Impact of physical functions on location of arm pain in youth baseball players

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Abstract The impact of characteristic physical functions on location of arm pain in youth baseball players is unclear. This study aimed to identify the differences in characteristic physical functions between youth baseball players with and without throwing-related arm pain and to clarify these differences according to location of shoulder and elbow pain during pitching. One-hundred nine junior high school baseball players (aged 12-15 years) who participated in a medical checkup underwent clinical assessment, ultrasonography, and physical function measurements. Bilateral passive range of motion (ROM) of the shoulder and elbow were measured. Shoulder muscle tests measured the strength of the throwing arm. Before the examinations, participants completed a questionnaire about their age, gender, years of play, and position in baseball. Participants were divided into 4 groups according to arm pain: non-injured group (no pain), shoulder pain group, medial elbow pain group, and osteochondritis dissecans (OCD) of the humeral capitellum group. Group differences in physical function and baseball exposure variables were analyzed through parametric and nonparametric tests. Twenty-six players sustained throwing-related pain in the shoulder or elbow. Elbow extension and flexion deficits were significantly greater with elbow injury. Our study suggests that dominant elbow extension and flexion ROM may increase the risk of throwing-related elbow pain in junior high school baseball players. We could not clarify the characteristics of shoulder pain in this study; thus, further research is required to improve understanding of these characteristics and their implications.

Keywords : baseball, youth player, throwing injury, elbow range of motion

Introduction

The baseball population in Japan exceeds 7 million players¹⁾. Participation in competitive sports has a positive influence on motor function development and health maintenance, but during the age in which bones and joints grow in spurts, excessive exercise and poor form lead to risks of injury. Lyman et al.²⁾ found that at least 50% of youth pitchers had experienced pain in the shoulder and elbow while throwing. In an epidemiological study of 218 baseball players aged 8 to 18 years, Makhni et al.³⁾ reported that only 26% of players never experienced arm pain related to throwing. Additionally, it has been reported that 5% of youth baseball pitchers sustain shoulder or elbow injuries severe enough to either require surgery or result in their retirement from the sport⁴⁾. Many youth baseball players experience pain; thus, it is crucial to determine how physicians can help prevent throwing injuries in youth baseball players.

In a systematic review⁵⁾, age, height, pitching for multiple teams, pitch velocity, arm fatigue, and the number of pitches per game (for shoulder injuries only) were considered risk factors for upper limb disorders in youth baseball players. However, it is still controversial which physical function parameters may affect throwing arm pain in such baseball players. Since age and height are considered non-modifiable risk factors, we sought to clarify the modifiable risk factors of physical function for preventing throwing-related injuries. Many previous studies have investigated the characteristics of physical function of youth baseball players. Previous studies have shown that decreased shoulder external rotation^{6,7)}, muscle tightness of the shoulder internal rotator⁸⁾, and increased side-to-side differences of shoulder horizontal adduction angle^{9,10)} are risk factors of throwing arm injuries. Yet, those studies only considered a combination of shoulder and elbow pain; few reports have compared and examined shoulder and elbow pain separately. It is possible that there are different physical functions that cause pain in different locations of the throwing arm. Therefore, it is

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necessary to investigate the characteristic physical functions related to each site of pain.

The purposes of this research were to investigate the incidence of shoulder and/or elbow pain in junior high school baseball players and to clarify the characteristic physical functions leading to pain in the shoulder and elbow.

Materials and Methods

This cross-sectional study included junior high school baseball players aged 12 to 15 years who were currently playing in Niigata, Japan. The present study was performed in accordance with the ethical standards formulated in the Helsinki Declaration of 1964 and was approved by an the Ethics Committee at Niigata University of Health and Welfare Institutional Review Board (IRB) (approval number: 17783-170210), and informed consent was obtained from all participants and their guardians before data collection.

Participants. The participants were 109 players belonging to a junior high school baseball team who participated in a medical checkup (age 12-15 years, average 13.4 ± 0.7 years; 99 right-handed throwers and 10 left-handed throwers). Participants were excluded if they had pain in the shoulder or elbow during throwing in the past and if they had any history of surgical operation. Before the medical checkup, all participants completed a detailed questionnaire and direct interview regarding his/her personal data (age, height, and weight), years of baseball played, position in baseball (pitcher, catcher, infielder, or outfielder), and experience with any episodes of elbow and/or shoulder pain while throwing a baseball. All participants underwent a clinical assessment, ultrasonography, and physical function measurements (range of motion [ROM], strength, and posture).

Those who had shoulder or elbow pain in the throwing arm at the medical checkup and with abnormal findings either on the ultrasonogram or clinical assessments were classified in the injured group, whereas those who did not currently have any pain during pitching and had no abnormal findings in clinical assessment and ultrasonography were classified in the non-injured group. The presence of pain in the throwing arm was determined based on the statement, "shoulder or elbow pain that caused them to not play in a game or practice". The injured group was divided into 3 groups according to the location of the pain: shoulder pain group, medial elbow pain group, and osteochondritis dissecans of the humeral capitellum (OCD) group. For the shoulder joint, the following clinical assessments (tenderness at the proximal humeral epiphyseal line, pain during shoulder rotation resistance, Hawkins test, full/empty can test, hyperexternal rotation test) and ultrasonography (LOGIQ eV 2; GE Co., Ltd., Qujing, China) of the humeral proximal epiphysis

were carried out. If any of the assessments were positive, participants were assigned the shoulder pain group. Similarly, for the elbow joint, we evaluated humeral medial epicondyle tenderness, flexion-extension pain and moving valgus stress test and performed ultrasonography of the humeral medial epicondyle region to identify medial elbow pain. Regarding the OCD group, irrespective of the presence or absence of pain, any case where abnormal findings were found in the small head of the humerus on the ultrasonogram was regarded as positive. Ultrasonography was performed by a physical therapist with more than 5 years of experience in the rehabilitation of throwing injuries of youth baseball players. A medical doctor, with more than 10 years of experience in diagnosing throwing injuries, double checked when abnormal findings were found.

Physical function measurements. The same examiner, with more than 2 years of physical therapy experience, measured bilateral passive ROM of glenohumeral external rotation (ER) and internal rotation (IR), elbow extension and flexion; and ER and IR of the hip were assessed using a standard goniometer. ROM of the shoulder was measured with participants in the supine position with the shoulder at 90° of abduction, elbow at 90° of flexion, and forearm in neutral rotation. The scapula was stabilized while performing the measurement. ROM of the hip was measured in the supine position, with the hip at 90° of flexion. Shoulder horizontal adduction (HA) ROM, as reported by Laudner et al.¹¹⁾, was measured in the supine position with the lateral border of the scapula stabilized by providing a posteriorly directed force via the examiner's hand to limit scapular protraction, rotation, and abduction. The upper extremity was passively and horizontally adducted across the body with the arm starting at 90° of abduction in neutral rotation. A digital inclinometer (DWL-80Pro; DigiPas Technologies, Irvine, CA) was aligned with the humerus, and the angle relative to a line perpendicular to the ground was recorded (intraclass correlation coefficient [ICC]: 0.91). These ROM measurements were taken once.

Bilateral muscle strength of the shoulder IR and ER and scapula muscle was also measured by a physical therapy student, with sufficient advance training and practice, using a handheld dynamometer (MicroFET; Hoggan Health Industries Inc., West Jordan, UT). This measurement technique has been shown to be valid and reliable for detecting weakness in the shoulder¹²⁻¹⁴⁾. IR strength was measured in the supine position, with the shoulder in 90° of abduction and the elbow in 90° of flexion. The participant's arm was placed in neutral rotation, and the participant maximally resisted against the dynamometer placed on the volar aspect of the wrist (ICC: 0.85). We tested ER strength in the prone position in a similar manner, with the dynamometer placed on the dorsal aspect of the wrist (ICC: 0.82). The lower trapezius muscle test

was performed in the prone position, with the arm in 150° of scaption with the thumb pointed up. The dynamometer was placed on the posterolateral corner of the acromion, and the participant maximally resisted a protraction-directed force (ICC: 0.89). The serratus anterior muscle test was performed in the supine position, with the shoulder at 90° flexion and the elbow at 90° of flexion. Resistance was applied to the ulna of the olecranon process along the long axis of the humerus (ICC: 0.94). For each muscle testing, subjects were asked to build their force gradually to a maximum voluntary effort over a 2-second period; and then, they maintained a maximum voluntary effort for a 3-second period. These measurements were taken twice and then averaged and analyzed.

For the posture measurement, the thoracic kyphosis angle was measured with the participant in a relaxed standing position. An inclinometer (Bubble Inclinometer; Baseline Inc., Irvington, NY, USA) was placed over the spinous processes of the first and second thoracic spines, and over the twelfth thoracic and first lumbar spines; each angle was recorded. These measurements were taken once. The thoracic kyphosis angle was calculated by the summation of these angles¹⁵⁾. The intra-tester and inter-tester reliabilities of this test have been established (ICC [single]: 0.95, 95% confidence interval [CI]: 0.91–0.97)^{16,17)}.

Shoulder total ROM (TROM) was calculated by adding the ER and IR values. Additionally, the following variables were calculated: glenohumeral ER difference, glenohumeral IR difference, difference in TROM, and side-to-side difference in HA, elbow extension ROM deficits, elbow flexion ROM deficits, hip ER difference, and hip IR difference. Each difference was calculated by subtracting the dominant side from the non-dominant side. Strength

ratios were calculated by using the ratio of the ER to IR force, and ratio of the serratus anterior to lower trapezius muscle force for the throwing side of each participant.

Statistical analysis. Continuous data were assessed for normality by using the Kolmogorov-Smirnov test. When data were normally distributed, one-way analysis of variance was used to compare the non-injured group, shoulder pain group, medial elbow pain group, and OCD group. Continuous data that failed the normality test were assessed with the Kruskal-Wallis test to compare the 4 groups. The position in baseball was examined using the chi-square test. All statistical analyses were conducted with the Statistical Package for Social Sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY). The level of statistical significance was set at $P < 0.05$.

Results

Study population. Of the 109 junior high school baseball players who participated in the medical checkup, 64 players were included in the analysis (Fig. 1). Of the 45 cases excluded, 2 players had undergone surgery for OCD and 43 players (39.4%) reported that they had had pain in the shoulder or elbow in the past.

Thirty-eight of the players who did not have any abnormality on the ultrasonogram and did not currently have shoulder or elbow pain were regarded as the non-injured group. There were 26 players in the injured group, 6 players in the shoulder pain group, 15 players in the medial elbow pain group, and 5 players in the OCD group. Five patients with extramedullary obstruction showed abnormal findings on the ultrasonogram, but they were all asymptomatic and did not have pain during pitching.

Fig. 1 Flow diagram of participants.

Comparison of the injured group and non-injured group.

There was no significant difference in age, height, weight, years of playing baseball, and position among the non-injured group, shoulder pain group, medial elbow pain group, and OCD group (Table 1).

The medial elbow pain group and OCD group had sig-

nificantly greater elbow extension deficits than the non-injured group (Table 2). The OCD group had significantly larger elbow flexion deficits than the non-injured group and shoulder pain group. In addition, no significant difference was found in the ROMs of the shoulder and hip, muscular strength ratio around the scapula, and posture.

Table 1. Summary of demographic data

	Non-injured group (n = 38) ^a	Injured groups			P Value
		Shoulder pain (n = 6) ^a	Medial elbow pain (n = 15) ^a	Osteochondritis dissecans of the humeral capitellum (n = 5) ^a	
Age, y ^b	13.2 ± 0.8	13.3 ± 0.8	13.5 ± 0.6	13.6 ± 0.5	.538
Height, cm ^b	166.3 ± 6.9	167.0 ± 8.3	167.6 ± 4.4	170.9 ± 10.5	.479
Weight, kg ^c	57.1 ± 10.0	57.8 ± 8.3	58.0 ± 10.8	61.2 ± 12.8	.889
Total years played ^c	4.9 ± 1.3	5.5 ± 1.4	5.3 ± 1.0	5.4 ± 1.1	.625
Position ^d					.530
Pitcher	8	3	5	1	
Catcher	3	0	2	0	
Infielder	18	2	6	1	
Outfielder	9	1	2	3	

^aValues are expressed as mean ± standard deviation, except position. ^bOne-way analysis of variance. ^cKruskal-Wallis test.

^dChi-square test.

Table 2. Differences in variables^a by group

	Non-injured Group (n = 38) ^b	Injured Groups			P Value
		Shoulder pain (n = 6) ^b	Medial elbow pain (n = 15) ^b	Osteochondritis dissecans of the humeral capitellum (n = 5) ^b	
Range of motion (deg)^c					
Glenohumeral ER difference	-1.9 ± 9.6	-8.7 ± 7.8	-5.8 ± 10.7	2.2 ± 10.4	.173
Glenohumeral IR difference	0.2 ± 14.2	3.0 ± 7.6	0.2 ± 12.6	7.2 ± 12.6	.821
Difference of shoulder TROM	-1.7 ± 18.2	-5.7 ± 11.5	-5.6 ± 17.9	9.4 ± 16.9	.400
Horizontal adduction deficits	1.9 ± 5.6	8.7 ± 16.7	3.1 ± 4.5	6.4 ± 3.6	.137
Elbow extention deficits	0.4 ± 3.0	2.3 ± 1.8	3.0 ± 2.4 [*]	5.6 ± 3.8 [*]	.004
Elbow flexion deficits	0.1 ± 4.0	1.5 ± 7.9	3.5 ± 6.8	14.0 ± 5.0 ^{*†}	.002
Hip ER difference	0.9 ± 6.5	0.5 ± 7.3	-1.1 ± 7.5	-7.0 ± 10.2	.360
Hip IR difference	-1.4 ± 6.2	-0.8 ± 11.1	0.2 ± 13.7	9.0 ± 18.8	.578
Muscle strength ratio					
Shoulder ER/IR strength ratio	0.7 ± 0.7	0.7 ± 0.2	0.6 ± 0.2	0.6 ± 0.3	.291
SA/LT muscle strength ratio	2.3 ± 0.6	2.0 ± 0.6	2.5 ± 0.9	2.0 ± 0.6	.478
Posture (deg)					
Thoracic kyphosis angle	30.0 ± 7.6	29.2 ± 5.8	29.7 ± 7.9	27.0 ± 9.7	.930

^aER, external rotation; IR, internal rotation; TROM, total range of motion; SA, serratus anterior; LT, Lower trapezius.

^bValues are expressed as mean ± standard deviation.

^cValues are expressed as non-dominant side minus dominant side.

*Statistically significant, non-injured group versus medial elbow pain group and osteochondritis dissecans of the humeral capitellum group, $P < .05$.

†Statistically significant shoulder pain group versus osteochondritis dissecans of the humeral capitellum group, $P < .05$.

Discussion

In this study, of 109 participants who underwent the medical checkup, 38 players (34.8%) had no pain in their shoulder or elbow during throwing. Additionally, 41.3% of the players had experienced shoulder or elbow pain during throwing in the past, and when combined with players who still had pain currently, a total of 60.6% of the players had experienced throwing-related pain. A similar trend was shown in a previous study; Lyman et al.¹⁸⁾ reported that more than half of the players from 9 to 14 years of age experienced shoulder or elbow pain during throwing.

Herein, characteristics of physical functions due to differences in the site of pain during throwing were compared. The results showed that in the medial elbow pain group and asymptomatic OCD group, the elbow extension deficits were increased significantly compared to the non-injured group. This finding suggests that when one has an abnormality in the elbow, the elbow extension range of the throwing side is reduced. In youth baseball players (9-14 years), the players with abnormal findings in the elbow showed a significant decrease in the extension range of the throwing side elbow¹⁹⁾. Our results showed that both the medial elbow pain group and OCD group had abnormal findings upon clinical assessment and ultrasonography, which support the previous study's finding. Throwing motion is a movement that includes rapid elbow extension and forearm pronation²⁰⁾. Repetitive throwing may cause tightness of the brachioradialis, biceps brachii and forearm flexor muscle groups, and change the alignment between humerus and ulna. In the medial elbow pain group, such muscle tightness may cause elbow extension deficit. However, in youth, ROM during throwing is about 80° (79° ± 14°); additionally, the maximum extension angle velocity appears immediately before ball release, but the elbow does not fully extend²⁰⁾. Thus, it is unclear what the influences are on the elbow extension deficit observed in this study and what influences directly change the mechanical stress on the elbow during throwing. In a prospective survey of elementary school baseball players, Sakata et al.²¹⁾ suggested that if the elbow extension deficit is more than 5°, it is a risk factor for the occurrence of elbow injury later. Therefore, decreased elbow extension ROM of the throwing side may have occurred before the occurrence of pain; and it is necessary to prospectively evaluate junior high school baseball players in the future.

Additionally, the OCD group was remarkably restricted in flexion range of the elbow compared to the non-injured group and shoulder pain group. It is thought that OCD is restricted in elbow flexion/extension range because of a change in the radius of the curvature of the joint due to the progression of hypertrophy of the humeral capitellum and radial head. However, all players with OCD herein were asymptomatic and had not experienced pain during

throwing. Thus, further research is needed on this topic.

Although we could not identify the characteristics of physical functions of players who had shoulder pain during throwing, the results showed that an HA deficit tended to be larger in the shoulder pain group than in the non-injured group, although it was not significant ($P = 0.137$). Shanley et al.¹⁰⁾ found a significant difference in HA of the throwing arm between injured and uninjured players ($P = 0.01$). They also found that adolescent pitchers (13-18 years) with a side-to-side difference in HA greater than 15° were 4 times more likely to get injured⁹⁾. The HA deficit was thought to be caused from posterior-inferior capsule and soft tissue tightness. An increase in glenohumeral IR difference may also reflect tightness of the posterior shoulder, but we found no significant difference ($P = .821$). The previous study reported that cross-body stretch, including horizontal adduction motion, was more effective to reduce posterior shoulder tightness compared to sleeper stretch, including glenohumeral IR motion²²⁾. It suggested that the HA deficit may reflect posterior shoulder tightness more specifically than the glenohumeral IR difference. Grossman et al.²³⁾ performed cadaveric studies to examine the effects of capsular changes suspected to occur in overhand athletes. They demonstrated that a posterior contracture caused the humeral head to translate posterosuperiorly, and this might be associated with shoulder injury. In addition, we focused on the characteristics of physical function in this study, but in the case of athletes with shoulder pain, it might be necessary to examine not only ROM and muscle strength but also the effects of throwing motion characteristics on shoulder joint function.

Our study has several limitations. First, this was a cross-sectional study, and it is unclear whether the characteristics of the obtained physical functions were due to pain generation or the cause of injury. Second, a player history of elbow or shoulder pain was based on retrospective recall from participants using a questionnaire before the medical checkup; thus, this may not have produced accurate and complete data. However, it was suggested that evaluating the presence or absence of restriction of elbow extension/flexion in the medical checkup is useful for the early detection of injury.

In conclusion, this study found that most junior high school baseball players experience shoulder and elbow pain during throwing. It is important to assess their elbow regularly to detect elbow injury early. Further research is needed to be better able to identify the risk of shoulder injury in junior high school baseball players.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

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