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ORIGINAL ARTICLE

Cross-sectional Study of the Hip Joint Condition in Young Baseball Players

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Objective: The hip joint is a crucial part of the kinetic chain for throwing baseball pitches. Nevertheless, few reports have described assessments of the functional development of the hip joint in young baseball players. **Methods:** We examined 315 young baseball players, 7–14 years old, all of whom had completed a self-administered questionnaire including items related to the dominant side and throwing-related hip joint pain sustained during the previous year. We measured the hip ranges of motion (ROMs: external and internal rotation and flexion) and hip muscle strengths (external and internal rotation) on the dominant and non-dominant sides. The differences of hip ROMs and muscle strengths between the dominant and non-dominant sides and between age groups were investigated. Correlations were calculated between the players ages and hip ROMs and muscle strengths. **Results:** No baseball player reported hip pain. The hip external rotation on the dominant side was smaller than that on the non-dominant side, whereas the hip internal rotation on the dominant side was greater than that on the non-dominant side. However, no significant difference was found between the dominant and non-dominant sides in terms of the hip muscle strength. Significant positive associations were found between the player's age and hip muscle strengths, whereas significant negative associations were found between the age and hip ROMs. **Conclusions:** Our data concerning the relationship between age and hip joint development could be useful for supporting strategies for the prevention and rehabilitation of throwing injuries; however, hip injuries might be rare among young baseball players.

Keywords: baseball; hip joint; hip pain; muscle strength; range of motion

INTRODUCTION

Pitching motions are accomplished through activation of the kinetic chain in which individual body parts, e.g., the lower extremity, pelvis, trunk, and upper extremity, are coordinated in their movements by muscle activity and body position to generate, summate, and transfer energy through the body into the arm.[1–3] In the pitching motion, the foot of the lead leg is planted to allow integral rotation of the hips, pelvis, and trunk, thereby providing increased speed and power in both hips after flexion through the kinetic chain.[3,4] Insufficient hip range of motion (ROM) or insufficient hip muscle strength may decrease the efficiency of energy transfer from the lower extremity and trunk to the upper extremity. Previous reports have indicated that early trunk rotation in the pitching motion predisposes a pitcher to throwing-related injury.[5] The hip joint is the primary joint that initiates trunk

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rotation.[6] It is important for baseball players to be aware of their hip joint condition and to understand the significance of hip ROMs and hip strengths in preventing throwing-related injuries. Several studies have demonstrated the relationship of sporting activities, such as football, hockey, rugby, and running, with the hip function of young athletes.[7–12] Loads of up to eight times the body weight on the hip joint are common in daily activities, such as jogging, and significantly greater forces than this are expected during competitive athletics.[13] However, few studies related to the onset status of hip injuries in young baseball players have been reported. The purposes of the present study were two-fold: (1) to assess differences in the ROMs and strengths of hip joints between the stance leg and the lead leg by age, and (2) to investigate the prevalence of hip joint complaints in young baseball players.

METHODS

Participants

The participants in this study were 315 members of regional junior baseball teams (mean age, 10.7 years; range 7–14 years). Medical check-ups were performed in February 2019 (preseason). Each participant completed a self-administered questionnaire that included items such as age, hand dominance, and the history of throwing-related hip joint pain sustained during the previous year. Players were excluded from the study if they had prior injury to, or had undergone surgery of, the hip joint. We defined the hip symptoms of the participants as conditions caused directly by throwing that resulted in absence from participation for at least 1 week. This study was approved by the Gunma University Hospital Clinical Research Review Board (Protocol Number: 1003). Written informed consent was obtained from all participants and their parents.

Anthropometric Measurements

Subjects' heights were measured using a digital height meter (A&D Corp., Tokyo, Japan), and body weights were measured using a multi-frequency segmental body composition analyzer (MC780U; Tanita Corp., Tokyo, Japan).

Testing Procedure

Hip joint ROMs were measured by three hip joint orthopedic surgeons, each with more than 10 years of experience. Participants were requested not to pitch within the 24-h period before the medical examination.[2] Physical examinations were conducted to assess the ROMs of both hips. For right-handed pitchers, the right hip joint was defined as the dominant side (stance leg side), and the left hip joint was defined as the non-dominant side (lead leg side). ROMs were measured with the participants prone on a table with hips adducted and the knees flexed to 90°. One examiner stabilized the pelvis and passively rotated the hip joint in IR and ER until an end feel was detected. Another examiner aligned the moveable arm of a goniometer along the tibial border and recorded the angle in degrees according to previously described methods.[14,15] Angles were measured in 0.1° increments using a digital goniometer with a bubble level (**Figure 1**)

A pilot test was conducted to evaluate the intra-tester reliability of the passive ROM measurements of the hip joint carried out in this study. Ten healthy men underwent measurement of passive ROMs of hip flexion, ER, and IR, with repeat measurements carried out 5 days later by the same examiner. The intraclass correlation coefficients were 0.96 for hip flexion, 0.86 for hip ER, and 0.98 for hip IR. To assess the interclass reliability, the same three ROM measurements in 10 healthy men were performed twice over a 2-week period by two independent hip joint orthopedic surgeons. The interclass correlation coefficients were 0.98 for hip flexion, 0.87 for hip ER, and 0.90 for hip IR.

Hip ER and IR muscle strengths were measured by a hip joint orthopedic surgeon with more than 10 years of experience. A handheld dynamometer (PowerTrack II Commander; JTECH Medical, Salt Lake City, UT, USA) was used for all strength measurements in this study.[16] For bilateral hip ER strength measurements, the participant was in the prone position with the hip in the neutral position and with 90° of flexion in the knee. The examiner applied resistance in a fixed position, and the subject being tested exerted maximum effort against the dynamometer and the examiner. The resistance against hip ER was applied 5 cm proximal to the proximal edge of the medial malleolus. For bilateral hip IR strength measurements, the resistance against hip IR was applied 5 cm proximal to the proximal edge of the lateral malleolus (**Figure 2**). The force required to resist the examiner for all hip-strength measurements was recorded in Newtons. Ten healthy men underwent hip ER and IR muscle strength measurements, and these were repeated 5 days later by the same examiner. The intraclass correlation coefficients were 0.87 for hip ER muscle strength and 0.85 for hip IR muscle strength. Next, ER and IR muscle strength measurements were performed in 10 healthy men twice over a 2-week period by two independent hip joint orthopedic surgeons. The interclass correlation coefficients were 0.92 for hip ER

Fig. 1. Measurement of the hip passive range of motion with the subject in the prone position.

muscle strength and 0.95 for hip IR muscle strength.

Statistical Analysis

We investigated the prevalence of hip joint complaints in the year before the medical checkup in 2019. Differences between the dominant and non-dominant hip joint ROMs and muscle strength were compared using a paired sample *t*-test or the Wilcoxon signed-rank test. We compared the hip ROMs and hip strengths of the dominant stance leg and the non-dominant lead leg by age. The Spearman rank correlation coefficient was used to elucidate the relationships between age and hip ROMs and hip strengths of the stance leg and the lead leg. Correlations were categorized as small (r=0.10–0.29), medium (r=0.30–0.49), or large (r=0.50–1.00).[17] All statistical analyses were performed using the IBM SPSS Statistics software package (version 26, IBM Japan, Tokyo, Japan). A P value of <0.05 was regarded as statistically significant.

RESULTS

Differences between the stance leg and the lead leg are shown in **Table 1**. The hip ER ROM of the stance leg was significantly smaller than that of lead leg, whereas the hip IR ROM of the stance leg was significantly greater than that of the lead leg. However, no differences were found between

Fig. 2. Measurement of the hip internal rotation strength with the subject in the prone position.

Table 1. Physical findings of the stance leg (dominant) and lead leg (non-dominant side) in all 315 participants

	Stance leg	Lead leg	P value
Hip ROM (degrees)			
Flexion	125.3 (10.1)	125.6 (12.0)	0.53
External rotation	58.6 (9.8)	61.0 (8.8)	<0.001 *
Internal rotation	58.3 (11.1)	56.9 (11.2)	0.006 *
Total rotation	117.0 (15.6)	117.9 (15.0)	0.15
Muscle strength (N)			
External rotation	15.8 (5.4)	15.6 (5.2)	0.31
Internal rotation	13.5 (4.5)	13.2 (4.7)	0.47

Mean values are shown with standard deviations in parentheses.
*Statistically significant: $P < 0.05$.

the stance leg and the lead leg for hip flexion ROM or the hip total rotation ROM (ER+IR). There were also no significant differences between the stance leg and the lead leg for hip ER and IR muscle strength. Differences in rotational ROMs for each leg are presented in **Table 2**. A significant difference was found in the lead leg between ER and IR, whereas no such difference was found in the stance leg. **Tables 3 and 4** show the means (with standard deviations) of the ROMs and hip strengths of the stance leg and the lead leg by age group. Hip rotational ROMs decreased with age, whereas hip ER and IR muscle strengths increased with age. The associations between age and hip joint ROMs and hip

Table 2. Comparison of hip rotational ROM and strength between ER and IR

	ER	IR	P value
ROM (degrees)			
Stance leg	58.6 (9.8)	58.3 (11.1)	0.94
Lead leg	61.0 (8.8)	56.9 (11.2)	<0.001 *
Strength (N)			
Stance leg	15.8 (5.4)	13.5 (4.5)	<0.001 *
Lead leg	15.6 (5.2)	13.2 (4.7)	<0.001 *

Mean values are shown with standard deviations in parentheses.
*Statistically significant: P < 0.05.

Table 3. Hip ROM of participants according to age cluster

Age (years)	n	ROM (degree)							
		Flexion		External rotation		Internal rotation		Total rotation	
		Stance leg	Lead leg	Stance leg	Lead leg	Stance leg	Lead leg	Stance leg	Lead leg
7	7	134.5 (9.6)	135.2 (7.9)	64.0 (12.0)	57.1 (6.7)	68.6 (8.2)	43.5 (4.9)	132.6 (19.0)	100.6 (6.9)
8	15	129.7 (6.4)	128.8 (6.0)	62.8 (10.6)	56.2 (6.1)	64.4 (12.0)	51.7 (12.2)	127.3 (14.1)	107.9 (11.7)
9	34	127.6 (9.3)	127.6 (11.1)	61.8 (7.1)	59.4 (7.5)	64.2 (8.8)	52.0 (11.1)	126.1 (12.4)	111.5 (11.9)
10	89	126.8 (8.8)	127.9 (8.2)	58.2 (9.9)	60.5 (8.7)	59.3 (9.5)	55.6 (9.4)	117.5 (12.8)	116.2 (12.7)
11	85	125.4 (9.7)	125.9 (9.4)	58.3 (9.0)	62.0 (9.8)	56.4 (12.3)[c]	57.4 (11.8)[a]	114.6 (15.2)[c]	119.3 (17.5)[a]
12	40	123.5 (11.7)	121.1 (21.8)	57.6 (12.9)	64.7 (7.8)[b]	56.1 (10.5)[c]	64.3 (8.2) [a,b,c,d,e]	113.6 (19.2)[c]	128.9 (10.7) [a,b,c,d,e]
13	32	118.4 (10.9) [a,b,c,d,e]	119.2 (10.7) [a,d]	56.4 (8.5)	58.9 (8.8)	55.2 (9.7)[c]	60.0 (10.8)[a]	111.6 (13.8)[a,b,c]	118..9 (12.3)
14	13	121.9 (10.2)	124.2 (9.7)	57.4 (9.5)	63.4 (8.7)	51.7 (11.5) [a,b,c]	58.2 (13.8)	109.2 (17.2)[a,b,c]	121.6 (18.6)[a]

[a] Significantly different (P< 0.05) from the 7-year-old group.
[b] Significantly different (P< 0.05) from the 8-year-old group.
[c] Significantly different (P< 0.05) from the 9-year-old group.
[d] Significantly different (P< 0.05) from the 10-year-old group.
[e] Significantly different (P< 0.05) from the 11-year-old group.

muscle strengths for the stance leg and the lead leg for all participants are shown in **Table 5**. Age was found to have significant large positive correlations with both hip ER and IR muscle strengths for both stance and lead legs. Moreover, significant medium or small negative correlations with age were found for bilateral hip joint ROMs. Significant bilateral negative associations or trends were found between most hip ROMs and most hip muscle strengths (**Table 6**). None of the subjects had a history of injury or surgery to the hip joint before the medical checkup, and no participant had hip pain during the interview period.

DISCUSSION

One of the distinguishing characteristics of our results is that the youth baseball players displayed greater IR ROM in the stance leg, but greater ER ROM in the lead leg. The results of the current study were consistent with those of earlier reports that examined hip ROM.[18] An earlier study demonstrated that adequate stance leg IR and lead leg ER allowed appropriate pelvis and trunk orientation on lead foot contact during the throwing motion.[19] It is essential to correctly position the foot at foot contact to optimize the shoulder ER in the kinetic chain during the throwing motion.[20] Furthermore, Kageyama et al. demonstrated that the hip internal rotational torque of the stance leg played an important role in generating a greater moment from the

Table 4. Rotational hip strength of participants according to age cluster

Age (years)	n	Muscle strength (N): External rotation, Stance leg	Muscle strength (N): External rotation, Lead leg	Muscle strength (N): Internal rotation, Stance leg	Muscle strength (N): Internal rotation, Lead leg
7	7	9.1 (1.8)	9.4 (1.3)	8.5 (1.7)	8.3 (0.8)
8	15	12.0 (3.5)	11.7 (2.5)	10.9 (3.6)	9.7 (2.4)
9	34	13.3 (3.3)	13.3 (3.4)	11.2 (3.5)	10.6 (2.8)
10	89	13.8 (2.9)	13.5 (2.8)	11.5 (2.9)	11.6 (3.1)
11	85	15.6 (4.1)[a]	15.7 (3.9)[a,b,d]	13.6 (3.3)[a,c,d]	13.8 (3.3)[a,b,c,d]
12	40	16.8 (4.7)[a,b,c,d,e]	16.8 (4.8)[a,b,c,d]	13.9 (4.0)[a,d]	14.7 (4.3)[a,b,c,d]
13	32	22.0 (6.9)[a,b,c,d,e,f]	20.9 (4.9)[a,b,c,d,e,f]	18.0 (4.4)[a,b,c,d,e,f]	16.8 (3.5)[a,b,c,d,e]
14	13	26.0 (8.6)[a,b,c,d,e,f]	26.2 (9.0)[a,b,c,d,e,f,g]	20.6 (7.6)[a,b,c,d,e,f]	19.9 (7.0)[a,b,c,d,e,f]

[a] Significantly different (P< 0.05) from the 7-year-old group.
[b] Significantly different (P< 0.05) from the 8-year-old group.
[c] Significantly different (P< 0.05) from the 9-year-old group.
[d] Significantly different (P< 0.05) from the 10-year-old group.
[e] Significantly different (P< 0.05) from the 11-year-old group.
[f] Significantly different (P< 0.05) from the 12-year-old group.
[g] Significantly different (P< 0.05) from the 13-year-old group.

Table 5. Correlation coefficients between age and hip joint ROMs and hip joint muscle strengths

Variable	ROM: Flexion, Stance leg	ROM: Flexion, Lead leg	ROM: External rotation, Stance leg	ROM: External rotation, Lead leg	ROM: Internal rotation, Stance leg	ROM: Internal rotation, Lead leg	Muscle strength: External rotation, Stance leg	Muscle strength: External rotation, Lead leg	Muscle strength: Internal rotation, Stance leg	Muscle strength: Internal rotation, Lead leg
Age	−0.29 **	−0.25 **	−0.15 **	−0.12 **	−0.30 **	−0.31 **	0.51 **	0.54 **	0.48 **	0.56 **

**Statistically significant P <0.01.

Table 6. Correlation coefficients between hip joint ROMs and hip joint muscle strengths

Variable	ROM: Flexion, Stance leg	ROM: Flexion, Lead leg	ROM: External rotation, Stance leg	ROM: External rotation, Lead leg	ROM: Internal rotation, Stance leg	ROM: Internal rotation, Lead leg
Muscle strength						
External rotation						
Stance leg	−0.41 **	−0.37 **	−0.21 **	−0.14 **	−0.22 **	−0.28
Lead leg	−0.39 **	−0.35 **	−0.18 **	−0.07	−0.15 **	−0.24
Internal rotation						
Stance leg	−0.36 **	−0.36 **	−0.32 **	−0.19 **	−0.11	−0.23
Lead leg	−0.37 **	−0.33 **	−0.26 **	−0.19 **	−0.14 **	−0.17

**Statistically significant P <0.01.

cocking phase to the acceleration phase.[21)] Inefficient stance leg IR may result in limiting the available energy transfer to the trunk and upper extremity in the pitching motion. Earlier studies demonstrated a significant relationship between limitations of the hip IR ROM of the stance leg at 90° of flexion (with the subject in the supine position) and shoulder/elbow injuries in young baseball players.[22,23)] Moreover, Oi et al. demonstrated that early pelvic rotation was correlated with decreased hip flexion of the stance leg and increased hip flexion of the lead leg from the cocking phase to the acceleration phase in young baseball players.[24)] These results suggested that decreased hip IR ROM of the stance leg at 90° of flexion could lead to insufficient trunk rotation and breakdown of the kinetic chain of the throwing cycle, which could result in elbow and shoulder pain. In our study, negative correlations were found between age and hip ROMs of the stance leg measured in the prone position. It would be beneficial for coaches and parents to understand the way in which hip ROMs change with age.

One important finding of the current study was that the hip ER strength was greater than the hip IR strength in both legs, and no significant difference was found between the stance leg and the lead leg in hip rotational muscle strengths. Picha et al. investigated the hip rotational muscle strength in youth baseball players aged 7–18 years.[15] They found that the stance leg was stronger than the lead leg only in internal rotation and suggested that strengthening the external rotators also may be beneficial for young baseball players. This is because a stronger stance leg is needed to provide a base of support for the rest of the body throughout the throwing motion. Our results were inconsistent with those of Picha et al. in that we found no significant differences of hip rotational strength between the stance leg and the lead leg. Differences in the methods of muscle strength measurement and the ages of the participants could explain these results. However, Picha et al. found that younger baseball players (7–11 years old) had greater hip ROMs and lower hip muscle strengths than older baseball players (12–18 years old). In our study, significant positive associations were found between age and hip muscle strengths, and negative associations were found between age and hip ROMs. From these findings of hip ROM and strength patterns during maturation, it is suggested that baseball training might beneficially be accompanied by flexibility exercises as the players grow. Another distinguishing characteristic of our study was the fact that no young baseball player had hip joint complaints during the study period. The function of the hip joint is essential for athletes who perform sports activities involving running, jumping, or kicking. In baseball, base running is an indispensable activity, and dash-running programs are adopted as part of daily practice. Furthermore, in batting, a player first leads with a step to transfer rotational power through the lower extremity into the trunk and finally into the upper extremities with maximal swing velocity through activation of the kinetic chain.[25] Repetitive throwing or batting in baseball players with upstream kinetic chain deficits may lead to increased stress and dynamic overload of the pelvic girdle, which may lead to injuries of the hip and groin. Coleman et al. reported the most recent updates on the epidemiology of baseball injuries from 2011–2014 in Major League Baseball (MLB) and Minor League Baseball (*MiLB*) players. During this period, approximately 5.5% of injuries among MLB and MiLB players involved the hip and/or groin, and 96% of these injuries were extraarticular, e.g., core muscle injuries.[26] Coleman's results were not consist with ours. Differences in the ages and baseball level of the study subjects may have influenced the results of these studies. Rossi et al. reported that there was no baseball player with avulsion fractures of the pelvic apophyses among 198 adolescent athletes over a 22-year period.[27] This result may support our finding that no players had a history of hip joint problems. However, younger baseball players with skeletal immaturity may suffer apophyseal pelvic avulsion fractures around the hip joint. Further studies are required that focus on the hip injuries of skeletally immature baseball players.

The current study has several limitations. First, the study design was cross-sectional. A longitudinal study should be conducted to investigate the development of hip joint ROMs and hip muscle strengths in individual young baseball players over time. Second, the data relating to hip joints problems were influenced by each participant's recall bias. Third, only hip flexion ROM and rotational ROMs and muscle strengths were measured. Additional ROMs and muscle strengths may be of interest based on the movements demanded in baseball playing. Fourth, we could not assess the hip joint condition in young baseball players with hip joint complaints. Fifth, the definition of a participant with hip symptoms was a condition caused directly by throwing that resulted in the loss of participation for at least 1 week. However, this definition of hip symptoms may be controversial. Sixth, we did not analyze the relationship between the hip joint condition and several risk factors of throwing-related injury, such as pitching mechanics, the number of pitches per game or day, innings pitched per season, games per year, pitch type, and pitch velocity, that have been described in earlier studies.[28,29,30,31] Lastly, we could not assess the association between the hip and trunk rotation motion and the hip rotational muscle strength that we measured. Further studies should be conducted to investigate the relation between hip joint complaints and hip joint conditions and the environmental factors of playing baseball. Such studies are necessary to elucidate the role of hip rotational muscle strength for young baseball players.

CONCLUSION

We investigated the prevalence of hip joint complaints in young baseball players during their growth period. There were no hip joint complaints during the period of our investigation. This study provides reference values for hip joint ROMs and hip joint rotational muscle strengths by age group in young baseball players aged 7–14 years without hip pain.

These results may serve as comparative data for young baseball players with hip injury.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

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