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Retroversion of the Humerus in the Throwing Shoulder of College Baseball Pitchers

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ABSTRACT

Background: Increased external rotation and decreased internal rotation have been noted to occur progressively in the throwing shoulder of baseball pitchers.

Hypothesis: Proximal remodeling of the humerus contributes to the rotational asymmetry between shoulders in pitchers.

Study Design: Descriptive anatomic study.

Methods: Both shoulders of 19 male college baseball pitchers were evaluated and retroversion of the humerus calculated by using the technique of Söderlund et al. Measurements were taken of passive glenohumeral external rotation at 0° and 90° of abduction and internal rotation at 90° of abduction under a 3.5-kg load. Subjects completed a questionnaire on the amount and duration of overhead throwing performed during the ages 8 through 16 years.

Results: All of the subjects had greater external rotation at 0° and 90° of abduction, decreased internal rotation at 90° of abduction, and greater retroversion of the humerus in their dominant compared with nondominant shoulders. A significant difference was found between dominant and nondominant external rotation at 0° and 90° of abduction, internal rotation at 90° of abduction, and retroversion of the humerus. In the dominant arm, there was a significant correlation between retroversion of the humerus and external rotation at 0° and 90° of abduction. There was also a significant correlation between the side-to-side difference in retroversion of the humerus compared with the side-to-side difference in external rotation at 90° of abduction.

Conclusions: Rotational changes in the throwing shoulder are due to bony as well as soft tissue adaptations.

Baseball pitchers have been noted to have increased external rotation and decreased internal rotation of their throwing shoulder when measurements are taken at 90° of abduction. This has been shown in children[16] and in pitchers at the college[9] and professional levels.[2,9] In one study of professional baseball players tested with their shoulders abducted to 90°, pitchers were noted to have 141° of external rotation on their dominant side and 132° on their nondominant side.[2] Maximum external rotation at the shoulder during pitching has been reported to be as much as 160° to 178°.[6,8,17] Some investigators have postulated that this high level of external rotation is due to changes in the glenohumeral capsule and musculature caused by pitching.[2,6,9,10,16,17] Others have attributed the increased external rotation to overuse. Such overuse has been postulated as resulting in a contracture of the posterior shoulder capsule and stretching of the anterior shoulder capsule, leading to a tendency toward anterior glenohumeral subluxation.[16] Some have described these changes in the soft tissues about the glenohumeral joint as "relative laxity."[9] Essentially, these changes represent an attempt by the shoulder to attain a balance between the flexibility needed to allow for greater external rotation and the stability needed to counter the anterior shear forces across the joint during the process of pitching.[9]

The purpose of this study was to evaluate the radiographs of shoulders from male college baseball pitchers to

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determine whether proximal remodeling of the humerus contributes to this rotational asymmetry.

MATERIALS AND METHODS

Nineteen male college baseball pitchers were evaluated. Each of the subjects had a physical examination of both shoulders, had radiographs taken of both shoulders, and completed a questionnaire regarding their throwing activity and injuries to their shoulders.

Physical Examination

Each of the 19 subjects had their dominant and nondominant shoulder measured for passive glenohumeral range of motion in external rotation at 0° of shoulder abduction. This was followed by passive range of motion measurements in internal and external rotation at 90° of shoulder abduction in the supine position. Patients were placed in the supine position to stabilize the scapulothoracic joint, thus ensuring that true glenohumeral motion was measured without any meaningful contribution from the acromioclavicular, scapulothoracic, or sternoclavicular joints. To ensure uniformity of the passive range of motion load that was applied to the wrist, a strap was created and attached to a hand-held dynamometer (Fig. 1). Each passive range of motion was assessed under a 3.5-kg load as measured by the hand-held dynamometer.

Radiographic Assessment

We used the method developed by Söderlund et al.[21] to determine retroversion of the humerus from a single radiograph taken in the semiaxial view. This method has been shown to conform to within 2° of measurements obtained by using a CT scan.[21] The subjects in this study were examined in the supine position on a standard radiography table with the shoulder at 90° of flexion and approximately 10° of abduction and the elbow in 90° of flexion with the forearm in a neutral position. The arm was held in this position by having the subject hold on to a radiographic cassette stand that was placed on the table with the subject. The x-ray beam was perpendicular to the film cassette positioned on the table behind the subject's shoulder and elbow (Fig. 2). This position allows for both the humeral head and the epicondyles to be clearly projected onto a single film. The boundary of the articular surface of the humeral head was defined and a line was drawn across it. The anatomic neck axis, or collum humeri axis, is defined on the film by a line perpendicular to this boundary. The epicondylar axis was then determined on the film and a line drawn through it. The retroversion of the humerus was then measured as the angle between the collum humeri axis and the epicondylar axis (Fig. 3). The radiographs obtained were examined in this manner by an orthopaedic surgeon without the knowledge of who the subjects were or with which arm they pitched.

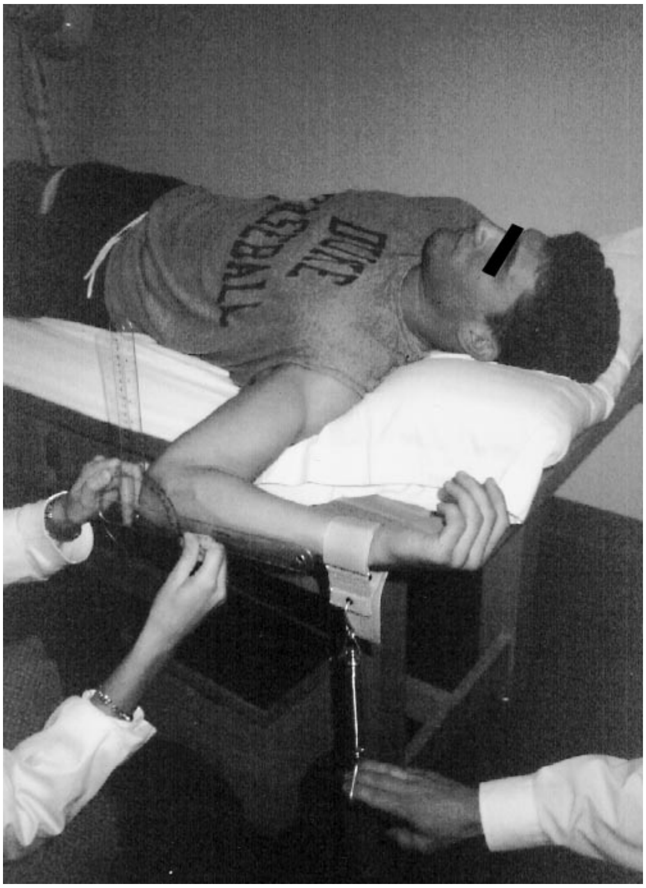

Figure 1. A subject performing passive glenohumeral external rotation at 90° of shoulder abduction. Note that each passive range of motion was assessed using a 3.5-kg load as measured by a hand-held dynamometer.

Questionnaire

Subjects were given a questionnaire to determine whether they had ever injured their throwing shoulder or experienced pain that had limited their activity and caused them to miss either games or practices. Also recorded was information on what positions were played in organized baseball from the ages of 8 through 16 years.

Statistical Analysis

Mean values and standard deviations were calculated for each range of motion, retroversion angles of the humerus in the subject's shoulders, subject's age, and number of years pitched from ages 8 through 16 years. An unpaired t-test was used to test differences between dominant and nondominant shoulders for each range of motion and retroversion of the humerus. Pearson's correlation coefficient was used to test the relationship between the retroversion angle of the humerus, range of motion, subject's age, and number of years pitched between ages 8 and 16 years. All statistical analyses were considered to be significant at a value of $P \leq 0.05$.

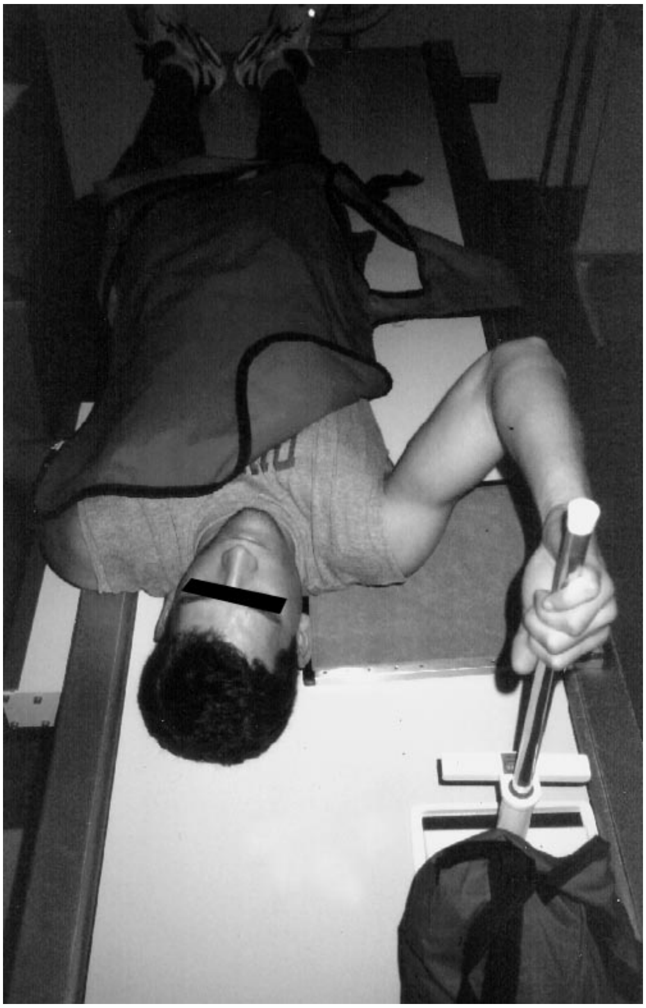

Figure 2. Subject positioning for single radiograph to determine humeral retroversion.

RESULTS

The subjects in this study were an average of 19.1 years of age (range, 18 to 21) and had pitched an average of 7.6 years (range, 2 to 9) of the possible 9 years asked about in the questionnaire. There were 7 left-handed and 12 right-handed pitchers. In addition to being pitchers, all of these subjects were also position players during the ages of 8 through 16 years. The subjects who reported missing games or practices because of pain in their throwing shoulder were the same subjects who reported having a previous shoulder injury. Notably, these all occurred before the beginning of their college baseball pitching careers.

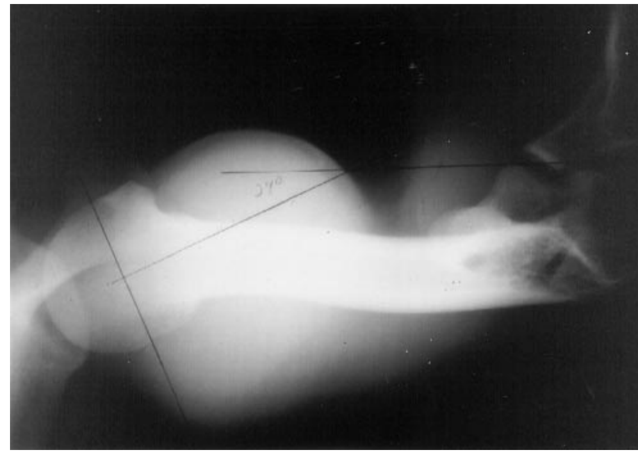

Figure 3. A radiograph of a subject's nondominant arm showing the humeral head retroversion (24°) measured as the angle between the collum humeri axis and the epicondylar axis.

Table 1 shows the mean values and standard deviations associated with all tested ranges of motion and retroversion angles of the humerus. All of the subjects in this study exhibited increased passive glenohumeral external rotation in their throwing arm compared with their nondominant arm at both 0° and 90° of abduction. All subjects also exhibited decreased passive glenohumeral internal rotation in their throwing arm compared with their nondominant arm. There was a statistically significant difference between dominant and nondominant passive glenohumeral external rotation at 0° of shoulder abduction (9.1°, $P = 0.0130$), external rotation at 90° of shoulder abduction (12.3°, $P = 0.0010$), and internal rotation at 90° of shoulder abduction (−12.1°, $P = 0.0090$). All of the subjects were also noted to have a greater retroversion angle of their dominant humerus, an average of 33.2° compared with 23.1° in the nondominant humerus. All subjects had a statistically significant difference in humeral retroversion between their dominant and nondominant shoulders (10.1°, $P = 0.0049$).

Statistical analysis was performed to compare retroversion of the humerus in the dominant arm with each range of motion of the dominant arm. There was a significant correlation of retroversion with passive glenohumeral external rotation at 0° of shoulder abduction ($P = 0.0015$, $r = 0.6756$) (Fig. 4A) and external rotation at 90° of shoul-

TABLE 1
Mean Range of Motion Measurements and Humeral Retroversion Angles (in Degrees)

Measurement	Dominant arm Mean ± SD	Nondominant arm Mean ± SD	Difference Mean ± SD
External rotation at 0° of abduction	90.1 ± 10.8	81.0 ± 10.7	9.1 ± 5.6
External rotation at 90° of abduction	126.8 ± 12.0	114.5 ± 9.1	12.3 ± 6.7
Internal rotation at 90° of abduction	79.3 ± 13.3	91.4 ± 13.6	−12.1 ± 8.6
Humeral retroversion	33.2 ± 11.4	23.1 ± 9.1	10.1 ± 4.7

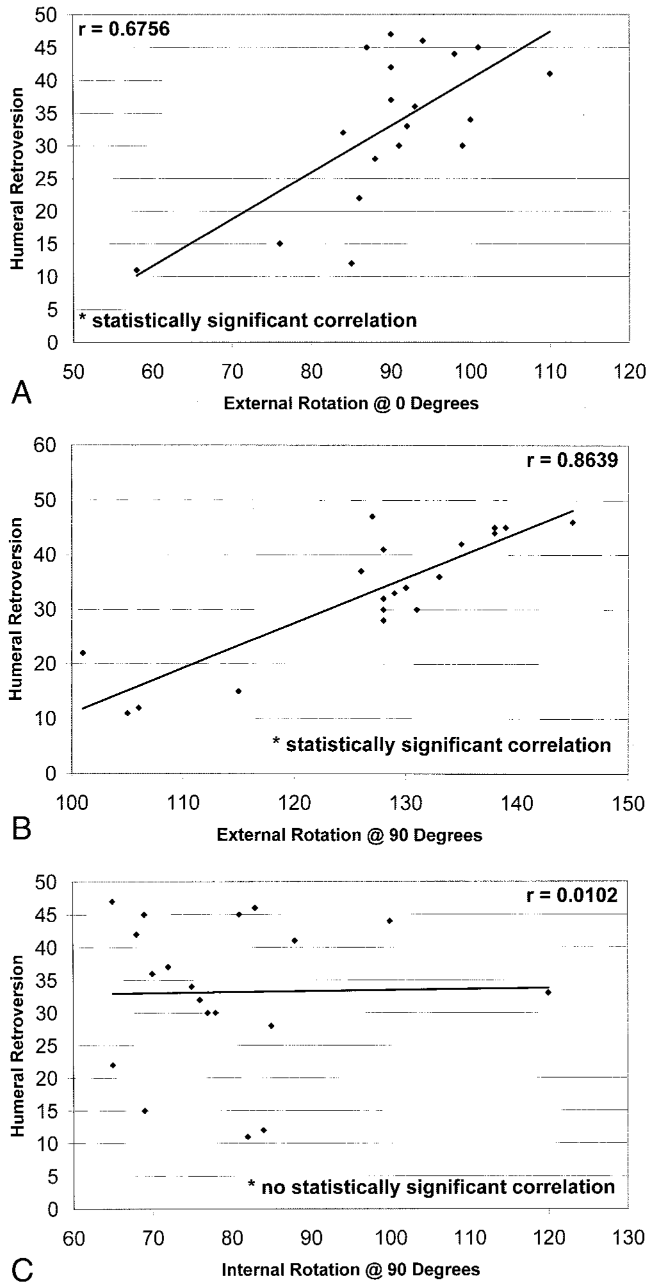

Figure 4. A linear regression scattergram of humeral retroversion in the dominant arm shows a statistically significant correlation of humeral retroversion with glenohumeral external rotation at 0° of shoulder abduction (A) and glenohumeral external rotation at 90° of shoulder abduction (B) but no significant correlation with glenohumeral internal rotation at 90° of shoulder abduction (C).

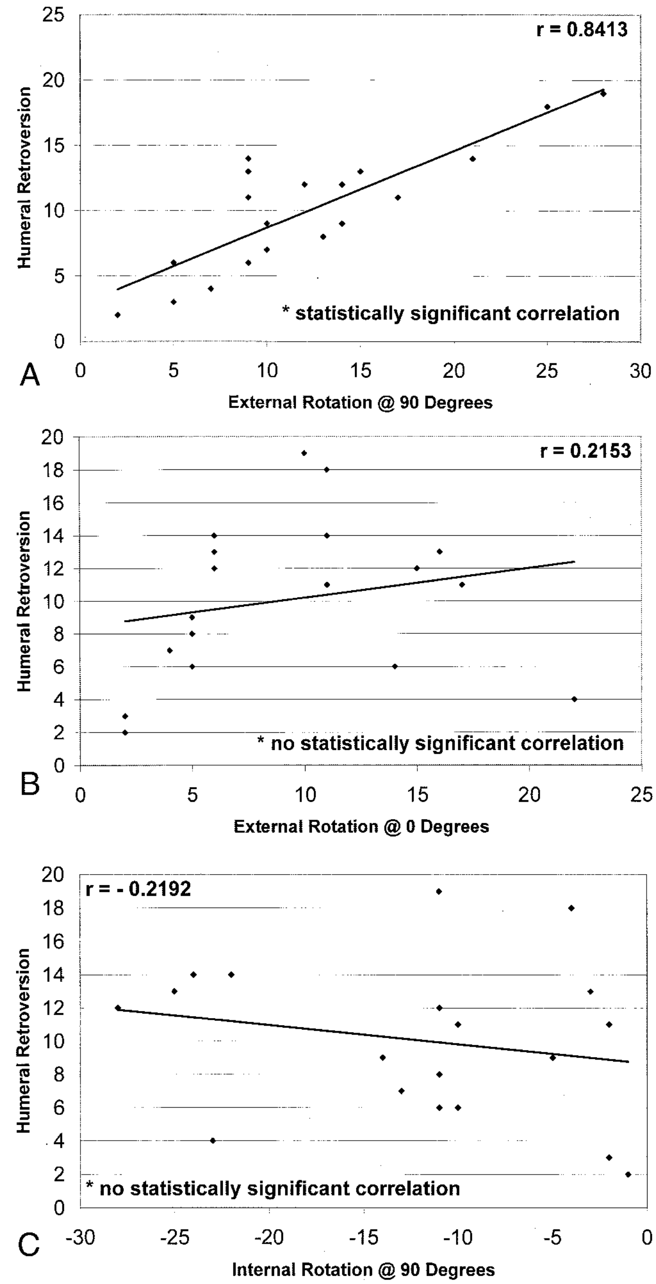

Figure 5. A linear regression scattergram of the side-to-side difference in humeral retroversion shows a statistically significant correlation of humeral retroversion with glenohumeral external rotation at 90° of shoulder abduction (A) but no significant correlation with glenohumeral external rotation at 0° of shoulder abduction (B) and glenohumeral internal rotation at 90° of shoulder abduction (C).

der abduction ($P = 0.0001$, $r = 0.8639$) (Fig. 4B). However, there was no significant correlation between humeral retroversion in the dominant arm and passive glenohumeral internal rotation at 90° of shoulder abduction ($P = 0.9670$, $r = 0.0102$) (Fig. 4C).

Statistical analysis was performed to compare retroversion of the humerus in the nondominant arm with each range of motion of the nondominant arm. A significant correlation was found between retroversion and passive glenohumeral external rotation at 0° of shoulder abduction ($P = 0.0019$, $r = 0.6645$) and between retroversion and external rotation at 90° of shoulder abduction ($P =$

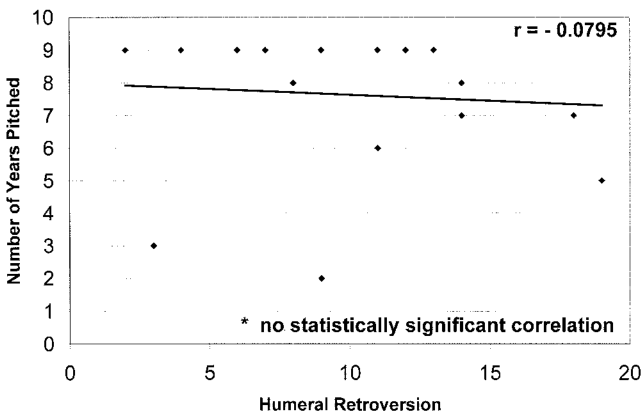

Figure 6. A linear regression, scattergram of humeral retroversion showing no statistically significant correlation of retroversion with the number of years pitched by the subject between ages 8 and 16 years.

0.0021, $r = 0.6593$). However, there was no significant correlation between humeral retroversion in the nondominant arm and passive glenohumeral internal rotation at 90° of shoulder abduction ($P = 0.0669$, $r = 0.4289$).

Statistical analysis was then conducted to determine the statistical significance of side-to-side differences in retroversion of the humerus compared with the side-to-side differences in each range of motion. There was a significant correlation between retroversion and passive glenohumeral external rotation at 90° of shoulder abduction ($P = 0.0001$, $r = 0.8413$) (Fig. 5A). However, there was no correlation between retroversion and passive glenohumeral external rotation at 0° of shoulder abduction ($P = 0.3761$, $r = 0.2153$) (Fig. 5B) or internal rotation at 90° of shoulder abduction ($P = 0.3673$, r = –0.2192) (Fig. 5C).

Statistical analysis showed no significant correlation between number of years pitched during the ages 8 through 16 years and any passive glenohumeral range of motion: external rotation at 0° of shoulder abduction ($P = 0.4131$, $r = 0.1994$), external rotation at 90° of shoulder abduction ($P = 0.2498$, $r = -0.2777$), and internal rotation at 90° of shoulder abduction ($P = 0.6080$, $r = -0.1257$). Moreover, statistical analysis showed no significant correlation between each subject's age and any tested passive glenohumeral range of motion, including external rotation at 0° of shoulder abduction ($P = 0.3531$, $r = 0.2256$), external rotation at 90° of shoulder abduction ($P = 0.6747$, $r = 0.1030$), and internal rotation at 90° of shoulder abduction ($P = 0.5036$, $r = -0.1635$). Additionally, no significant correlation was found between retroversion of the humerus and number of years pitched between ages 8 and 16 years ($P = 0.7462$, r = –0.0795) (Fig. 6) or between humeral retroversion and the subject's age ($P = 0.6262$, $r = 0.1195$).

DISCUSSION

Our study has reaffirmed the findings of previous authors that pitchers have greater external rotation and decreased internal rotation in their throwing shoulder as compared with their nonthrowing shoulder.[2,6,9,10,16,17,19] Retroversion of the humerus in normal shoulders has been previously evaluated.[5,11–15,22] Kronberg et al.[15] found that, in normal shoulders, greater retroversion of the humerus was consistent with an increased range of external rotation at 90° of shoulder abduction, but no difference was found between subjects' dominant and nondominant shoulders for each tested range of motion. Our results are consistent with their findings, revealing that greater retroversion of the humerus is significantly associated with an increased range of external rotation at 90° of shoulder abduction. However, we also found a statistical difference between the subjects' dominant and nondominant shoulders for all tested ranges of motion. In both our study and that of Kronberg et al.,[15] a statistical difference in retroversion of the humerus was found when comparing dominant and nondominant shoulders.

In addition, we found that passive glenohumeral external rotation at 0° and 90° of shoulder abduction significantly correlated with retroversion of the humerus in the dominant arm. Our results also indicated a significant correlation between the side-to-side difference in retroversion of the humerus and the side-to-side difference in glenohumeral external rotation at 90° of shoulder abduction. Surprisingly, we did not find a significant correlation of the side-to-side difference in passive glenohumeral internal rotation at 90° of shoulder abduction and retroversion of the humerus. Our only explanation for the lack of such a correlation is that the study group may have been too small, or perhaps internal rotation is progressively decreased by the throwing motion but not in a manner that correlated to the change in humeral retroversion.

Our findings are consistent with those of Pieper.[19] He noted that almost all of the handball players he studied had increased external rotation and decreased internal rotation in their throwing shoulders. In another study by Pieper,[18] 51 professional European handball players were examined. Among the 38 athletes who were asymptomatic, a significant increase of retroversion of the humerus was noted, an average 14.4° on the dominant compared with nondominant shoulder. Among the 13 athletes who had chronic shoulder pain, there was no significant difference in humeral retroversion between shoulders. In fact, the average retroversion of the humerus decreased by 5.2° in the dominant compared with nondominant shoulder. Pieper concluded that the increased retroversion among the 38 asymptomatic athletes could be attributed to an adaptive process or a biopositive response to practice during childhood. He believed that this increased humeral retroversion allowed these athletes to undergo increased external shoulder rotation without putting excessive strain on their anterior capsulolabral complex, thus avoiding chronic pain and possibly anterior instability.

The change in retroversion develops in the proximal physis of the humerus over time. It has been shown that 80% of overall humeral growth takes place in the proximal physis, and of that 80%, 90% of such growth occurs after 11 years of age.[20] It is possible that forces acting around the proximal physis of the humerus during growth, such as those associated with throwing a baseball, will have an effect on the way in which the humerus grows. It has been shown that there is 67 ± 11 N·m of torque across the glenohumeral joint during the cocking phase of pitching.[9] Forces as high as 90 ± 20 N·m have also been measured.[8]

Therefore, we believe that in addition to soft tissue adaptation there is a bony adaptation that also influences the amount of rotation occurring at the glenohumeral joint. This adaptive change in the retroversion of the humerus may be beneficial in two respects. First, with greater retroversion of the humerus there is the potential for increased external rotation at the glenohumeral joint. This increased rotation may add to the energy available within the kinetic chain and therefore may allow greater velocity to be generated. Second, the glenohumeral joint may, in fact, be more stable to anterior force because of the greater retroversion of the humerus. This is because the anterior soft tissue structures would have to stretch less for a given amount of external rotation. If the soft tissues are able to stay within their elastic range, they will be better stabilizers of the glenohumeral joint. This is especially important when considering the kinetics of baseball pitching. During the cocking phase of baseball pitching, it has been noted that the glenohumeral joint undergoes an anterior shear force of 380 ± 90 N.[9]

The concept of an envelope of function (or load acceptance) for joints as described by Dye[7] is useful in understanding the proximal remodeling of the humerus and possibly the chronic pain from anterior instability, which is seen in the throwing athlete. If, during skeletal development, the forces or stresses stay within the range of load acceptance or begin to reach the highest level of load, then physiologic and adaptive remodeling occurs. Similarly, if after skeletal maturity the forces or stresses about the glenohumeral joint exceed the range of load acceptance, symptoms or injury may occur. These may manifest as physeal injuries in the skeletally immature patient, whereas in the skeletally mature patient, the symptoms and injuries often are the result of stress reactions in bone, anterior capsulolabral laxity, or instability.

Little League shoulder has been described as a spectrum of lesions about the proximal epiphyseal plate of the humerus and may reflect proximal stress accommodation of the humerus that exceeds the range of load acceptance.[1,3,4] Pitchers with shoulder pain who are skeletally immature and do not appear to have radiographic changes of their proximal humerus are often told that they have soft tissue strains causing pain. However, the pain they experience may actually be osseous in origin, attributable perhaps to rapid remodeling or torsion on the proximal humeral physis. Such pain and remodeling may be what was previously experienced by the subjects in this study who reported past shoulder problems, since all of the shoulder problems occurred before their college baseball pitching career began. It is possible that these subjects were not completely skeletally mature and that their pain was originating from the proximal physis of the humerus. If the pain had actually originated from another anatomic location, as previously suspected, it might not have subsided over time. Instead, the pain did subside and these players were not limited in their ability to pitch in college baseball.

CONCLUSIONS

Rotational changes in the throwing shoulder are adaptive in nature and reflect either a prolonged exposure to the sport or exposure to repetitive throwing at a particular time in the athlete's growth process. The college pitchers in this study started throwing baseballs at a young age and continued throwing over a duration of several years. This factor, in combination with the radiographic results of the study, suggests that there has been an adaptive change in the rotational symmetry of their shoulders. This study demonstrates that these changes are due not only to soft tissue adaptation but to hard tissue adaptation as well. The change in retroversion of the humerus is associated with increased external rotation and decreased internal rotation in the throwing shoulder of these pitchers. Breakdown in a young baseball pitcher's shoulder may involve either hard or soft tissues as the rotational stresses of throwing are encountered. By combining this knowledge of asymmetric retroversion of the humerus with the concept of range of load acceptance for the shoulder joint, we hypothesize that the risk of injury and overuse pain can be correlated in part to the presence or absence of skeletal adaptation in baseball pitchers and other throwing athletes.

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