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Risk factors associated with throwing injuries in young baseball players

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Background: Few studies have retrospectively analyzed the relationship between joint range of motion (ROM) and muscle flexibility and shoulder and elbow throwing injuries in a large number of elementary school baseball players. The purpose of this study was to retrospectively identify the physical factors related to shoulder and elbow throwing injuries in younger baseball players.
Methods: A total of 2466 younger baseball players belonging to our Prefecture Rubber Baseball Federation who participated in medical check-ups from 2016 to 2019 were analyzed. Players completed a questionnaire and had a medical check-up that included a physical examination and ultrasonography. ROM (internal rotation [IR] angle and external rotation angle) of the shoulder and hip and the finger-to-floor distance and heel-to-buttock distance were measured. The straight leg raise was also performed. The results of two groups (normal group and injury group) were compared using the χ^2 test, Mann-Whitney U test, and Student *t* test. Stepwise forward logistic regression models were developed to identify risk factors.
Results: On univariate analysis, nine of the 13 evaluated items showed significant decreases in ROM and muscle flexibility in the injury group. On multiple logistic regression analysis, grade, finger-to-floor distance, IR angle of the dominant side shoulder, and IR angle of the nondominant side hip were significantly associated with the occurrence of throwing injuries. Decreased total shoulder angle was observed not only on the dominant side but also on the nondominant side in the injury group.
Conclusion: Decreased ROM and muscle flexibility were risk factors for baseball-related throwing injuries in elementary school baseball players. To prevent shoulder and elbow throwing injuries, players, coaches, medical staff, and parents need to be aware of these findings.
Level of evidence: Level III; Retrospective Cohort Comparison; Prognosis Study

Keywords: Baseball; elbow; shoulder; range of motion; tightness; young

The study design was reviewed and approved (Accession No. O-0678) by the ethics committee of our institute. Informed consent was obtained from all participant's guardians or representatives. In this study, the consent explanation document was handed over to the participants (including their guardians or representatives), sufficient explanation was given in writing, and consent was obtained by returning the questionnaire at the free will. This study was conducted in compliance with the principles of the Declaration of Helsinki. The procedures performed were in accordance with the ethical standards of the committees responsible for human experimentation (institutional and national) and the Declaration of Helsinki.

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Baseball is one of the most popular sports in the world; the total number of baseball players in the world is 65 million, including softball players.[30] There are over 10,000 elementary school teams in Japan.[12] In baseball, the pitching motion that is routinely repeated in practices and games is unavoidable to some extent. The pitch has been traditionally divided into 6 phases: 1) wind-up, 2) stride, 3) cocking, 4) acceleration, 5) deceleration, and 6) follow-through.[2] Biomechanical research has shown that maximal elbow varus torque is produced shortly before the acceleration phase.[4] The accumulation of microtrauma due to repeated dynamic overhand throwing is thought to be the cause of throwing injuries.[17] It is said to be common among baseball players across multiple levels of competition and various age ranges.[28]

In young players, injury patterns are influenced by the age-related stage of elbow development.[16] Childhood throwing injuries include osteochondral lesions such as traction apophysitis of the medial epicondyle (MEC) lesions, osteochondritis dissecans of the capitellum (OCD), and epiphyseal separation in the proximal humerus (Little Leaguer's shoulder).

In Japan, Iwame et al[11] have been conducting medical check-ups of young baseball players since 1981 for early detection of throwing injuries during the growth period. With this as a reference, a medical check-up system for baseball elbow using an ultrasound device has been widely implemented.[7,11,19,21]

Harada et al[7] found 2 cases of OCD (1.3%) and 33 cases of MEC lesions (21.6%) in 153 players aged 9 to 12 years using ultrasound imaging. Matsuura et al[19] reported that the prevalence of OCD on ultrasonography in 1040 young baseball players was 2.1%.

However, despite the recent development of medical check-ups for the early detection of throwing injuries, there is a lack of consensus on how to prevent them.

The number of pitches thrown, pitch velocity, pitch type, days of training, joint range of motion (ROM), and muscle flexibility have been identified as risk factors for throwing injuries in baseball players.[4,6,25]

We have been doing medical check-ups since 2010 and have examined more than 2000 elementary school baseball players, focusing on ROM and muscle flexibility. Few past reports have retrospectively analyzed a large number of players. The purpose of this study was to clarify the risk factors for throwing injuries to help prevent them in young baseball players.

Material and methods

Participants

This study had a retrospective, observational design including data collected during medical check-ups of elementary school baseball players belonging to our Prefecture Rubber Baseball Federation on December 4, 2016, December 17, 2017, December 16, 2018, and December 15, 2019. This medical check-up is an annual event performed since 2010 by our hospital for the early detection and treatment of various injuries.

Questionnaires, physical function measurement, physical examination, and ultrasonography were used to collect the data, and 2466 participants were finally enrolled in the study. Of 2446 participants, 2305 were males and 141 were females.

Questionnaire

A self-reported questionnaire that contained items regarding sex, grade, height and weight, playing position (pitcher and/or catcher or not), dominant side, and history of elbow and/or shoulder and/or other pain was mailed to the participants. It was sent several months before the check-up, and we asked them to fill in their all past injuries and present symptoms, that is, one month before the check-up. On the day of the check-up, we referred to the results of the questionnaire.

Physical function measurements

The ROM of internal rotation (IR) angle and external rotation (ER) angle of the shoulder and hip joints were measured. And following past reports, we measured finger-to-floor distance (FFD), heel-to-buttock distance (HBD), and straight leg raise (SLR) as evaluations of flexibility.[10,13] Two physical therapists assessed them. One therapist confirmed the form of the participants, while the other measured the distance and angle using a measurement tape or goniometer (Fig. 1).

The FFD is the distance between the fingertip and the floor when the participant bends in an upright standing position and extends the fingers toward the floor. The HBD is the distance between the heel and the buttocks. The participant was placed in the prone position, and the HBD was measured using a tape measure with the knee passively bent. In the SLR, the leg with the knee held straight was raised parallel to the edge of the table, with the participant in the supine position. Thereafter, the hip flexion angle was measured. ROM of the shoulder was measured with the participant in a supine position with the shoulder abducted at 90° with the scapula stabilized by applying a posterior force to the coracoid process. ROM of the hip was examined in a supine position with the knee bent at 90°.

Physical examination and ultrasonography

Two orthopedic surgeons performed physical examination and ultrasonography for initial screening in the medical check-ups. ROM and the valgus stress test of the elbow joint, and tenderness and throwing pain of the shoulder and elbow joints were included in the physical examination. Limitation of ROM was regarded as present if there was a difference between the dominant and nondominant elbows.

Ultrasonography was performed only on the capitellum of the dominant elbow for early detection of OCD. Anterior view images were taken with the participant seated and the elbow fully extended. Posterior view images were taken with the elbow fully flexed to obtain a sufficient view of the anterior aspect of the capitellum. Ultrasonographic findings were graded as follows

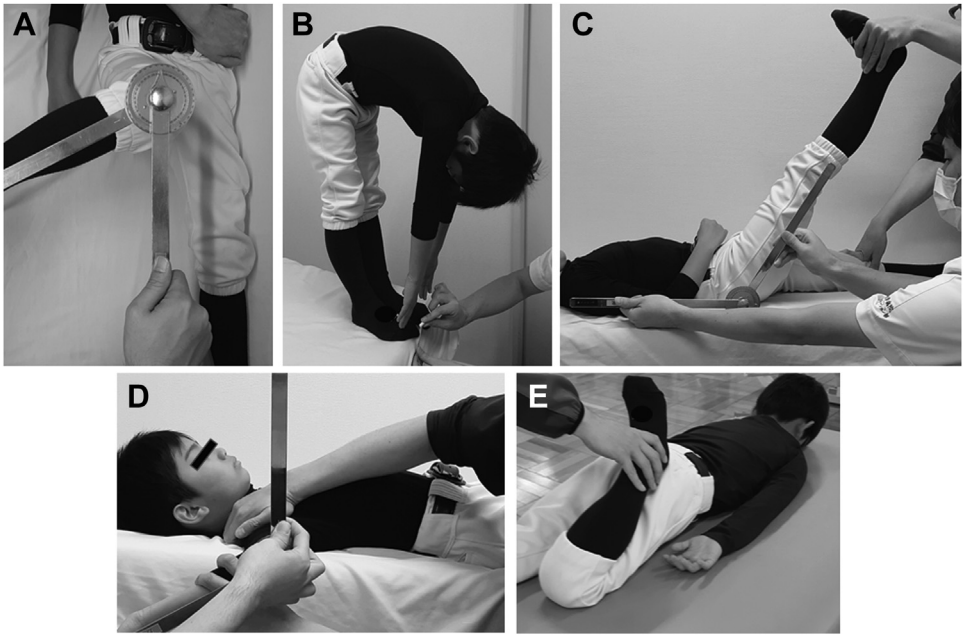

Figure 1 Measurement techniques for (**A**) range of motion of the hip, (**B**) finger-to-floor distance, (**C**) straight leg raise, (**D**) range of motion of the shoulder, and (**E**) heel-to-buttock distance.

according to the classification proposed by Ishizaki[9]: grade 0, normal; grade 1a, irregular surface of subchondral bone; grade 1b, a cystic lesion of the subchondral bone surface; grade 2, irregularity of the subchondral bone; and grade 3, discontinuity of the subchondral bone. Grades 1a, 1b, 2, and 3 were defined as abnormal findings of the capitellum.

Secondary examination

For participants with positive findings on physical examination and ultrasonography, a secondary examination was conducted after the radiographic examination. Radiography of the elbow was performed in four directions: anteroposterior and lateral views, 45° flexion anteroposterior, and 30° ER views.

Secondary examination was performed by shoulder and elbow surgeons and sports orthopedists and included physical examination, ultrasonography, and radiographic examination to diagnose the throwing injuries, such as MEC lesions, Little Leaguer's shoulder, and OCD. We found 37 cases of OCD (1.5%) in 2446 players.

Divide into an injury group and a normal group

Based on the results of these medical check-ups, the participants were divided into an injury group of 313 players and a normal group of 2133 players.

Finally, players who were negative at the primary screening or who proceeded to the secondary examination but were examined again and found to be normal along with the x-ray findings were classified as the normal group, while players who were diagnosed with throwing injuries at the secondary examination were classified as the injury group. At the secondary examination, a shoulder elbow surgeon or sports orthopedic surgeon examined the players. In addition, the players who were found to be normal at the secondary examination also include those who were diagnosed with false-positive ultrasound results.

And muscle flexibility and ROM were compared between the two groups. In our yearly check-up for young baseball players, there are many different types of throwing injuries that affect young baseball players, and this is our first study to assess the association between all throwing injuries and ROM and muscle flexibility without disaggregating by damage type.

Statistical analysis

Continuous variables are presented as means and standard deviations, whereas categorical variables are presented as numbers and percentages. The χ^2 test was used to test position, Mann-Whitney U test was used to test grade, and Student t test was used for continuous variables to compare baseline characteristics and associations of joint ROM and muscle flexibility between the groups.

A stepwise forward logistic regression analysis, after adjusting for significant variables identified on univariate analyses, was performed to identify the risk factors for shoulder and elbow injuries and to calculate odds ratios (ORs) and 95% confidence intervals. The Hosmer-Lemeshow test was used to test the model's calibration.

For the shoulder joint, the total angle was defined as the ER angle plus the IR angle. Then, the ER angle, IR angle, and total angle of the shoulder were compared between the normal group and the injury group, in addition to between the dominant and nondominant sides.

All statistical analyses were conducted with the IBM SPSS Statistics 22 software program (IBM Japan Ltd., Tokyo, Japan), and $P < .05$ was considered to indicate significance.

Table I Basic characteristics of the participants

Basic characteristic	Normal group (n = 2133)	Injury group (n = 313)	*P* value
Grade	4.7 ± 1.2	5.0 ± 1.2	<.001*
Height (cm)	140.8 ± 9.8	143.0 ± 9.6	<.001*
Weight (kg)	36.0 ± 10.7	37.4 ± 9.0	.039*
Position (%)	45.7 (974/2133)	50.2 (157/313)	.136

Position, pitcher and/or catcher number/total number.
* $P < .05$.

Results

The baseline characteristics of the participants are listed in Table I. Grade, height, and weight were significantly higher in the injury group than in the normal group. There was no difference in position (percentage of pitchers and/or catchers) between the injury group and the normal group.

Univariate analysis

In the injury group, FFD ($P < .001$, OR: 0.97), SLR of the dominant side ($P = .007$, OR: 0.99), SLR of the nondominant side ($P = .003$, OR: 0.99), HBD of the nondominant side ($P = .050$, OR: 1.04), IR angle of the dominant side shoulder ($P < .001$, OR: 0.98), IR angle of the nondominant side shoulder($P < .001$, OR: 0.99), ER angle of the dominant side hip ($P < .001$, OR: 0.98), IR angle of the dominant side hip ($P < .001$, OR: 0.98), and IR angle of the nondominant side hip ($P < .001$, OR: 0.96) were significantly less than in the normal group (Table II).

Multivariate analysis

The results of multiple logistic regression analysis are shown in Table III. Grade ($P = .008$, OR: 1.16), FFD ($P = .014$, OR: 0.98), IR angle of the dominant side shoulder ($P = .003$, OR: 0.99), and IR angle of the nondominant side hip ($P < .001$, OR 0.97) were significantly associated with the occurrence of throwing injuries.

The result of the Hosmer-Lemeshow test was $P = .442$. The percentage of correct classifications was 87.3%. Thus, the resulting regression model was accurate.

Shoulder joint ROM

The results of the analysis of shoulder joint ROM are shown in Table IV. In the comparison between the normal group and the injury group, the IR angle and total angle of both the dominant and nondominant sides were significantly decreased in the injury group. Meanwhile, in the comparison between dominant and nondominant sides in both the normal group and the injury group, the dominant side showed a significant increase in the ER angle and a significant decrease in the IR angle compared to the nondominant side. The total angle was significantly decreased on the dominant side in the normal group, but there was no significant difference in the injury group.

Discussion

The most important findings of this study were that grade, FFD, shoulder IR angle of the dominant side, and hip IR angle of the nondominant side were risk factors for throwing injuries in younger baseball players.

From the analysis of shoulder ROM, the shoulder total angle, which means the IR plus ER angles, of not only the dominant side but also the nondominant side was also a risk factor for throwing injuries. There were few previous reports of retrospective studies including a large number of young baseball players. Therefore, we believe the present study provides useful information.

Grade

Previous studies have reported that the risk of arm injury among pitchers increases with age, height, and weight.[17] In general, height and weight are expected to increase as the school year progresses. Height and weight also showed significant differences on univariate analysis. In a prospective study, Lyman et al[17] reported that age and weight were developmental risk factors for elbow injury in 9- to 12-year-old baseball players. Their hypothesis focused on the secondary ossification centers that are the most vulnerable points in the young elbow; these centers begin to ossify between the ages of 2 and 11 years and do not fuse to the long bones until as late as 17 years of age. This may explain why the rate of throwing-related elbow injuries increases with age. Heavier players may be putting more of a burden onto their immature skeletons, exacerbating elbow weakness, resulting in an increased likelihood of throwing injuries. Taller players likely have longer arms, which weigh more than do shorter arms, resulting in more weight being maintained by the shoulder joint during pitching. This creates a higher torque on the shoulder joint and could be the source of throwing injuries.[5]

Table II Associations of joint ROM and muscle flexibility with throwing injury

	Normal group (n = 2133)	Injury group (n = 313)	OR	95% CI	*P* value
FFD (cm)	1	3	0.97	0.95 - 0.98	<.001*
SLR (deg)					
Dom	67	65	0.99	0.98 - 0.99	.007*
Non-dom	68	65	0.99	0.98 - 0.99	.003*
HBD (cm)					
Dom	1	2	1.04	1.00 - 1.08	.059
Non-dom	1	2	1.04	1.00 - 1.08	.050*
Shoulder ER angle (deg)					
Dom	104	103	0.99	0.99 - 1.00	.389
Non-dom	100	99	0.99	0.98 - 1.00	.051
Shoulder IR angle (deg)					
Dom	59	54	0.98	0.97 - 0.99	<.001*
Non-dom	65	61	0.99	0.98 - 0.99	<.001*
Hip ER angle (deg)					
Dom	47	45	0.98	0.97 - 0.99	<.001*
Non-dom	47	46	0.99	0.98 - 1.01	.200
Hip IR angle (deg)					
Dom	49	46	0.98	0.97 - 0.99	<.001*
Non-dom	49	45	0.96	0.95 - 0.98	<.001*

ROM, range of motion; *OR*, odds ratio; *CI*, confidence interval; *FFD*, finger-to-floor distance; *SLR*, straight leg raise; *HBD*, heel-to-buttock distance; *ER*, external rotation; *IR*, internal rotation; *Dom*, dominant; *non-dom*, nondominant; *deg*, degree.
* $P < .05$.

Table III Multivariable logistic regression analysis of risk factors associated with throwing injury

	OR	95% CI	*P* value
Grade	1.16	1.04 - 1.29	.008*
FFD	0.980	.96 - .99	.014*
Shoulder IR angle of the dominant side	0.99	.98 - .99	.003*
Hip IR angle of the nondominant side	0.97	.96 - .99	<.001*
Percentage of correct classifications, 87.3%			

OR, odds ratio; *CI*, confidence interval; *FFD*, finger-to-floor distance; *IR*, internal rotation.
* $P < .05$.

Pitching motion

Pitching does not merely involve motion of the shoulder or elbow but also the general motion chain of the lower limb, trunk, upper limb, and fingers.[1,3,18] Lack of a smooth general motion chain induces throwing injuries of the upper limb.[14] Lower limb and trunk motions are part of the general motion chains. Lower limb dysfunction, including ankle, knee, and hip joint dysfunction, may be related to throwing injuries of young baseball players.

Shoulder and hip joint IR deficit

Saito et al[24] have shown that decreased flexion and IR angles of the hip joint were significantly more common in baseball players with elbow dysfunction than in those with no elbow dysfunction. Sekiguchi et al[25] showed that a decreased IR angle of the hip joint of the stride leg was significantly related to shoulder and elbow pain in young baseball players (range: 9 to 12 years old).

Shanley et al[26] performed a prospective investigation of high school softball and baseball players. They concluded that there was a significant difference of the IR angle of the shoulder between players with or without throwing injuries. Shitara et al[28] also reported that a decreased IR angle of the shoulder was one of the risk factors for shoulder and elbow injuries in high school baseball players. Based on the present findings, a decreased IR angle of the dominant side shoulder and IR angle of the nondominant side hip were found to be risk factors for throwing injuries in young baseball players.

Table IV Shoulder joint ROM

	Normal group	Injury group	*P* value
Dominant side			
ER angle (deg)	104	103	.389
IR angle (deg)	59	54	<.001*
Total angle (deg)	163	157	<.001*
Nondominant side			
ER angle (deg)	100	99	.051
IR angle (deg)	65	61	<.001*
Total angle (deg)	165	160	<.001*
	Dominant side	**Nondominant side**	***P* value**
Normal group			
ER angle (deg)	104	100	<.001*
IR angle (deg)	59	65	<.001*
Total angle (deg)	163	165	<.001*
Injury group			
ER angle (deg)	103	99	<.001*
IR angle (deg)	54	61	<.001*
Total angle (deg)	157	160	.145

ROM, range of motion; *ER*, external rotation; *IR*, internal rotation; *deg*, degree.
Total angle, ER angle plus IR angle.
* $P < .05$.

Total angle of the shoulder

The total angle of the shoulder means the ER angle plus the IR angle of the shoulder. Shanley et al[26] reported that there was no significant difference in the total angle of the shoulder between injured players and noninjured players in high school baseball and softball players. On the other hand, Wilk et al[31] reported that a 5-degree loss of the total shoulder angle induces a 2.6 times greater risk of elbow injury in professional baseball pitchers. Ruotolo et al[22] reported that there was no significant difference in the total shoulder angle between the dominant and nondominant sides in college baseball players without shoulder pain, whereas there was a significantly decreased total shoulder angle on the dominant side compared with the nondominant side in college players with shoulder pain. In the present study, the decreased total shoulder angle of the dominant side due to the decreased IR angle might appear to be a risk factor for throwing injuries. It is well known that repeated pitching motion results in an increased ER angle and a decreased IR angle of the shoulder. The causes of these findings were considered to include tightness of the posterior articular capsule[8,29] and decreased humeral retroversion angle.[20,32] However, a decreased total shoulder angle was observed not only on the dominant side but also on the nondominant side in the injury group in the present study. These findings indicated that decreased original shoulder ROM might be considered one of the risk factors for throwing injuries independent of the pitching motion.

Finger-to-floor distance There have been few reports of FFD as a risk factor for throwing injuries. From the present results, FFD was considered one of the risk factors for throwing injuries. FFD is one of the useful values for detecting general joint laxity including that of the spine.[15] Sairyo et al[23] have suggested that a flexible spine in flexion and/or flexible hamstrings were the main mechanisms for improving FFD. This suggested that decreased flexibility of the lumbar and hamstring muscles may induce limitations of the general motion chain.

However, the problem of ROM and general joint flexibility might be considered a correctable risk factor for throwing injuries.[27] In the present study, decreased FFD, IR angle of the dominant shoulder, and hip IR angle of the nondominant side were found to be risk factors. Although additional investigation is required, by applying the results of the present study to solving these problems, the incidence of throwing injuries in young baseball players may be decreased.

Limitations

Several limitations must be taken into consideration with respect to the present study. First, the present study was conducted without randomization. Second, there might be the possibility of study bias due to the retrospective design. Third, self-reports were used to assess elbow or shoulder pain; the limitations imposed by self-reporting bias are recognized, especially because the participants were relatively young. Fourth, this result was measured during the

off-season; if the measurement were performed during the season, the ROM may change due to the impact of throwing, which may change the results. In addition, we were not able to evaluate changes over time in the presence or absence of throwing injuries and in the increase or decrease in ROM. For example, the ROM of players who recovered from an injury was not evaluated. Moreover, we believe that reduced ROM is the cause of the throwing injury, but it could be a consequence.

Conclusion

Decreased ROM and muscle flexibility were risk factors for baseball-related throwing injuries in elementary school baseball players. In particular, grade, FFD, shoulder IR on the dominant side, and hip IR on the nondominant side showed significant associations.
With repetition of the pitching motion, shoulder ER increases and IR decreases. Decreased shoulder IR and total angle of the nondominant side unaffected by pitching were risk factors for throwing injuries. To prevent shoulder and elbow throwing injuries, players, coaches, medical staff, and parents need to be aware of these findings.

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