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Morphologic features of humeral head and glenoid version in the normal glenohumeral joint

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Background: The morphologic features and clinical significance of version of the humeral head and glenoid remain unclear. The purpose of this study was to evaluate the normal values of humeral head version and glenoid version on computed tomography scans and to clarify their features in the normal glenohumeral joint.
Methods: Images for analysis were computed tomography scans of 410 normal shoulders from healthy volunteers. Values of humeral head and glenoid version were measured. In glenoid version measurement, 3-dimensionally corrected slices were reconstructed to eliminate scapular inclination. Differences in humeral head version and glenoid version were assessed between dominant and nondominant shoulders and between men and women. Correlation analyses were also performed in the values of version between dominant and nondominant shoulders and between humeral head version and glenoid version.
Results: The values of humeral head retroversion were widely distributed from −2° to 60°, with an average of 26° ± 11°. Average glenoid retroversion was 1° ± 3°, ranging from −9° to 13°. Both humeral head retroversion and glenoid retroversion were significantly higher on the dominant side than on the nondominant side and significantly higher in men than in women. Humeral head version and glenoid version values were well correlated with those of the contralateral shoulder. No correlation was found between humeral head version and glenoid version.
Conclusions: This study found differences in humeral head version and glenoid version by sex and shoulder dominance in a large sample. Both the humeral head and glenoid are thought to be more retroverted in high-demand shoulders.
Level of evidence: Basic Science Study, Anatomy, Imaging.

Keywords: Shoulder morphology; glenoid morphology; glenoid retroversion; humeral head retroversion; humeral torsion; humerus morphology; shoulder arthroplasty

This study was approved by the Institutional Review Board of Ito Municipal Hospital (reference study number 2012001).

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Numerous studies have investigated shoulder geometry and morphology, but most of these dealt with shoulders in pathologic states. Thus, details of the normal glenohumeral joint have not been sufficiently evaluated. It is important to understand the morphologic features of the normal shoulder for anatomic reconstruction of the glenohumeral joint. Furthermore, few studies have examined both the scapula and humerus in the same shoulder.

In past studies, computed tomography (CT) scans have been widely used to measure humeral head version[1,5,6,9,16] and glenoid version.[4,9,10,14,17] Humeral head retroversion varies widely among cases,[2,13,16] and throwing athletes are reported to have high retroversion of the humeral head and glenoid.[6,9,23,27] Some arthritic shoulders show severe glenoid retroversion, which could be a risk factor for poor outcomes after arthroplasty.[30,31] The normal values and range of version must be documented because it is not possible to determine which cases are abnormal without understanding normal shoulders. With a small number of studies involving the normal population, however, their morphologic features and clinical significance remain unclear. The purpose of this study was to evaluate the normal values of humeral head version and glenoid version on CT scans and to clarify their features in the normal glenohumeral joint.

Materials and methods

A total of 207 healthy volunteers ranging from 20 to 40 years of age were prospectively recruited for this study. All volunteers gave their informed consent to participate in this study, and candidates with any past illnesses or injuries in the shoulder girdles were excluded. Two cases were excluded after examination because an asymptomatic bone cyst in the humeral head was found on the CT scans of their right shoulders. Thus, 410 shoulders from 205 volunteers (mean age, 30.6 ± 5.0 years; age range, 20-40 years; 108 women, 97 men) were included in this study. The dominant shoulders were right in 194 and left in 11. In determining shoulder dominance, the throwing side was defined as the dominant shoulder. Ninety-four cases (51 women, 43 men) had played asymmetric overhead sports for more than 3 years before the age of 18 years. In this study, asymmetric overhead sports included baseball, softball, tennis, volleyball, and badminton. On the other hand, rugby, basketball, Judo, skiing, and the like were excluded from the overhead sports group. All volunteers were engaged in light work, and no one performed heavy labor or competitive sports activity at the time of investigation.

Bilateral axial CT scans including the whole scapula, proximal humerus, and distal humerus were taken with 3-mm-thick slices (GE Healthcare HiSpeed NX/i Pro, Amersham, England; or Toshiba Aquilion TSX-101A, Tokyo, Japan). During the examination, the volunteers were positioned with the elbow extended and the forearm supinated. To prevent arm motion, the palm was placed and fixed under the volunteer's buttock. The DICOM (Digital Imaging and Communication in Medicine) data were analyzed with OsiriX MD 1.4.1 software (Pixmeo, Geneva, Switzerland). Humeral head version and glenoid version were assessed in both sides of the shoulders. The humeral head axis was defined as the line perpendicular to the cord of the articular surface of the humeral head at the slice with the maximum humeral head diameter (Fig. 1, A). The margins of the anatomic neck of the humerus were indicated by the junctions between the articular surface of the humeral head and a depression corresponding to the insertion of the articular capsule. The elbow epicondylar axis was defined as the line drawn between medial and lateral epicondyles at the slice where the epicondyles were the most prominent (Fig. 1, B). When it was difficult to determine the anatomic neck margin or the epicondyles, other slices were checked to identify them. Humeral head retroversion was calculated as torsion of the humeral head axis with respect to the elbow epicondylar axis of the humerus (Fig. 1, C).[1,16] In glenoid version measurement, 3-dimensionally corrected slices were reconstructed to exclude the effect of scapular inclination. Because images taken in the clinical setting can result in invalid measurement of glenoid version,[3,17] the axial images were corrected for scapular inclination. First, 3 bone landmarks of the scapula were selected with use of the software to determine the scapular plane: the inferior tip of the scapular body, the center of the glenoid surface, and the medial pole of the scapula (Fig. 2, A).[8,15,18,21,26] Three-dimensionally corrected slices were reconstructed as the plane including the center of the glenoid surface and the medial pole of the scapula and perpendicular to the scapular plane (Fig. 2, B).[4] The glenoid line was the line connecting the anterior rim with the posterior rim of the glenoid. The scapular axis was defined as the line connecting the medial pole of the scapula and the center of the glenoid line. As Friedman et al[14] described, glenoid version was calculated as the angle between the glenoid line and the line perpendicular to the scapular axis (Fig. 2, C). Two-dimensional analysis of glenoid version was performed on the midglenoid slices in which scapular inclination was corrected 3-dimensionally. In this study, the values of version were calculated as retroversion. Thus, a positive number means retroversion, and a negative number means anteversion of the humeral head and glenoid. Two evaluators independently reviewed all measurements twice with a minimum of a 1-month interval between measurements. Each measurement started from slice selection in humeral head version and from slice reconstruction in glenoid version.

Statistical analyses were performed with IBM SPSS Statistics 20.0.0 software (IBM, Armonk, NY, USA). Intrarater and interrater reliabilities were evaluated with intraclass correlation coefficients (ICC) first. Version measurement reliability was examined in both humeral head version and glenoid version. Intrarater reliability for each of 2 observers was calculated by repeated measurements with a 1-month interval (ICC model 1,1). Interrater reliability was calculated by blinded measurements of 2 observers (ICC model 2,1). After assessment of reliability, the values of humeral head version and glenoid version were averaged across the 2 observers and their 2 measurements.

Humeral head version and glenoid version values were compared with the Wilcoxon signed rank test, and their distributions were compared with the F test. Differences in humeral head version and in glenoid version were then compared between the dominant shoulder and the nondominant shoulder by Wilcoxon signed rank tests and between men and women by Mann-Whitney U tests. For dominant shoulders, differences in a history of overhead sport participation were also assessed with Mann-Whitney U tests for humeral head version and glenoid version.

Finally, correlation analyses were performed with Spearman rank correlation tests. The correlations between dominant and nondominant shoulders were analyzed for humeral head version and glenoid version. Correlation analysis between the values of humeral