Physeal changes and range-of-motion differences in the dominant shoulders of skeletally immature baseball players

Scott D. Mair, MD, a Tim L. Uhl, PhD, ATC, PT, b Rudy G. Robbe, MD, c and Kathleen A. Brindle, MD, d Lexington, KY, Washington, DC

The purpose of this study was to document range-of-motion differences and radiographic changes in the dominant shoulder of skeletally immature throwers and to determine how pain associated with throwing may relate to these changes. Seventy-nine male youth baseball players (aged 8-15 years) completed a questionnaire, a shoulder examination, and a series of radiographs to determine physeal changes and humeral retroversion. Radiographs were reviewed and interpreted by a blinded musculoskeletal radiologist. Measurement of proximal humeral physeal width revealed a significant increase on the dominant side for the entire group, in subjects with a history of symptoms during the current season, and in subjects who had never had symptoms. Visual radiographic changes were commonly found in subjects with a history of pain (16/26 [62%]) as well as in those subjects without symptoms (29/53 [55%]). Subjects had increased external rotation of the dominant arm as compared with the nondominant arm, and this pattern increased in magnitude as the throwers aged. Range-of-motion and radiographic asymmetry of the shoulders is common, is often asymptomatic, and may represent adaptive changes in this population. (J Shoulder Elbow Surg 2004;13:487–491.)

Several studies suggest that anatomic changes probably occur in skeletally immature throwers as a result of the repetitive throwing motion and that these changes impact concurrent and subsequent shoulder pathology.1,6,9,10,14,21 Proximal humeral physeal changes associated with shoulder pain in young throwers have been documented in the literature.1,6,9 Dotter9 described a "fracture through the epiphyseal cartilage of the proximal humerus" and coined the term Little Leaguer’s shoulder to describe these radiographic findings and shoulder pain associated with the act of throwing in a skeletally immature athlete. Subsequent authors similarly have reported on symptomatic young baseball players with abnormal radiographic findings at the proximal humerus with various visual descriptions such as demineralization, epiphysiolysis, and physeal widening.1,3,6,21

Previous reports of these humeral physeal changes have been noted in symptomatic throwers. Torg et al20 obtained shoulder and elbow radiographs on 44 youth baseball players (aged 9-18 years). In the shoulders, no radiographic abnormalities considered to be significant were reported. However, in a series of 23 patients diagnosed with Little League shoulder, Carson and Gasser6 noted continued widening of the proximal humeral physis in several athletes after symptoms had resolved. It is unclear whether physeal changes always produce symptoms. It is possible that radiographic changes are common in throwers and may even be adaptations to the act of throwing.

It has been well documented that adult throwing athletes generally have increased external rotation in the dominant shoulder, as compared with the nondominant side. The prevailing theory had been that this was a result of stresses placed on the anterior capsuloligamentous structures, leading to increased anterior laxity with a subsequent increase in the amount of external rotation that could be achieved.4,5,11,14 Recently, several studies have indicated that throwers have increased retroversion of the proximal humerus in the dominant arm.8,15-17 It is now postulated that this bony alteration may be the most important factor in the increased external rotation commonly seen in throwers. Numerous authors have postulated that this is an adaptation that occurs in the proximal humerus when the physis is open and may be protective against shoulder injury.10,15-17 The purpose of our study was to document radiographic findings and range-of-motion measurements in the throwing shoulder of Little League baseball players with an open proximal humeral physis. A
determination was made on the incidence of radiographic changes as compared with the nondominant shoulder and the degree to which radiographic changes resulted in symptoms. An attempt was also made to study whether changes in retroversion occur in young throwers and how these changes relate to range of motion.

MATERIALS AND METHODS

Male volunteers, aged 8 to 15 years, were recruited from local youth baseball leagues. A total of 79 volunteers agreed to participate (mean height, 158 ± 15 cm; mean weight, 51 ± 16 kg). The goals and components of the study were explained to all subjects and their parents. The parents and subjects signed an informed consent form approved by the University of Kentucky Institutional Review Board. Boys were excluded from this study if they had a past history of humeral or scapular fracture or previous shoulder or elbow dislocation. All subjects were actively involved in youth baseball during the testing.

Each subject filled out a written questionnaire with a parent or legal guardian regarding demographic information, shoulder symptoms, and throwing history. Shoulder range of motion was then measured in each subject by a single investigator. The participant was placed in the supine position with the arm abducted 90° and the elbow flexed to 90° and actively rotated the shoulder into maximal internal and external rotation twice. The average of two trials was recorded for statistical analysis. A Tracker electrical inclinometer (JTech Medical Industries, Salt Lake City, UT) was used for all range-of-motion measurements. This method of measuring range of motion was found to be reliable (internal rotation ICC [intraclass correlation coefficient]2,1 = 0.91 and external rotation ICC2,1 = 0.93).

Strength was measured with a Power Track II handheld dynamometer (JTech Medical Industries). The subject remained in the same position as above with the arm abducted and elbow flexed to 90° while maintaining the arm in neutral rotation. The subject performed two maximal isometric contractions of both internal and external rotation. The average of two trials was recorded for statistical analysis. This method of testing was found to be reliable (internal rotation ICC2,1 = 0.96 and external rotation ICC2,1 = 0.93).

In all subjects, 6 plain radiographs were obtained for evaluation of subjective physeal changes, physeal width, and humeral retroversion. A certified radiology technologist obtained the 3 radiographs on each shoulder. A single lead vest was placed from the thyroid to genitalia to shield the boy from radiation exposure. The standard shoulder antero-posterior view in external rotation was obtained with the arm externally rotated 40°. The standard shoulder antero-posterior view in internal rotation was obtained at 60° of internal rotation. The final radiograph (semiaxial view) was obtained with the arm forward flexed to 90° and horizontally abducted 15° (Figure 1). This position was maintained during radiograph exposure by a specially designed jig. A single musculoskeletal radiologist made all radiologic measurements and determinations. The radiologist was blinded as to whether the subjects were right or left shoulder dominant and made visual predictions as to which shoulder was the dominant side. This visual determination was based on previously described criteria such as physeal widening, sclerosis, demineralization, and fragmentation. The radiologist objectively measured physeal width on both antero-posterior radiographs and humeral retroversion from the semiaxial view. Measurements were performed with a magnifying glass and precision dial calipers. The physis was measured at the lateral cortex on each view. The intrarater reliability of the measured physeal width and retroversion is reported (Table I). Because of the low reliability of retroversion measurements, no statistical comparisons were made with the use of these values. The low reliability obtained with this view may be attributed to underdeveloped bony landmarks in this age group, the subjective nature of determining the epicondylar and head-neck axis, and/or problems with reproducibility of shoulder position despite the jig.

RESULTS

The age distribution of the 79 subjects is summarized in Table II. Survey results revealed that the boys started playing organized baseball at a mean age of 4.9 ± 1.1 years. They reported that they practiced or participated in baseball for a mean of 7.7 ± 2.5 months per year. During a typical week, players...
averaged 6.1 ± 2.4 hours of practice with their team and an additional 2.2 ± 1.6 hours outside of organized practice. They participated in 2.3 ± 0.9 games per week, lasting approximately 2.7 hours each.

Three types of pain were determined from the questionnaire: group 1 (ever had pain in the throwing shoulder), 26 of 79 subjects (33%), group 2 (shoulder pain or acting after throwing during the current season), 13 of 79 (16%), and group 3 (current shoulder symptoms related to throwing), 7 of 79 (9%).

The musculoskeletal radiologist evaluated 79 sets of radiographs. In 33 cases she could not make a determination of shoulder dominance from visual radiographic observations. In 45 cases the dominant shoulder was determined correctly by visual radiographic observation. In one case the radiologist incorrectly labeled the dominant shoulder. Direct measurements of physeal width in all subjects are summarized in Table II. In the entire group, dominant physeal width was significantly greater than nondominant physeal width by use of a paired t test ($P = .003$).

Comparisons were made between the radiologist’s ability to predict arm dominance with the three pain groups by use of $\chi^2$ analysis. The ability of the radiologist to predict arm dominance was not significantly influenced by subjective complaints of pain, as defined in any of the three pain groups. Objective measurements of mean physeal width (on external rotation and internal rotation views) were also analyzed with respect to complaints of pain, by use of a 1-way analysis of variance. Subjects reporting pain in group 2 were found to have a greater mean physeal width than those without symptoms ($P < .05$). No significant difference was found with respect to symptoms of group 1 ($P = .32$) and group 3 ($P = .16$).

The majority of subjects (16/26 [62%]) who reported some history of pain (group 1) did demonstrate visual changes allowing the radiologist to predict arm dominance. However, a similar number of asymptomatic throwers (29/53 [55%]) demonstrated the same findings. When only those throwers who had never had symptoms were examined, objectively measured mean physeal width remained significantly greater in the dominant arm compared with the non-dominant arm ($P = .004$).

Each subject was asked to estimate the number of throws they made during a typical practice and game on a 5-point Likert-type scale (Table IV). An estimated volume of throwing (number of throws per week) was correlated with pain groups, age, strength, and physeal widths. Moderate correlations were found between volume of throwing and age of subjects ($r = 0.41$, $P = .000$) and dominant arm internal rotation strength ($r = 0.31$, $P = .005$).

A side-to-side comparison revealed a mean increase in external rotation of $6° ± 9°$ on the dominant side ($P = .000$). A mean decrease of $2° ± 4°$ was noted in internal rotation on the dominant side ($P = .01$). Pearson correlation revealed that the side-to-side difference in external rotation increased with age ($r = 0.26$, $P = .019$) whereas internal rotation difference did not significantly correlate with age ($r = 0.1$, $P = .35$). There was a trend toward increased external rotation difference when compared with number of years playing baseball ($r = 0.22$, $P = .056$). No correlation was noted with respect to external rotation or internal rotation differences compared with the presence of shoulder symptoms in any of the three pain groups. In addition, total range of motion (external rotation plus internal rotation) did not correlate with symptoms.

**DISCUSSION**

Radiographic changes in the proximal humeral physis are most commonly discussed in relation to the diagnosis of Little League shoulder. This diagnosis is usually made when a patient has symptoms of pain associated with the act of throwing in combination with certain radiographic findings. Such changes include increased physeal width, epiphysiolysis, fragmentation, and sclerosis. Although these radiographic changes have been described as a component of Little League shoulder, the prevalence of these changes in asymptomatic throwers is not well defined.

In our study a blinded musculoskeletal radiologist was able to determine the throwing shoulder correctly based on visual radiographic criteria in 45 of 79 subjects while only incorrectly predicting the dominant shoulder in 1 case. The ability to note physeal differences did not correlate with symptoms. Direct measurements of physeal width did produce data showing that a greater difference in physeal width was more common in athletes with a history of shoulder symptoms during the current season. It is possible that increased physeal width may be more likely to produce pain than other radiographic changes, such as sclerosis or fragmentation. In subjects who reported never having shoulder pain, physeal width

---

**Table II** Age distribution of subjects

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>No. of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>15</td>
<td>7</td>
</tr>
</tbody>
</table>

---
was still found to be significantly greater in the dominant proximal humerus. Thus, it appears that physeal changes commonly occur in the throwing shoulder and often may be a normal response to throwing. A spectrum of changes at the proximal humeral physis may exist. In those young throwers with shoulder pain, the physeal changes may be the source of symptoms. However, stresses that produce demonstrable changes at the physis clearly do not always produce pain (Figure 2).

Recent comparisons of the throwing and nonthrowing arms of adult throwers demonstrated an increased retroversion angle in the throwing arm. The increase in humeral retroversion that occurs in throwers has been suggested to be an adaptation to extensive and repetitive external rotation, which occurs during throwing. This alteration in humeral version probably occurs during musculoskeletal growth. Despite efforts to make the radiographic data reproducible, we were unable to produce reliable data using the semiaxial view. Although this view has been found to be very accurate when compared with computed tomography scans in adults, we do not recommend its use in studying children.

Table III  Descriptive statistics for physeal width

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>n</th>
<th>t Value</th>
<th>Significance (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dominant IR physis width</td>
<td>3.13</td>
<td>0.67</td>
<td>79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nondominant IR physis width</td>
<td>2.91</td>
<td>0.63</td>
<td>79</td>
<td>3.57</td>
<td>P = .001</td>
</tr>
<tr>
<td>Dominant ER physis width</td>
<td>2.89</td>
<td>0.74</td>
<td>79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nondominant ER physis width</td>
<td>2.72</td>
<td>0.61</td>
<td>79</td>
<td>2.90</td>
<td>P = .005</td>
</tr>
<tr>
<td>Dominant physis mean width</td>
<td>3.01</td>
<td>0.64</td>
<td>79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nondominant physis mean width</td>
<td>2.81</td>
<td>0.56</td>
<td>79</td>
<td>3.81</td>
<td>P = .003</td>
</tr>
</tbody>
</table>

IR, Internal rotation, ER, external rotation.

Table IV  Self-reported estimated number of throws during a single game or practice expressed as percentage of total subjects

<table>
<thead>
<tr>
<th></th>
<th>1: &lt;50 throws</th>
<th>2: 50-100 throws</th>
<th>3: 100-150 throws</th>
<th>4: 150-200 throws</th>
<th>5: &gt;200 throws</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game</td>
<td>11.4%</td>
<td>43.0%</td>
<td>33.0%</td>
<td>10.1%</td>
<td>2.5%</td>
</tr>
<tr>
<td>Practice</td>
<td>16.5%</td>
<td>38.0%</td>
<td>29.1%</td>
<td>10.1%</td>
<td>6.3%</td>
</tr>
</tbody>
</table>

Figure 2  Anteroposterior view in external rotation of dominant (A) and nondominant (B) shoulder in a 12-year-old pitcher. Radiographs demonstrate visual radiographic changes and increased physeal width at the dominant physis. This player has never had shoulder symptoms.
Increased external rotation in the dominant shoulder of adult throwers is well documented.\(^4,5,8,11,15-17\) This finding has been previously reported in young tennis players.\(^11,12\) On the basis of our data, the side-to-side difference in external rotation increases as the young thrower ages. Given our problems in measuring retroversion, we were unable to determine the source of this increase in external rotation. However, as changes in range of motion are correlated to bony changes in adult throwers, it is reasonable to postulate that the increased external rotation in the young thrower is a result of changes in the bony architecture. It is likely that the radiographic physeal changes commonly seen in our study subjects represent rotational bony changes that occur as a result of repeated throwing.

We recognize that limitations exist in this study. We did not control for the impact additional sport participation such as tennis or swimming may have had on the bony and muscular tissue, as this population is involved in a variety of activities that could not be reliably characterized into meaningful groups. In addition, the survey instrument used was devised to estimate the volume of throwing by each participant. Given the lack of a preexisting valid survey instrument, the purpose was to estimate a general volume of throwing. The throwing volume for each participant is a relatively rough estimate.

Musculoskeletal development responds to external stressors. In skeletally immature baseball players, radiographic changes at the proximal humeral physis are common. Increased physeal widening, one of the criteria for diagnosis of Little League shoulder, does appear to have the potential to produce shoulder pain. However, many young throwers without symptoms also have demonstrable radiographic changes at the proximal humeral physis. In the evaluation of the young thrown, comparison radiographs can be of value. After consideration of the normal response of the proximal humerus to the act of throwing, perhaps it is reasonable to suggest that our evaluation of young throwers for shoulder overuse syndromes should be more dependent on history and physical examination and less dependent on radiographic findings than had previously been reported.

REFERENCES