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ORIGINAL ARTICLE

Differentiation of bony and soft-tissue adaptations of the shoulder in professional baseball pitchers

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Background: Baseball pitching places tremendous forces on the arm, which may lead to structural tissue adaptations that are represented by changes in rotational range of motion (ROM). These adaptations often include both bony and soft tissue; however, the contribution of each tissue to the change in motion is not always clinically attainable. The purposes of this study were to determine the adaptations of ROM, bone, and soft tissue bilaterally and to examine the correlation between clinical ROM and humeral retroversion (HR)–corrected ROM. We hypothesized that glenohumeral internal rotation (IR) and total motion would be decreased and glenohumeral external rotation (ER), posterior capsule thickness (PCT), and HR would be increased in the dominant arm; that HR-corrected ROM would be significantly different than clinical ROM; and that HR-corrected ROM would be correlated with total motion difference.
Methods: Thirty professional baseball pitchers participated in this study. HR, PCT, and glenohumeral IR and ER were evaluated in the dominant and nondominant shoulders of each subject.
Results: The dominant arm exhibited significantly more retroversion, ER, and PCT than the nondominant arm. The dominant arm also had significantly less IR and total motion than the nondominant arm. The total ROM difference was significantly correlated with both HR-corrected glenohumeral IR deficit and ER gain.
Conclusion: HR-corrected glenohumeral IR deficit and ER gain may more accurately reflect the contribution of soft-tissue changes to ROM. Unfortunately, measurement of HR is not always clinically attainable, making clinical management difficult.
Level of evidence: Basic Science Study; Anatomy

Keywords: Humeral retroversion; throwing athlete; shoulder; glenohumeral; range of motion; GIRD; ERG

Baseball pitchers place tremendous forces and torques at the glenohumeral joint to both accelerate and decelerate the arm during overhead throwing.[10] These large forces and torques coupled with significant repetition have been shown to result in pronounced clinical changes in shoulder range of motion (ROM).[2,14,18,30,34,36,41-43] The most commonly observed changes

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in shoulder ROM include a decrease in glenohumeral internal rotation (IR) and an increase in external rotation (ER) in the dominant arm compared with the nondominant arm. This bilateral difference has been referred to as the glenohumeral internal rotation deficit (GIRD) and external rotation gain (ERG). These ROM differences are manifested as a result of structural adaptations in the dominant shoulder, including both bony and soft-tissue changes.

In overhead athletes, the first of several structural changes that occur at the glenohumeral joint is typically bony adaptation, which appears as increased humeral retroversion (HR) (ie, the distal humerus rotates into ER) on the dominant arm compared with the nondominant arm.[6,7,26,39,40,45] At birth, the humeri of both arms are oriented into a large degree of HR.[8,9,19,20] During development, there is a natural de-rotation process that occurs at the epiphyseal growth plate in the direction of humeral anteversion (ie, the distal humerus rotates into IR).[9] It has been found that 80% of this process is completed by the age of 8 years.[8,9] However, if throwing occurs prior to growth plate closure, then increased stress is placed on the humeral growth plate, diminishing the humeral anteversion process and resulting in increased HR on the dominant arm compared with the nondominant arm. Previous studies have consistently shown that the dominant arm of throwing athletes has greater HR than the nondominant arm and correlates with the clinical loss in IR and gain in ER.[6,7,23,26]

Adaptations in the soft tissue of the glenohumeral joint have also been observed in overhead throwers, leading to posterior shoulder tightness (due to infraspinatus and teres minor tightness and/or posterior capsule tightness)[21,24,37,38] and anterior shoulder laxity,[3,4,15,16] presenting as GIRD and ERG, respectively. After an acute throwing episode, decreased IR has been attributed to reactive tightening of the posterior rotator cuff.[17,27,28] Chronically, these throwing episodes have been shown to cause increased posterior capsule thickness (PCT) and stiffness.[1,31,32] The increased ER observed has been thought to occur as a result of stress from the late cocking phase of pitching resulting in stretching of the anterior capsule and subsequent capsule laxity.[2,3]

It is current clinical practice to use the bilateral ROM values to calculate GIRD and ERG. When significant values are present, clinicians often attribute them to soft-tissue changes. However, previous work has demonstrated that HR is also a significant factor.[23,25,33] It is possible to isolate the bony contribution to ROM through measurement of HR using ultrasound[39] or radiography[7]; however, this measurement is not always clinically attainable. As a result, clinicians typically rely on ROM to determine clinical management, without regard to true anatomic ROM, and may struggle to optimize treatment strategies. Previous studies have suggested comparing total rotational motion (IR plus ER) bilaterally (total motion [TM] difference) as a way to determine whether the shift in the arc of motion is related to HR in the throwing shoulder.[44] However, this method has not been correlated with HR-corrected ROM. Therefore, the objectives of this study were (1) to compare HR, PCT, and ROM bilaterally and (2) to examine the correlation between clinical ROM and HR-corrected ROM. We hypothesized that (1) glenohumeral IR and TM would be decreased and glenohumeral ER, PCT, and HR would be increased in the dominant arm; (2) HR-corrected ROM would be significantly different than clinical ROM; and (3) HR-corrected ROM would be correlated with TM difference.

Materials and methods

Participants and study design

Thirty professional (both Major and Minor League) baseball pitchers (age, 22.5 ± 3.5 years; mass, 96.1 ± 8.8 kg; height, 190.8 ± 4.9 cm) participated in this study. The exclusion criteria included current injury or surgery in the past 6 months. Subjects were enrolled during spring training from 1 professional baseball organization. HR, PCT, and glenohumeral IR and ER were evaluated in the dominant and nondominant shoulders of each subject.

Humeral retroversion

HR was assessed using ultrasound techniques as previously described and validated.[22] The subject was positioned supine with 90° of shoulder abduction and elbow flexion. The examiner positioned a 15-MHz linear transducer (SonoSite Titan Diagnostic Ultrasound Scanner; Fujifilm SonoSite, Bothell, WA, USA) on the subject's anterior shoulder, perpendicular to the long axis of the humerus in the frontal plane. The same examiner manually rotated the humerus such that the bicipital groove was centered on the ultrasound image. The ultrasound was then positioned, aided by use of a grid on the ultrasound display, such that a line connecting the greater and lesser tubercles was parallel to the horizontal plane. Last, the second examiner placed a digital inclinometer on the ulnar side of the forearm to record the forearm inclination angle, defining the amount of HR present. This measurement was repeated 3 times, and an average HR angle was determined.

Posterior capsule thickness

PCT was measured using ultrasound as previously described and validated.[32] The subject was positioned upright in a chair with the arm at the side and forearm resting on the thigh. The examiner positioned a 15-MHz linear transducer (SonoSite Titan Diagnostic Ultrasound Scanner) on the posterior shoulder, visualizing the glenoid labrum, humeral head, rotator cuff, and posterior capsule, defined as the tissue immediately lateral to the tip of the labrum between the humeral head and rotator cuff. A standard B-mode image was captured, and the PCT was measured using ImageJ software (National Institutes of Health, Bethesda, MD, USA). The imaging procedure was repeated 3 times, and an average thickness was determined.

Glenohumeral IR and ER

Glenohumeral IR and ER were measured using a digital inclinometer as previously described.[35] The subject was positioned supine, with the dominant arm at 90° of shoulder abduction in the frontal