J Shoulder Elbow Surg (2016) ■■, ■■–■■

ELSEVIER

Journal of Shoulder and Elbow Surgery

www.elsevier.com/locate/ymse

ORIGINAL ARTICLE

Effects of glenoid inclination and acromion index on humeral head translation and glenoid articular cartilage strain

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Background: Previous clinical studies have reported associations between glenoid inclination (GI), the acromion index (AI), and the critical shoulder angle (CSA) on the one hand and the occurrence of glenohumeral osteoarthritis and supraspinatus tendon tears on the other hand. The objective of this work was to analyze the correlations and relative importance of these different anatomic parameters.

Methods: Using a musculoskeletal shoulder model developed from magnetic resonance imaging scans of 1 healthy volunteer, we varied independently GI from 0° to 15° and AI from 0.5 to 0.8. The corresponding CSA varied from 20.9° to 44.1°. We then evaluated humeral head translation and critical strain volume in the glenoid articular cartilage at 60° of abduction in the scapular plane. These values were correlated with GI, AI, and CSA.

Results: Humeral head translation was positively correlated with GI ($R = 0.828$, $P < .0001$), AI ($R = 0.539$, $P < .0001$), and CSA ($R = 0.964$, $P < .0001$). Glenoid articular cartilage strain was also positively correlated with GI ($R = 0.489$, $P = .0004$) but negatively with AI ($R = -0.860$, $P < .0001$) and CSA ($R = -0.285$, $P < .0473$).

Conclusions: The biomechanical shoulder model is consistent with clinical observations. The prediction strength of CSA is confirmed for humeral head translation and thus presumably for rotator cuff tendon tears, whereas the AI seems more appropriate to evaluate the risk of glenohumeral osteoarthritis caused by excessive articular cartilage strain. As a next step, we should corroborate these theoretical findings with clinical data.

Level of evidence: Basic Science Study; Computer Modeling

Keywords: Glenoid inclination; acromion index; critical shoulder angle; humeral head translation; glenohumeral osteoarthritis; musculoskeletal model

Osteoarthritis and rotator cuff tendon tears are the 2 most common shoulder disorders.[26] The long-term soft-tissue degeneration process is assumed to be multicausal,[4,34] and it is well accepted that biomechanical factors play a significant

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1058-2746/$ - see front matter © 2016 Journal of Shoulder and Elbow Surgery Board of Trustees. All rights reserved.
http://dx.doi.org/10.1016/j.jse.2016.05.031

role.[3,4,10] More specifically, biomechanical factors might be related to the morphology of the scapula.

Glenoid orientation was the first candidate for association with degeneration.[17,39,41] An upward glenoid inclination (GI) was correlated with an increased occurrence of supraspinatus tendon tears,[17] the opposite,[2] or no effect at all.[22] The acromion extension was subsequently proposed by Nyffeler et al.[29] They introduced the acromion index (AI), which was found to be significantly higher in patients with full-thickness rotator cuff tears than in controls and significantly lower in patients with osteoarthritis than in patients with tendon tears. This association was partly disputed by other research groups.[1,16,30] The critical shoulder angle (CSA), combining both GI and AI, was later proposed by Moor et al[27] (Fig. 1). CSA was reported to be significantly different between healthy subjects, patients suffering from osteoarthritis, and patients with rotator cuff tears. These initial results were recently confirmed, whereas the specific effect of GI was dissociated from CSA.[7] In vivo joint motion and various morphologic parameters were also tested for correlation, but only CSA proved to be significantly higher in subjects with pathologic rotator cuffs than in controls.[31] Two biomechanical cadaveric experiments confirmed the specific effect of AI and GI on glenohumeral joint stability, as well as their relation with CSA.[15,28]

Despite the radiologic observations and recent in vitro simulation studies, the biomechanical rationale between GI, AI, and CSA on the one hand and glenohumeral osteoarthritis and rotator cuff tendon tears on the other hand is not completely understood yet. The relative importance of these 3 anatomic parameters and their hypothetical effects on tendon tears or osteoarthritis are indeed still controversial.[1,16,30]

Therefore, the goal of this work was to evaluate the independent and combined biomechanical effects of 3 anatomic parameters (namely GI, AI, and CSA) on glenoid articular cartilage strain and humeral head translation. To investigate this question, we used a numerical shoulder model and varied independently GI and AI for testing any correlation between those quantities. From the hypothesis that articular cartilage strain is associated with osteoarthritis, and superior humeral head translation with tendon tears,[17,29] we estimated by extension the relative importance of these different anatomic parameters on the reported occurrence of glenohumeral osteoarthritis and rotator cuff tendon tears.

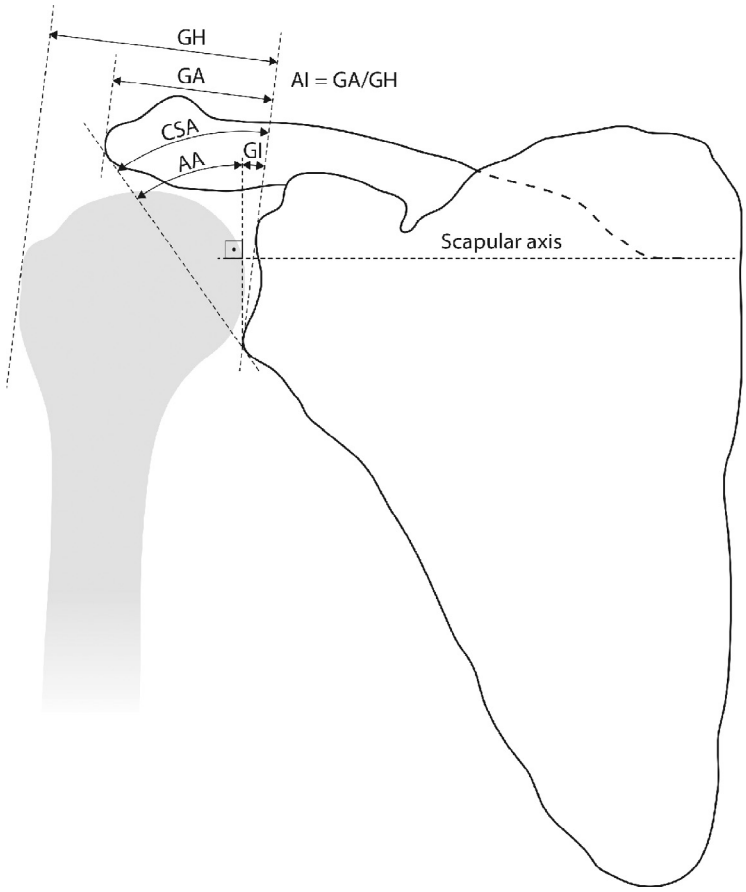

Figure 1 Illustrative diagram of definitions of glenoid inclination (GI),[38] acromion index (AI),[29] acromion angle (AA), and critical shoulder angle (CSA).[27] The glenoacromial distance (GA) and glenohumeral distance (GH) are used to define AI.[29]