Contact Analysis Of The Glenohumeral Joint During Simulated Throwing Motion

Hiroaki Inui, Hiroshi Tanaka, Katsuya Nobuhara.
Nobuhara Hospital & Institute of Biomechanics, Hyogo, Japan.


Introduction: The disabled throwing shoulder involved articular side tears of the supraspinatous or infraspinatous, labral lesions, Bennett lesions, humeral head lesions or cysts, and glenoid bony lesions. In most cases it is difficult to point out when those lesions occurred, because they might be caused by repetition of throwing motion. Also, throwing is a rapid motion, especially in the acceleration phase with the arm internally rotated. It is difficult to detect which phase during throwing motion would relate to the lesions. It is ideal the joint always remains centered for the prevention of these injuries. However, there is a mismatch between the diameters of the head and the glenoid and the concavity compression mechanism which mainly stabilizes the joint might be influenced by arm positioning. It remained unclear how joint stability was maintained or affected during throwing motion. We hypothesized there was a variation of the point application of the load on the joint during throwing activity, and investigated contact area of the glenohumeral joint during arm rotation in elevation.

Methods: Ten volunteers (10 men) without symptoms or a history of shoulder disease were enrolled in this study. Their mean age was 26 years (range, 21-35 years). All participants provided informed consent. The present study was approved by the IRB of our hospital.

The right arm was both maximally externally and internally rotated at abduction angles of 90°in the coronal plane to the trunk. The elbow was flexed in 90°. The amount of pronation or supination of the forearm was not specified. Images of these positions were obtained using a 0.2-T MRI system (Magnetom Open; Siemens, Munich, Germany). Each upper extremity was controlled by a positioning device while maintaining the same relaxed position without disturbing scapular motion. The shoulders were imaged using a three-dimensional (3D) gradient echo (repetition time, 56 ms; echo time, 25 ms; flip angle, 40°) with 2-mm sections. All images were obtained with an 18-cm field of view and a 256 × 192 matrix. Each imaging process required an average of 10 min. The cortical bones were manually digitized and were transferred to a computer (O2; SGI, Mountain View, CA). A 3D image of each subject was generated using computer software (3D-Virtuoso; Siemens). This software allowed anatomies to be viewed from any angle and provided instant access to 3D information.

The center of the humeral head was determined by fitting a sphere, while the axis of the humeral shaft was determined by fitting a cylinder. The point just posterior to the coracoid base on the glenoid rim was defined as the upper rim, and the point just anterior to the lateral border of the scapula was defined as the lower rim. The line connecting these points was defined as the glenoidal long axis with its middle point defined as the glenoid center. Three parameters including abduction, horizontal abduction, and axial rotation were used to determine joint positioning in each position. The slope of the humeral long axis on the glenoid was determined by measuring the angle relative to the glenoidal long axis (abduction angle) and analyzing the plane of abduction. The latter was shown by the angle of its plane to the glenoid plane (horizontal abduction angle). Axial rotation of the glenohumeral joint was visualized on the computer screen as follows. The equator was set on the head surface in the plane parallel to the humeral long axis, including the head center and bicipital groove. Its parallel lines were analogous to the
latitudes. The rotation was referenced to the latitude by rotating the globe to align the longitude, including the midpoint of the glenoidal long axis, with the vertical. The angle at which the glenoidal long axis became parallel to the latitude was defined as 0 degrees, and all values in external rotation were defined as positive.

Least distance between the glenoid and the humerus was calculated by exploratory method. The closest contact area (CCA) was defined as the circle, a dot in which was less than 0.5 mm to the other bone. The contact area was defined as the circle around the closest contact area, a dot in which was less than 2.0 mm to the other bone. The patterns of area projected both on the glenoid and the humeral head were shown.

**Results:** Glenoid contact area

In the externally rotated position, each head center existed slightly posterior to the glenoid center. The pattern of contact area was diverse and in some cases, it existed on the subacromial surface (Fig. 1). In the internally rotated position, each head center projected orthogonally to the glenoid consisted with the glenoid center. The pattern of contact area was consistent with its CCA around the center of the glenoid (Fig. 2).

**Humeral contact area**

In the externally rotated position, contact area existed in posterior surface of the head, and it translated about the equator of the head, indicating the glenoid trajectory during throwing activity existed mainly in posterior aspect of the head.

**Discussion:** The objective of this study was to clarify a variation of the point application of the load on the joint during throwing activity by analyzing contact area of the joint in computer generated three-dimensional images.

The head center shifting posterior to the glenoid center in the externally rotated position. This translation might be induced by tightening in the anterior capsule and might be affected by laxity of the capsule which is different between the subjects. Harryman and associates demonstrated this posterior humeral translation was obligatory when the displacing force generated by ligament tension overwhelmed the concavity compression stability mechanism. In addition to its translation, contact area on the glenoid was diverse even though it mainly located on the postero-superior side of the head. In some subjects, it located under the surface of the acromion.

In the internally rotated position, the head remained centered and contact area was consistent with its CCA around the glenoid center. Obligatory translation as was shown in external rotation was not seen in the internally rotated position with the glenoid locating in the middle of the head surface. Thus, positioning of the joint was always consistent.

The obligatory translation of the head and the variation of the point application of the load on the glenoid in externally rotated positions might be changed when the arm is actively rotated. However, it can be said that the glenohumeral joint is inherently unstable with the arm externally rotated in elevation. From the cocking to the acceleration phase when the arm was externally rotated, joint positioning would be more apt to be affected compared to the follow-through phase after ball release when the arm was internally rotated.

**Significance:** Through investigating patterns of contact area in the glenohumeral joint, it was indicated joint positioning was more apt to be affected from the cocking to the acceleration phase with the arm externally rotated than the follow-through phase after ball release with the arm internally rotated.
Fig. 1 Contact area and humeral head center (the white square) in the externally rotated position.