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Original Article

Correlation of Shoulder and Elbow Injuries with Muscle Tightness, Core Stability, and Balance by Longitudinal Measurements in Junior High School Baseball Players

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Abstract. [Purpose] The present study longitudinally investigated injury occurrences and the risk factors for muscle tightness, core stability, and dynamic standing balance among junior high school student baseball players. [Subjects] Thirty-nine male students, belonging to baseball clubs at 2 junior high schools, participated in this study. [Methods] Study measurements were obtained twice, once in the early stage of the baseball season (March) and once at the end of the season (July). All subjects underwent muscle tightness testing, the Star Excursion Balance Test (SEBT), and trunk endurance testing during each measurement session. [Results] Fifteen players experienced episodes of elbow or shoulder pain while throwing. Players in the pain group demonstrated a significant increase in the tightness of their shoulder internal rotators, axis-leg quadriceps, and axis-leg hamstrings. There was no clear evidence of differences of changes in core stability and dynamic standing balance between the groups. [Conclusion] The results of this study suggest that lower extremity muscle tightness early in a season and the subsequent decline in the flexibility of the axis-leg quadriceps and hamstrings during the season may be due to an increased upper extremity load while throwing, thus producing shoulder and elbow pain.
Key words: Injury prevention, Flexibility, Growth phase

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INTRODUCTION

Baseball is one of the safest sports available for today's youth, with an estimated 4–6 million Japanese people involved in this sport. However, many of the serious injuries observed in adult baseball pitchers may have begun to develop when they are youths[1)]. Older and shorter players, as well as those who lift weights, pitch with a fatigued arm, and throw a large number of pitches in a season, are associated with an increased incidence of elbow and shoulder pain[2, 3)]. The importance of muscular strength and flexibility of the shoulder and lower extremity has been described for them[4–8)]. In addition, elbow and shoulder injuries are associated with bodily features such as relative muscle tightness and bony vulnerability during growth phases. However, few longitudinal studies have investigated young baseball players throughout growth phases. The present study longitudinally investigated injury occurrences and the risk factors of muscle tightness, core stability, and dynamic standing balance among junior high school student baseball players. Determining these factors may help to prevent injuries among youth players.

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SUBJECTS AND METHODS

Thirty-nine male students belonging to baseball clubs at 2 junior high schools participated in this study. Study measurements were obtained twice, once in the early stage of the baseball season (March) and once at the end of the season (July). All subjects underwent muscle tightness testing, the Star Excursion Balance Test (SEBT), and trunk endurance testing during each measurement session. Five subjects were lost to follow-up because of fractures, ankle sprains, and medical diseases. Subjects were included in a pain group if they developed shoulder or elbow injuries, indicated by episodes of elbow or shoulder pain while throwing, between early and end of the season measurements. Similarly, those who did not develop an injury during the season were included in the non-pain group. The non-pain group included players who sustained a slight external wound, such as a blow to the body; players who sustained leg or back injuries/pain were excluded from the study. Before enrollment in the study, the subjects provided written informed consent. The study conformed to the Declaration of Helsinki and was approved by the Gunma University (Japan) Ethics Committee.

Muscle tightness was measured according to the method described by Tolii[9] by measuring the angle of each joint connected to the bilateral iliopsoas, quadriceps, hamstring, and gastrocnemius muscles. Additionally, the tightness of the bilateral hip external rotator and internal rotator muscles was measured in the supine position, with the hip flexed at 90 degrees. The tightness of the shoulder external and internal rotator muscles was measured in the supine position with shoulder abduction at 90 degrees (Fig. 1).

We chose to examine the SEBT in the anterior, posterior, lateral, and medial directions, according to the recommendations of Hertel[10]. Errors were recorded if the subject's hands did not remain on his hips, the position of the stance foot was not maintained, the heel did not remain in contact with the floor, or the subject lost his balance during the trial. The participants completed 3 test trials in each of the 4 directions. Leg length was used to normalize the excursion distances by dividing the distance reached by the leg length and then multiplying by 100[11]. Leg length was measured from the anterior superior iliac spine to the distal tip of the medial malleolus using a standard tape measure while the participants lay in a supine position. In this study, we classified one leg as the axis leg and the contralateral leg as the step leg, depending on the player's stance while pitching.

During the trunk endurance test, we conducted the prone bridge test[12] and the side bridge test[13]. In the prone bridge test, each subject began in the prone position and was propped up on his elbows. The elbows were spaced shoulder-width apart, and the feet were set close together, but not touching. The subject then raised his pelvis from the floor so that only the forearms and the toes were in contact with the floor. The shoulders, hips, and ankles were maintained in a straight line until fatigue or pain prevented maintenance of the test position[12]. In the side bridge test, the subjects assumed a sideways plank position with one elbow under the shoulder and the upper arm perpendicular to the floor[13, 14]. The top foot was placed on the lower foot, and the subjects were instructed to support themselves with their hips lifted off the floor while maintaining the body in a straight line, supporting themselves on only one elbow and their feet[13, 14]. This position was maintained for as long as possible.

The Wilcoxon signed-rank test was performed for each test item and each group for intragroup comparisons of early and late season measurements. A Mann-Whitney test was performed for intergroup comparisons of early and late season measurements. Statistical analyses were performed using SPSS version 20 for Windows (IBM Corp., Armonk, NY, USA). A $p < 0.05$ was considered statistically significant for all analyses.

RESULTS

Among the 39 participants, 15 experienced episodes of elbow or shoulder pain while throwing (pain group) (mean age, 13.5 ± 0.5 years; height, 162.3 ± 7.4 cm; weight, 55.4 ± 10.8 kg). Of the 15 patients in the pain group, three had shoulder pain, eight had elbow pain, and four had both elbow and shoulder pain. The 16 subjects who never experienced elbow or shoulder pain were included in the non-pain group (mean age, 13.3 ± 0.4 years; height, 155.9 ± 6.3 cm; weight, 46.2 ± 6.5 kg).

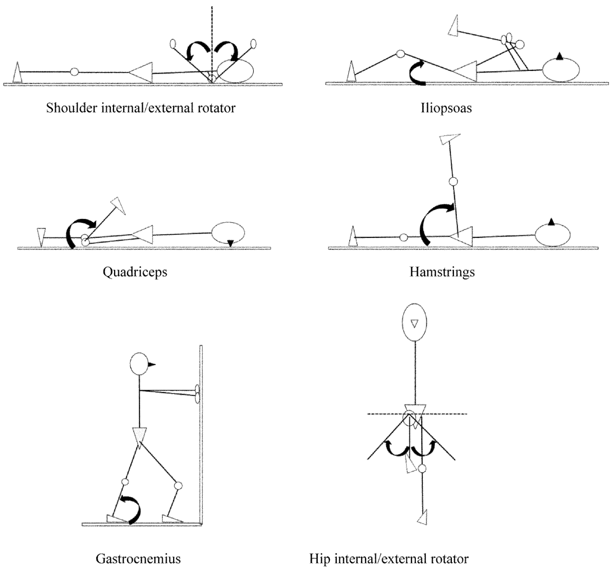

Fig. 1. Diagrammatic representation of the tightness test measurements

The muscle tightness measurements for both groups are shown in Tables 1 and 2. Compared with the non-pain group, players in the pain group demonstrated a significant increase in the tightness of their shoulder internal rotators, axis-leg quadriceps, and axis-leg hamstrings. At the early season measurement, the players in the pain group had significantly increased tightness in the hip external rotator of the step leg and in the quadriceps of the axis leg than those in the non-pain group. The end-of-season SEBT measurements demonstrated significant increases, compared with early season measurements for both groups. In addition, in the early stage of the season, the pain group demonstrated significantly higher values for the posterior direction of the step-leg stance and medial direction of the axis-leg stance compared with the non-pain group (Table 3). Table 4 shows the results of the bridge tests for both groups. No significant differences were seen in either the intragroup comparisons or intergroup comparisons.

DISCUSSION

In this longitudinal investigation, the subjects who experienced episodes of elbow or shoulder pain while pitching also demonstrated significant increases in tightness of the shoulder internal rotator, quadriceps tightness in the axis leg, and hamstrings tightness in the axis leg during the season. Reinoid et al.[4] reported significant decreases in shoulder internal rotation range of motion (ROM) after pitching. In addition, Tippett[8] reported that significant increases were observed in the hip internal rotation and extension ROM of the axis leg compared with the step leg. In their studies[4, 8], professional and college baseball player participated. In the current study, the participating baseball

Table 1. Muscle tightness test results for the non-pain group

Variable		Early in the season	End of the season	
Shoulder internal rotation (degrees)	Dominant side	58.9 ± 12.5	58.7 ± 13.8	
Shoulder external rotation (degrees)	Dominant side	108.7 ± 8.2	105.7 ± 7.0	
Hip internal rotation (degrees)	Axis leg	50.0 ± 10.5	40.9 ± 7.8	**
	Step leg	53.9 ± 12.2	43.3 ± 10.3	**
Hip external rotation (degrees)	Axis leg	62.8 ± 10.8	55.2 ± 11.1	**
	Step leg	60.9 ± 8.3	50.8 ± 11.6	**
Quadriceps tightness (degrees)	Axis leg	150.4 ± 5.0	150.1 ± 4.0	
	Step leg	152.3 ± 4.2	151.9 ± 5.2	
Hamstring tightness (degrees)	Axis leg	72.7 ± 4.4	68.2 ± 12.1	
	Step leg	74.1 ± 4.3	68.8 ± 11.8	*
Iliopsoas tightness (degrees)	Axis leg	8.3 ± 3.4	8.1 ± 2.9	
	Step leg	8.1 ± 3.8	9.1 ± 2.5	
Gastrocnemius tightness (degrees)	Axis leg	53.0 ± 5.9	50.1 ± 6.2	*
	Step leg	52.1 ± 6.3	51.3 ± 7.2	

Date are expressed as mean ± SD. *: $p < 0.05$, **: $p < 0.01$

Table 2. Muscle tightness results for the pain group

Variable		Early in the season	End of the season	
Shoulder internal rotation (degrees)	Dominant side	71.1 ± 16.3	65.7 ± 16.6	
Shoulder external rotation (degrees)	Dominant side	104.5 ± 8.2	100.4 ± 8.9	*
Hip internal rotation (degrees)	Axis leg	44.1 ± 11.9	37.5 ± 7.6	*
	Step leg	43.9 ± 11.8	40.9 ± 8.4	
Hip external rotation (degrees)	Axis leg	64.4 ± 9.5	56.5 ± 9.7	**
	Step leg	62.7 ± 6.7	50.6 ± 12.4	**
Quadriceps tightness (degrees)	Axis leg	147.3 ± 7.6	144.3 ± 9.5	*
	Step leg	146.7 ± 7.4	146.6 ± 9.0	
Hamstring tightness (degrees)	Axis leg	74.7 ± 8.3	68.3 ± 9.2	*
	Step leg	74.0 ± 9.3	68.1 ± 8.6	*
Iliopsoas tightness (degrees)	Axis leg	7.5 ± 2.0	8.6 ± 2.3	
	Step leg	6.8 ± 3.0	7.7 ± 1.4	
Gastrocnemius tightness (degrees)	Axis leg	51.9 ± 9.4	51.0 ± 6.7	
	Step leg	51.1 ± 8.6	52.5 ± 5.6	

Date are expressed as mean ± SD. *: $p < 0.05$, **: $p < 0.01$

Table 3. Star excursion balance test results

	Non-pain group			Pain group		
Variable	Early in the season	End of the season		Early in the season	End of the season	
Step-leg stance						
Anterior direction (%)	87.1 ± 5.0	92.0 ± 5.7	**	88.3 ± 6.8	92.0 ± 8.7	**
Posterior direction (%)	76.3 ± 5.8	87.7 ± 6.2	**	81.1 ± 5.7	91.1 ± 6.9	**
Lateral direction (%)	84.3 ± 5.8	91.9 ± 5.1	**	87.4 ± 5.6	93.6 ± 6.4	**
Medial direction (%)	66.8 ± 8.2	74.7 ± 9.1	**	73.2 ± 7.6	81.2 ± 9.2	**
Axis-leg stance						
Anterior direction (%)	86.5 ± 5.8	90.0 ± 4.5	*	88.1 ± 6.0	92.0 ± 7.5	**
Posterior direction (%)	75.2 ± 7.6	86.2 ± 6.3	**	79.4 ± 6.4	88.7 ± 7.1	**
Lateral direction (%)	83.5 ± 6.0	89.7 ± 5.1	**	86.6 ± 4.1	93.3 ± 5.9	**
Medial direction (%)	67.2 ± 7.5	76.1 ± 9.6	**	74.8 ± 5.2	81.7 ± 6.5	**

Date are expressed as mean ± SD. *: $p < 0.05$, **: $p < 0.01$

Table 4. Trunk endurance test results

Variable	Non-pain group		Pain group	
	Early in the season	End of the season	Early in the season	End of the season
Prone bridge (s)	98.1 ± 27.8	94.9 ± 28.2	92.2 ± 26.2	82.8 ± 22.0
Side bridge (s)				
Dominant side (s)	86.6 ± 28.5	80.9 ± 26.1	71.0 ± 31.1	73.2 ± 25.1
Nondominant side (s)	83.5 ± 26.4	80.8 ± 21.3	77.5 ± 21.1	71.0 ± 26.0

Date are expressed as mean ± SD.

players were still in a growth phase. Therefore, the changes in the flexibility of the lower extremities and shoulders of the pain group athletes may have been different from those observed in the older players in the previous studies. During the throwing motion, the body weight may remain on the axis leg or the trunk rotation and hip extension and rotation may increase the load on the lower extremity, causing muscle flexibility to decrease. Moreover, the pain group already demonstrated significantly greater tightness of the hip external rotator of the step leg and of the quadriceps of the axis leg during the early stage of the season compared with the non-pain group. Tightness in these muscles has been reported to be associated with an increased risk of upper extremity injury[15]. Therefore, the results of this study suggest that lower extremity muscle tightness early in a season and the subsequent decline in the flexibility of the axis-leg quadriceps and hamstrings during the season may be due to an increased upper extremity load while throwing, resulting in shoulder and elbow pain.

Core stability is important for both high performance and injury prevention. Bouisset[16] proposed that pelvic and trunk stabilization is necessary for extremity movement. The necessity of this stability is also part of the upper extremity rehabilitation for injured baseball players[17]. Moreover, the relationship between balance and sports injury risk has been established in many reports, but the relationship between balance and upper extremity injury occurrence is less clear. A baseball player needs to produce sufficient energy and momentum throughout the entire kinetic chain to quickly throw a ball to its proper destination. In this study, we tested the hypothesis that subjects with good core stability and dynamic standing balance have a reduced risk of upper extremity injury. However, the results indicated that there was no clear evidence of differences of changes in core stability and dynamic standing balance between the groups over the course of a season. On examination of the average values for the core stability test, the pain group showed a lower value in both bridge tests, suggesting that the correlation between core stability and occurrence of upper extremity injuries needs to be more fully considered.

In the SEBT, during the early season measurements, the pain group demonstrated significantly higher values in the posterior direction of the step-leg stance and in the medial direction of the axis-leg stance than did the non-pain group athletes. Thus, the pain group may have had better dynamic standing balance than did the non-pain group. In this regard, the SEBT reach distance was correlated with hip ROM and strength[18, 19]. Although this study did not involve specific measurements of muscular strength, muscular strength of the hip may have been higher in the pain group than in the non-pain group. Thus, the added muscular strength of the hips may have generated greater upper extremity power during throwing. However, these opinions are only speculative.

The limitations of this study include testing of core stability using an endurance test. Furthermore, we examined the anterior, posterior, lateral, and medial directions in the SEBT. Very quick movements are required for baseball players, suggesting the need for an evaluation that focuses on dynamic core stability. Moreover, consideration of the reach in the anteromedial, anterolateral, posteromedial, and posterolateral directions may be necessary in the balance test. In the future, a longer-term investigation is also required.

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