAD D	27.0 (8.4)	±3.1	31.5 (10.3)	±3.5	.1
HAD ND	30.8 (9.4)	±5.6	37.3 (13.2)	±7.2	.08
EXT D	1.0 (8.0)	±2.9	1.0 (9.0)	±4.8	.4
EXT ND	4.5 (5.2)	±1.9	4.9 (5.2)	±2.8	.4
Questionnaire					
Q1	—	—	—	—	—
Q2	8.6 (1.9)	±0.7	7.6 (1.5)	±0.8	.04 ^b
Q3	10.6 (2.1)	±0.7	10.3 (2.0)	±1.1	.3
Q4	See Table 3				
Q5	4.4 (2.6)	±0.9	4.7 (2.2)	±1.1	.3
Q6	8.9 (2.9)	±1.0	9.7 (2.0)	±1.0	.1
Q7	29.0 (17.1)	±6.3	18.1 (12.2)	±6.6	.02 ^b
Q8	5.5 (1.8)	±0.7	3.5 (1.8)	±1.0	.002 ^b
Q9	74.2 (25.5)	±9.4	56.6 (32.9)	±17.8	.05
Q10	7.6 (7.4)	±2.7	4.3 (6.3)	±3.4	.08
Q11	3.5 (6.1)	±2.2	1.5 (1.7)	±0.9	.07

^aD, dominant/pitching shoulder/elbow; ER, shoulder external rotation; EXT, elbow extension; HAD, shoulder horizontal adduction; IR, shoulder internal rotation; ND, nondominant/nonpitching shoulder/elbow; Q, question; ROM, range of motion; TROM, total shoulder range of motion (ER + IR).

^bStatistically significant between-group difference ($P < .05$).

(45.6° ; SD, 19.0) ($P = .03$) in the dominant shoulder. The injury group also had significantly greater IR ROM on the nondominant shoulder (65.3° ; SD, 9.5) when compared with the no-injury group (55.0° ; SD, 13.7) ($P = .01$). ER, TROM, HAD, and EXT did not differ significantly between groups on either dominant or nondominant limb. Based on questionnaire responses, players in the injury group started pitching later than those in the no-injury group (age, 8.6

vs 7.6 years; $P = .04$), pitched more games in a season than no-injury players (29.0 vs 18.1 games; $P = .02$), and pitched more innings in a game than no-injury players (5.5 vs 3.5 innings; $P = .002$) (Table 5).

DISCUSSION

The current investigation supported our hypotheses that (1) there would be a statistically significant limb difference on ER, IR, HAD, and EXT ROM but not in TROM and (2) injured pitchers would have an increased pitching frequency and innings pitched compared with noninjured pitchers. However, our study did not support the hypothesis that injured pitchers would have significantly limited IR and HAD ROM when compared with noninjured pitchers. Participants in the injury group had greater IR ROM than those in the no-injury group. The injury group also had less HAD ROM compared with the no-injury group; however, this did not reach statistical significance.

The results of our current investigation supported previous findings showing that baseball pitchers develop ROM adaptation in the pitching arms.^{15,29,32} Supported by many studies, our study population demonstrated greater ER ROM and less IR ROM in their pitching shoulder; however, TROM did not differ limb to limb. Sweitzer et al²⁷ conducted a study on professional baseball pitchers and found that they had greater ER ROM and less IR and HAD ROM in the pitching arms when compared with nonpitching arms but failed to find a difference in TROM.

GH ROM deficit in the pitching arms of baseball pitchers has been linked to pitching-related upper extremity injuries.^{26,27,33} Shanley et al²⁶ studied shoulder ROM in baseball and softball players and found that a decrease in IR and HAD ROM predisposed athletes to shoulder and elbow injuries. Similarly, Wilk et al³³ investigated shoulder ROM of professional baseball pitchers and suggested that pitchers with more than 5° of difference in TROM compared with nonpitching arms would be at close to 3 times greater risk of elbow injuries.

One of the findings from this current study was that injured pitchers had significantly greater IR ROM than noninjured pitchers. This is the opposite of what many past studies have found. However, there is a tendency toward greater ROM in the younger population than in the older population, as suggested by Astolfi et al.³ They studied GH bony and ROM adaptations in the youth population and found a trend toward greater IR ROM in younger athletes than in older athletes.³ The younger pitchers in our sample might have affected our results. Also, Tyler et al³¹ studied adolescent pitchers for their shoulder ROM and suggested that no IR ROM loss might lead to increased risk of pitching-related injury. These findings are opposite to what the majority of studies have suggested, which is that a loss of IR ROM predisposes a pitcher to an injury.

Another finding in our study was that injured pitchers reportedly pitched more often during a season and pitched more innings per game pitched than noninjured pitchers. The finding is consistent with other

investigations. Lesniak et al¹⁸ found a correlation between the number of innings pitched and findings and suggested that the increased number of innings pitched might be correlated with abnormal MRI findings in the pitching shoulder.¹⁸

There are several other potential risk factors that we did not investigate in the current study. Weak shoulder muscle strength has been linked to pitching-related shoulder injury.^{30,31} Weakness in the posterior rotator cuff and scapular stabilizers as well as imbalance in strength between ER and IR muscles has been found to be related to throwing-related shoulder pain.³⁰

Pitching mechanics are also thought to play an important role in pitching-related injury. Pitchers with better mechanics would have less joint torque placed on the shoulder and elbow.¹⁰ Also, older pitchers seem to pitch with more proper pitching mechanics than younger pitchers, who also tend to pitch with less consistent mechanics.^{13,25}

The role of lower extremity and pelvic control has also been discussed as a potential injury risk factor.^{5,7,8,11} A study by Endo and Sakamoto¹¹ showed that there might be a correlation between decreased lower extremity flexibility and upper extremity injury in youth baseball pitchers. Pitchers' inability to control pelvic movement during motion has been linked not only to injury but also to pitching performance.^{7,8} Pitchers with better pelvic control are shown to have better pitching performance, according to a work done by Chaudhari et al.⁷

Our study was not without limitations. Pitching profiles of our participants were self-reported and not recorded by coaches or investigators. Also, even our participants in the no-injury group had suffered an injury to their lower extremity. We were not able to determine whether their lower extremity injuries had any correlation to their ROM or pitching profile, since this was not the focus of this study. Reported past medical history was also based on recall. This might have affected the results. We did not look at other risk factors that could have caused their injury, such as muscle strength and pitching mechanics. There were athletes who played other positions in addition to pitching, and the number of throws made playing other positions was not accounted for. We are not sure whether those additional throws that the players made had any link to injuries that occurred while pitching. These limitations of this investigation may limit the validity of the results and their potential clinical usefulness.

CONCLUSION

Baseball pitchers in Japan presented with similar ROM adaptation to that seen in US pitchers when the pitching arm was compared with the nonpitching arm. Our study showed that injured pitchers had greater IR ROM on their pitching arm when compared with noninjured pitchers. Further study is needed to confirm and validate this finding, which is in contrast to the past literature. Also, increased pitching frequency and the increased number of innings pitched per games may predispose baseball pitchers to pitching-related upper extremity injury. Pitchers who present with potential risk factors for

an injury may benefit from engaging in injury prevention programs, as suggested by numerous investigators.^{9,12}

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