Correlation of Multiple Acromion Morphological Parameters on Radiographs in a Chinese Population

Mingyang Yu (yumingyang1983@163.com)
Affiliated Zhongshan Hospital of Dalian University
Xiaoming Zhu
Affiliated Zhongshan Hospital of Dalian University
Shilong Zhao
Affiliated Zhongshan Hospital of Dalian University
Ailing De
Affiliated Zhongshan Hospital of Dalian University
Yao Zhang
Affiliated Zhongshan Hospital of Dalian University
Lin Guo
Affiliated Zhongshan Hospital of Dalian University
Dongyi Li
Affiliated Zhongshan Hospital of Dalian University
Fengde Tian
Affiliated Zhongshan Hospital of Dalian University
Ning An
Affiliated Zhongshan Hospital of Dalian University
Ruihu Hao
Affiliated Zhongshan Hospital of Dalian University
Changcheng Wang
Affiliated Zhongshan Hospital of Dalian University

Research article

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Abstract

Background Previous clinical studies have reported associations between the acromion index (AI), lateral acromion angle (LAA), and critical shoulder angle (CSA) and the occurrence of rotator cuff tears. The objective of this study was to analyze the correlations of these different anatomic parameters. Materials and Methods Healthy Chinese participants (n = 66) and Chinese patients with rotator cuff tears (n = 70) identified between January 2014 and October 2015 were included in this study. Standardized true anteroposterior radiographs were used to measure the AI, LAA, and CSA in each study participant. Results The mean AI was significantly larger (0.71 standard deviation [SD], 0.05; range 0.58–0.89 vs. 0.64 SD, 0.06; range 0.55–0.78; $P < 0.001$), the mean LAA was significantly smaller (77.0° SD, 5.73; range 61.0°–94.5° vs. 82.0° SD, 7.33; range 67.6°–98.3°; $P < 0.001$), and the mean CSA was significantly larger (36.1° SD, 5.29; range 21.3°–42.4° vs. 31.6° SD, 5.29; range 21.4°–45.8°; $P < 0.001$) in patients with full-thickness rotator cuff tears compared with healthy participants. Conclusions There were a negative linear relationship between the AI and LAA (rotator cuff tears: $R = -0.759$, $P < 0.01$; healthy participants: $R = -0.813$, $P < 0.01$) and a positive linear relationship between the AI and CSA (rotator cuff tears: $R = 0.854$, $P < 0.01$; healthy participants: $R = 0.912$, $P < 0.01$) in patients with rotator cuff tear and healthy participants; we termed this phenomenon “The Acromion Rule.” The AI, LAA, and CSA are independent predictors of rotator cuff tears in a Chinese population.

Introduction

The potential relationship between variations in acromion morphology and rotator cuff tears has been investigated in multiple studies.[1–4] Many of these used anthropometric techniques to identify a number of relevant parameters, including the acromion index (AI), which was used to assess lateral extension of the acromion, and the lateral acromion angle (LAA), defined as the angle between the inferior surface of the acromion and the surface of the glenoid cavity. The findings showed that a high AI was associated with risk of full-thickness rotator cuff tear[1,5,6] and identified a statistically significant correlation between the LAA and magnetic resonance imaging (MRI)-determined rotator cuff tear.[6] In another study, Moor et al. used the critical shoulder angle (CSA) to comprehensively analyze the inclination of the glenoid and the AI and LAA. They found that a significantly larger CSA was associated with degenerative rotator cuff tears.[7,8] Interestingly, we noted that all these parameters use the surface of the glenoid cavity as the baseline for measurement. Therefore, we hypothesize that the relationship between the AI, LAA, and CSA is relevant in the diagnosis of rotator cuff tears. To the best of our knowledge, no study has assessed the correlations between these multiple parameters of acromion morphology.

In this study, we evaluated radiologic parameters of acromion morphology in two Chinese populations. The objective of the study was to identify correlations between the AI, LAA, and CSA in a healthy Chinese population and in Chinese patients who suffer from rotator cuff tears.

Materials And Methods

Ethics

The experimental protocol was established according to the ethical guidelines of the Helsinki Declaration, and ethical approval for this study was provided by our university.

Study subjects

Healthy participants and patients with rotator cuff tears identified between January 2014 and October 2015 at our university were eligible for this study. The healthy group consisted of 66 volunteers who were asymptomatic and underwent a routine medical examination in our institution. We evaluated them using the Shoulder-Rating Score Sheet, clinically evaluating them for any evidence of shoulder pathology emphasizing on the impingement sign, abduction and adduction sign, as well as evidence of any functional limitation and regional tenderness.[4] Healthy participants were volunteers in whom MRI 1.5T of the rotator cuff showed no signs of edema, calcification, or rupture of tendons. Patients with rotator cuff tears were included if they were suffering from sustained shoulder dysfunction and chronic pain and had obvious rotator cuff tears detected by MRI. Exclusion criteria were primary osteoarthritis in the affected shoulder, calcified tendonitis, fracture, frozen shoulder, sequelae of infection, glenohumeral instability, or prior surgery.

Radiologic parameters of acromion morphology

Standardized true anteroposterior radiographs were used to measure AI, LAA, and CSA in healthy participants and patients with rotator cuff tears [Figure 1]. Individuals stood in front of an X-ray cassette with a neutral rotation of the forearm and the arm at the side of the body without any abduction. The coronal plane of the body was rotated until the glenoid plane was vertical to the X-ray cassette. The X-ray beam was directed horizontal to the glenoid plane. The measurements were recorded by two independent observers.

Acromion index

As shown in Figure 2, line “a” represents the glenoid plane, connecting the superior and inferior borders of the cortical bone of the glenoid. Line “b” and line “c” are parallel to line “a” and at a tangent to the lateral border of the acromion and proximal humerus, respectively. The AI was defined as the ratio between the distance from line “a” to line “b” (GA) and the distance from line “a” to line “c” (GU).[8]

Lateral acromion angle

The LAA (angle α) is formed by the intersection of line “a” and line “d.” Line “d” (the proximal line) is parallel to the sclerotic line of the cortical undersurface of the acromion [Figure 2].

Critical shoulder angle

The CSA combines the measurements of inclination of the glenoid and the AI. The CSA is formed by line “a” and line “e.” Line “e” extends from the inferolateral point of the acromion to the inferior fossa margin of the glenoid [Figure 2].

Statistical analyses

Statistical analyses were performed using SPSS statistical software (version 21.0). The postobserved power analysis was done. According to the formula of sample size, the average AI was 0.6 in control group and 0.7 in rotator cuff tear group. The standard deviation (SD) of AI was 0.1 in two groups, the power was 0.9, the alpha was 0.05, and the result is need at least 24 patients in each group. On the basis of observed correlations of −0.813–0.912, at α = 5% and power = 80%, a sample of 10 cases was required. Since the sample size taken was quite high as compared to the required sample size, we can say that the power of our study is very high.

Between-group comparisons were evaluated using Student’s *t*-test and Chi-square test. Correlations between parameters were investigated with Pearson’s correlation test. Statistical significance was set at $P < 0.05$.

Results

This study included 66 asymptomatic participants (26 males and 40 females) and 70 patients with rotator cuff tears (22 males and 48 females). Patients with rotator cuff tears were significantly older than healthy participants (51.85 ± 8.92 vs. 47.52 ± 8.39; P = 0.004).

The mean AI of the patients with rotator cuff tears was significantly larger than the mean AI of the healthy participants (0.71 SD, 0.05; range 0.58–0.89 vs. 0.64 SD, 0.06; range 0.55–0.78; P < 0.001). The mean LAA of the patients with rotator cuff tears was significantly smaller than the mean LAA of the healthy participants (77.0° SD, 5.73; range 61.0°–94.5° vs. 82.0° SD, 7.33; range 67.6°–98.3°; P < 0.001). The mean CSA of the patients with rotator cuff tears was significantly larger than the mean CSA of the healthy participants (36.1° SD, 5.29; range 21.3°–42.4° vs. 31.6° SD, 5.29; range 21.4°–45.8°; P < 0.001) [Table 1].

There were a negative linear relationship between the AI and LAA (rotator cuff tears: $R^2 = 0.5417$, $P < 0.001$, $r = -0.759$, $P < 0.01$; healthy participants: $R^2 = 0.6168$, $P < 0.001$, $r = -0.813$, $P < 0.01$) and a positive linear relationship between the AI and CSA (rotator cuff tears: $R^2 = 0.5611$, $P < 0.001$, $r = 0.854$, $P < 0.01$; healthy participants: $R^2 = 0.5437$, $P < 0.001$, $r = 0.912$, $P < 0.01$) in healthy participants and patients with rotator cuff tears [Figures 3 and 4]. AI, LAA, and CSA were independent predictors of rotator cuff tears.

Discussion

Understanding the influence of acromial morphology on the pathogenesis of rotator cuff injury is important for developing effective treatment and management strategies for this condition. The causal relationship between the variation of lateral acromial extension and the risk of a full-thickness rotator cuff tear was first investigated by Nyffeler et al.[7] who originally defined the AI. They found that a larger lateral extension of the acromion provides a higher ascending force than a smaller lateral extension of the acromion during abduction of the shoulder. Banas et al.[8] revealed that the LAA may be useful for evaluating patients thought to have or to be at risk for rotator cuff tear. They reported an association between the angle of lateral tilt of the acromion and the prevalence of subacromial tear. Moor et al.[9] developed a radiological parameter, the CSA, which takes into account both the tilt of the glenoid in the frontal plane and the AI. They showed that the CSA was correlated with wear of the rotator cuff tendons and the articular cartilage of the glenohumeral joint but eliminated the influence of degenerative changes in the humerus. In a second study, Moor et al.[10] evaluated the predictive power of the AI, LAA, and CSA to determine the presence of degenerative rotator cuff tear. They concluded that the CSA is the most valuable measure to distinguish between patients with intact rotator cuff tendons and those with torn rotator cuff tendons. Notably, we found that the surface of the glenoid cavity is the baseline for measurement of the AI, LAA, and CSA. Therefore, we hypothesized that there is a relationship between these parameters that are relevant in the diagnosis of rotator cuff tears.

To the best of our knowledge, the current study is the first to comprehensively analyze the association between multiple morphological parameters of the acromion, the AI, LAA, and CSA, with rotator cuff tear. In contrast to other studies, we measured three radiologic parameters of acromial morphology in each healthy participant or patient using the same true standardized anteroposterior radiograph. Our findings confirmed the results of Nyffeler et al., Banas et al., and Moor et al. In addition, we demonstrated two other phenomena. First, we found an inverse relationship between the AI and LAA; the lateral extension of the acromion increased as the inclination of acromion increased. Second, we found a positive relationship between the AI and CSA; the lateral extension of the acromion increased as the angle between the line connecting the lowest point of the glenoid plane and the inferolateral point of the acromion and a line delineating the glenoid plane increased. We call this phenomenon “The Acromion Rule” [Figure 5]. These findings imply that the lateral extension of the acromion, the upward tilt of the glenoid fossa, and the downward tilt of the acromial cortex represent relevant risk factors for rotator cuff tear.

We sought to understand if “The Acromion Rule” is congenital or acquired. There is an ongoing debate about whether the shape of the acromion is congenital or acquired. In 2001, based on macroscopic, radiographic, and microscopic examination of the acromion process, Nirav et al. hypothesized that changes in acromion morphology are a secondary degenerative phenomenon rather than congenital.9 We developed “The Acromion Rule” according to Nyffeler et al., and based on imaging studies, we speculate that “The Acromion Rule” is acquired rather than congenital. The middle deltoid muscle originates on the acromion; therefore, during active abduction, the deltoid muscle provides ascending and compressive forces, which acts on the acromion [Figure 6]. If collagen, fibrocartilage, and bone grow along the reverse plane of the compressive force component, the AI will increase. If collagen, fibrocartilage, and bone grow along the reverse plane of the ascending force, the AI will decrease. At present, the clinical study of many scholars has found that patients with rotator cuff tear are significantly higher than healthy ones.1–8 Due to the mechanical factors of the acromion, the large AI variation, and the morphological variation of the acromion became the cause of rotator cuff tear.

There were several limitations associated with this study. First, we did not account for a possible association between the shape of the acromion and the presence of rotator cuff tear in our study participants. Second, we did not account for a possible association between the acromiohumeral interval and the presence of rotator cuff tear. Third, our study was performed in a Chinese population, and the findings may not be generalizable to populations in other regions. Fourth, the age difference between the patients with rotator cuff tears and the healthy participants may have affected the results. Finally, this study does not take into account the intrinsic pathology of rotator cuff tear and the correlation between rotator cuff tear and factors such as diabetes, genetics, and smoking.

Conclusions

Future multicenter studies are required to elucidate whether “The Acromion Rule” exists in other ethnic groups.

Abbreviations

AI: Acromion index; LAA: lateral acromion angle; CSA:critical shoulder angle; SD: standard deviation; SPSS: Statistic Package for Social Science; MRI: magnetic resonance imaging; Fres: resultant deltoid force; Fa:ascending force component; Fc:compressive force component;

Declarations

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Availability of data and materials

Please contact the author for data requests.

Authors' contribution

MY designed the clinical studies, and drafted the manuscript. XZ, SZ, AD carried out the clinical studies. YZ, LG, DL revised the manuscript. FT, NA and carried out the data acquisition and data analysis. RH, CW carried out literature search and manuscript editing.

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors. The experimental protocol was established according to the ethical guidelines of the Helsinki Declaration, and ethical approval for this study was provided by Dalian University Affiliated Zhongshan Hospital. All patients or guardians, after reading, filled in and signed the consent form and agreed to participate in the study.

Consent for publication

This section is not applicable for our study.

Competing interests

The authors declare that they have no competing interests.

Author details

1.Departments of Orthopaedics, Affiliated Zhongshan Hospital of Dalian University, Dalian,

2.Department of radiology, Affiliated Zhongshan Hospital of Dalian University, Dalian,

*Corresponding author, Email:yumingyang1983@163.com

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Table

Table 1: Baseline characteristics of the study participants

Parameter (mean±SD)	Patients with rotator cuff tears (n=70)	Healthy controls (n=66)	t/χ^2	P
Gender (male/female)	36/34	30/36	0.485	0.486
Age, years	51.85±8.92	47.52±8.39	2.92	0.004
AI (°)	0.71±0.05	0.64±0.06	7.44	<0.001
LAA (°)	76.97±5.73	82.03±7.33	4.46	<0.001
CSA (°)	36.13±5.29	31.57±5.29	5.24	<0.001

AI=Acromion index, LAA=Lateral acromial angle, CSA=Critical shoulder angle, SD=Standard deviation

Figures

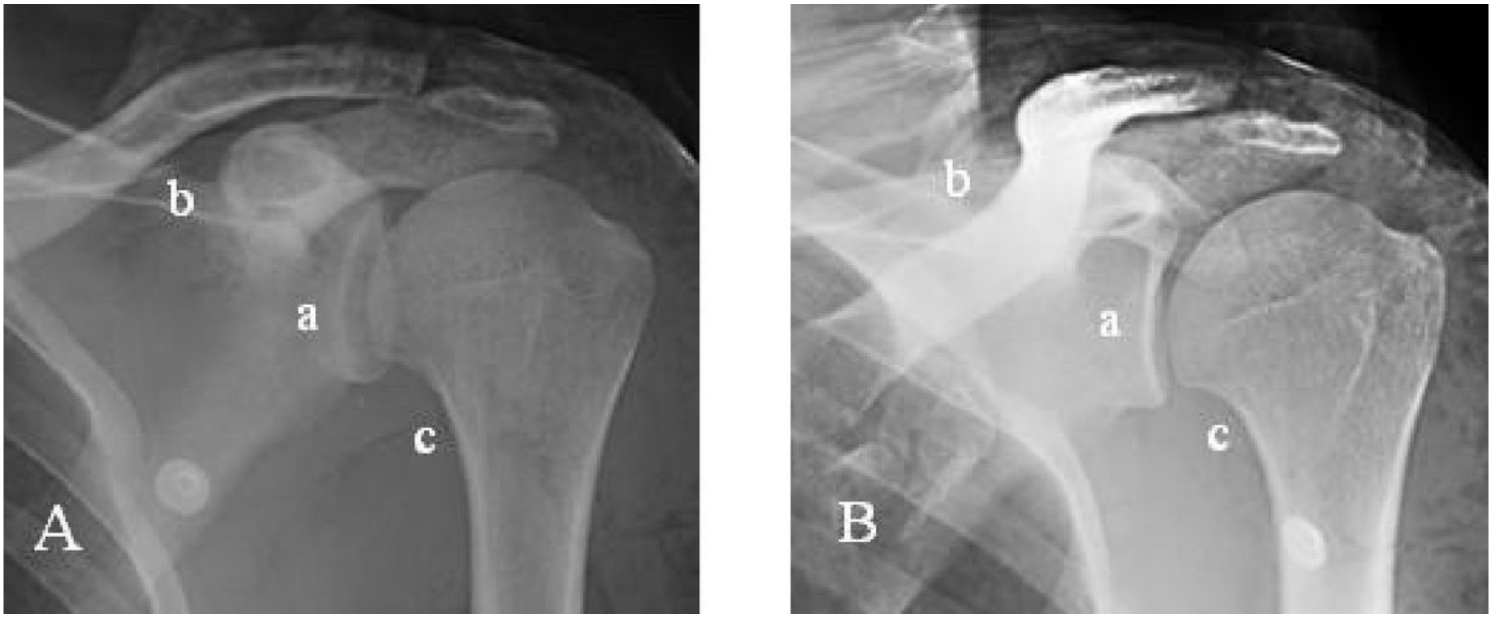

Figure 1

Standardized anteroposterior radiographs (A): The outline of the glenoid is an oval (a), the middle of the clavicle is straight (b), and the outline of the glenoid and head of the humerus overlap (c). (B): The outline of the glenoid is a line (a), the middle part of the clavicle is overlapping (b), and the joint space is visible (c)

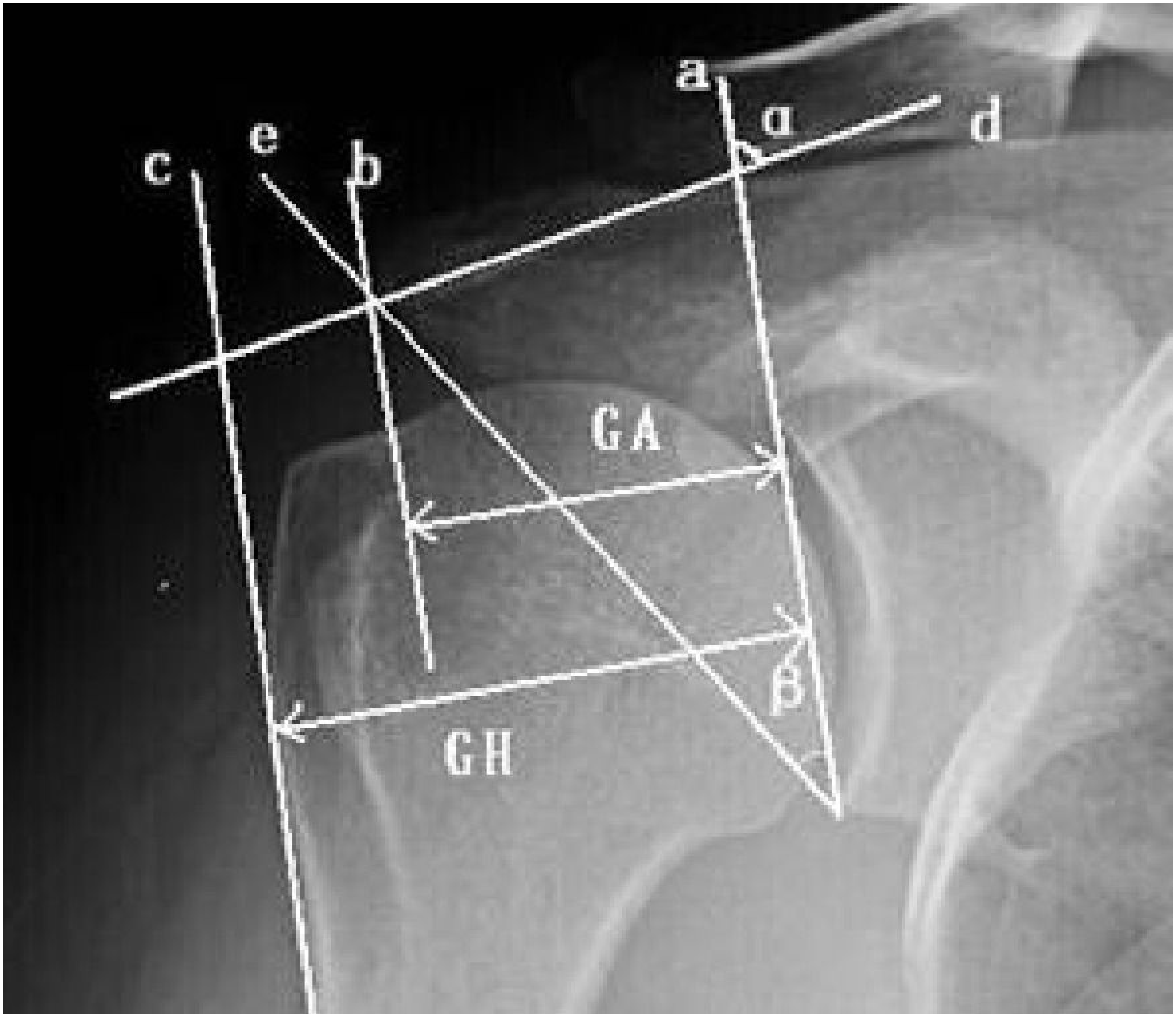

Figure 2

The acromion index was calculated by dividing the distance from line “a” to line “b” (GA) by the distance from line “a” to line “c” (GH). The lateral acromion angle (lateral acromion angle, angle α) was assessed between line “a” and line “d.” The critical shoulder angle (critical shoulder angle, angle β) was assessed between line “a” and line “e”

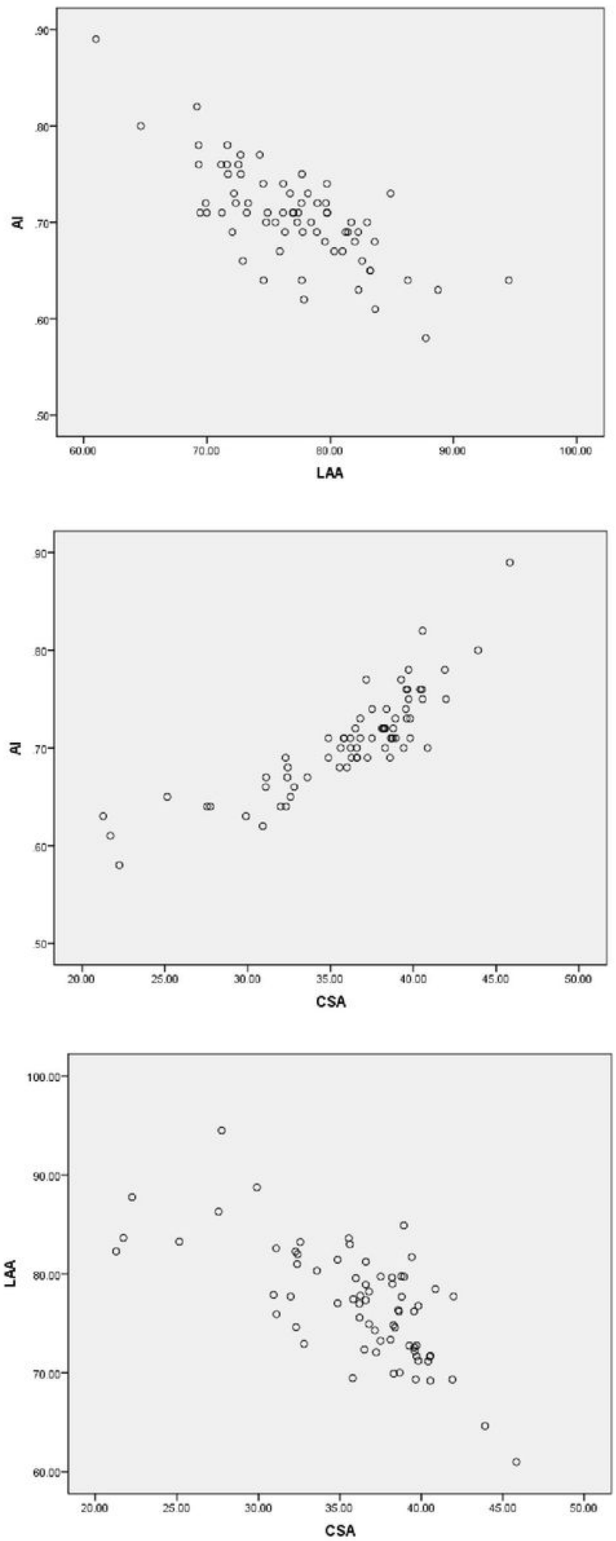

Figure 3

Patients with rotator cuff tears: There were a negative linear relationship between acromion index and lateral acromion angle and a positive linear relationship between acromion index and critical shoulder angle

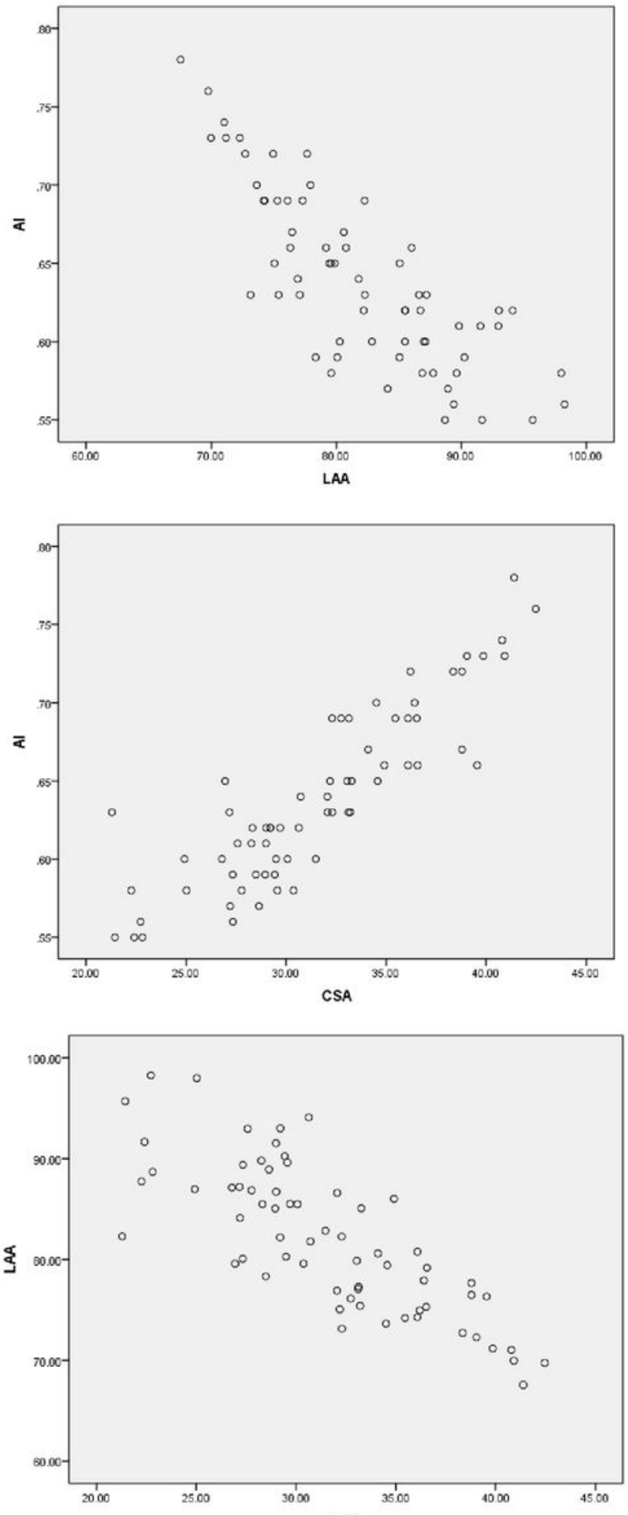

Figure 4

Healthy participants: There were a negative linear relationship between acromion index and lateral acromion angle and a positive linear relationship between acromion index and critical shoulder angle

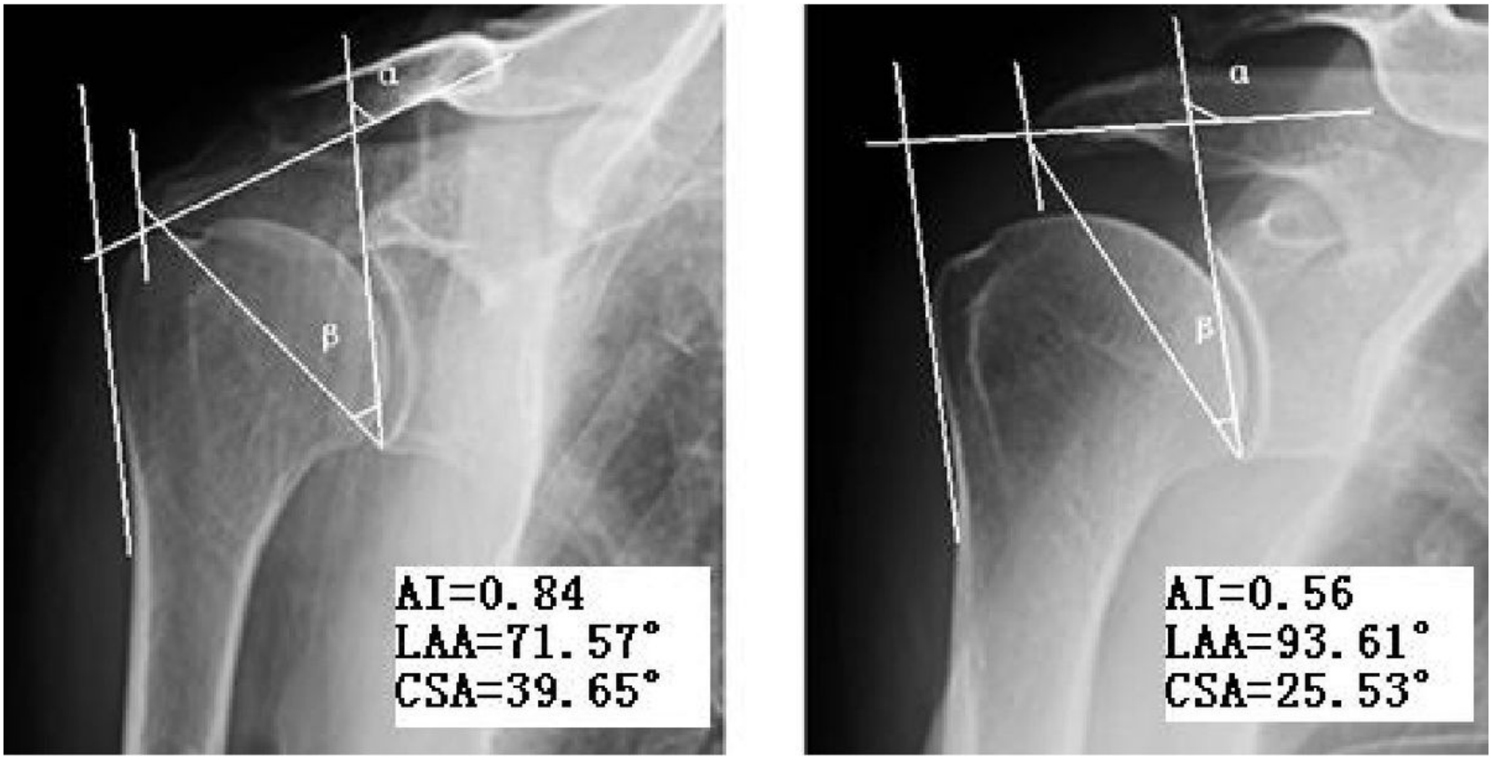

Figure 5

Radiographs demonstrate an inverse relationship between acromion index and lateral acromion angle and a positive relationship between acromion index and critical shoulder angle

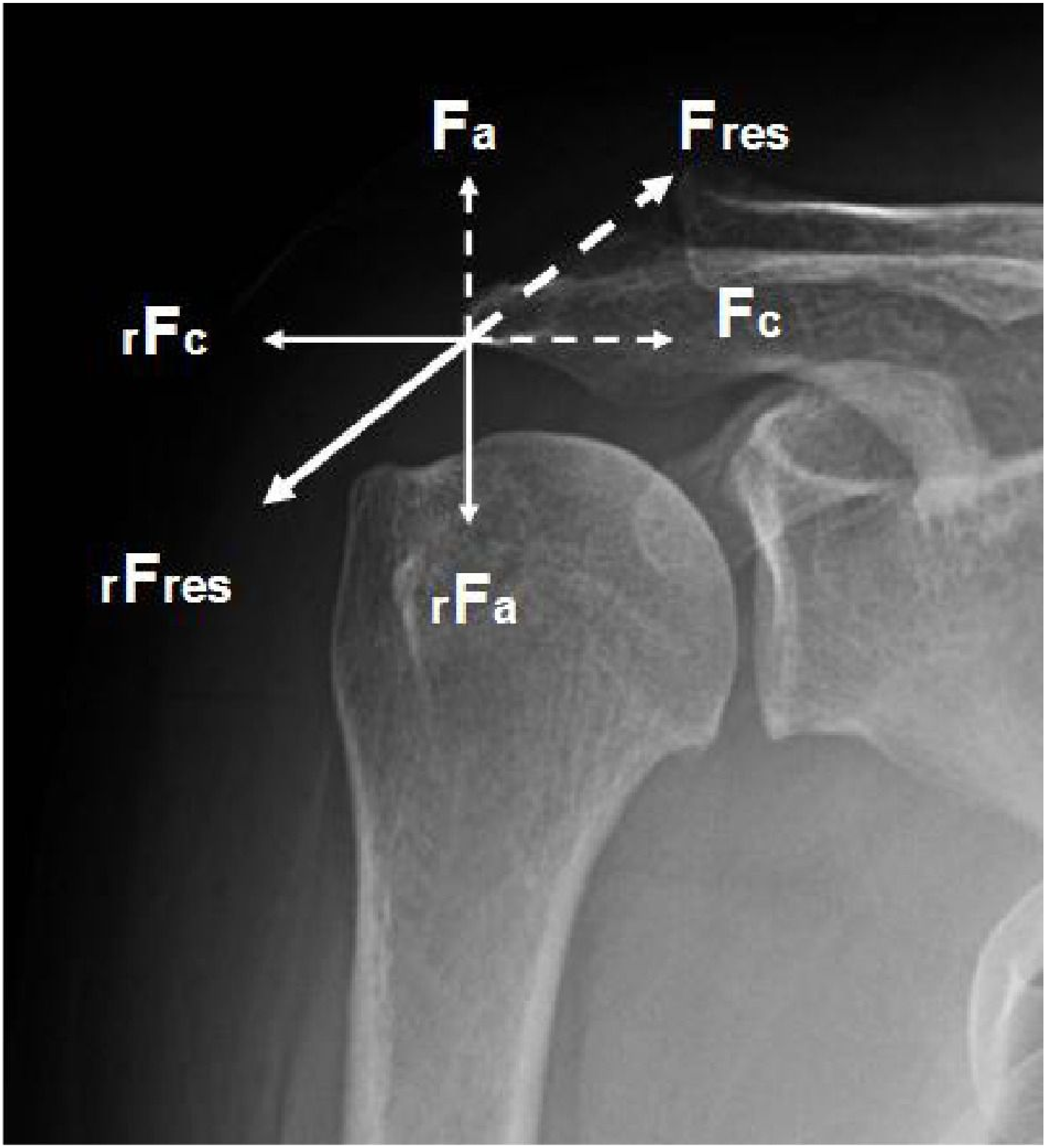

Figure 6

Schematic representation of the reaction force from the middle deltoid to the acromion. The orientation of the resultant deltoid force (Fres), which consists of an ascending force component (Fa) and compressive force component (Fc), depends on the orientation of the muscle fibers at their origin on the acromion. rFres, rFa, and rFc are reaction forces associated with Fres, Fa, and Fc, respectively