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ORIGINAL ARTICLE

Validation of the inter-individual variability of the lateral offset of the acromion

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Abstract

Introduction Anatomical variations of the lateral offset of the acromion (LOA) are supposed to be a factor favoring of the development of rotator cuff tears. The primary objective of this study is to quantify the inter-individual variations of the lateral offset of the acromion.

Methods The morphology of 103 dried scapula was studied. Scapula with an os-acromiale, fractures and osteoarthritic changes of the glenoid cavity were excluded. We measured the distance between the medial edge of the spine and the supra-glenoidal tubercle of the glenoid fossa (L_0), as well as the distance between this medial point and the most lateral point of the acromion (L_{max}). Then, the acromial offset = ($L_{max} - L_0$), in absolute value (mm) and in relative value (% of L_{max}) were calculated.

Results The absolute average offset is 3.2 cm (SD = 0.4040 cm), the relative average offset is 23.07% (SD = 2.195%). We observed a non-Gaussian distribution of the LOA, with two peaks of distribution of which average and the median offset measurements are situated between these two distributions.

Conclusion This study shows that there are two different morphologies for the scapula, characterized by the lateral offset of their acromion: small or large lateral offset. Clinical implications in shoulder pathology seem important because the resultant of the constraints applied by the deltoid to the joint would favor either rotator cuff tears, or scapulohumeral arthrosis.

Keywords Scapula · Shoulder · Acromion · Morphometry · Cuff · Impingement

Introduction

The morphology of the acromion and the tendinous degenerative pathologies of the shoulder are supposed to be connected. Since Neer's publications and the development of the concept of "the impingement syndrome" [21–23], many authors tried to which anatomical characteristics of the acromion would determine or be responsible of the onset of rotator cuff lesions [5, 6, 13, 24, 25, 30]. Bigliani et al. found an increase of prevalence of rotator cuff lesions in hooked acromion on a cadaveric study [6]. They set a classification of acromion morphology in three types, determined on 'Y' view [5]. Recently Nyffeler et al. [25] think that the lateral offset of the acromion with regard to the surface of the glenoid fossa also called "acromial index" would be one predisposing factors of rotator cuff tears in case of large extension or osteoarthritis in case of reduced lateral extension. The acromial index is estimated on plain antero-posterior view (AP views) of the shoulder and uses the plan of the glenoid cavity as reference. This has been confirmed by a clinical study published in 2013 [19]. Those authors recommend reducing the lateral offset of the acromion in case of cuff repair to prevent failures of the healing process.

Our null hypothesis is that the lateral offset of the acromion (LOA) is constant and proportional to the width of the scapula. The primary objective was to quantify the lateral development of the acromion to determine the inter-individual variations of this lateral offset.

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Materials and methods

Specimen selection

103 unpaired dried scapula of the collection of dry bones of the Institute Anatomy of Strasbourg were of use for this study. Initially 122 specimens were selected. Because some osseous deformations would interfere in our measurement protocol, 19 (15.7%) were excluded: 6 (4.9%) because of the presence of an os-acromiale, 6 (4.9%) because of macroscopic signs of degenerative osteoarthritis of the glenoid fossa, and finally 7 (5.7%) because of obvious signs of fractures or recurrent instability (impaction fracture of the antero-inferior rim of the glenoid cavity).

We first defined four constant landmarks of the scapula: the medial edge of the spine, the supra-glenoidal and the infra-glenoidal tubercles, the lateral border of the acromion.

Measurements

Each specimen was scanned (precision 0.001 mm) using a handheld Microscribe 3D digitizer (Immersion, San Jose, CA, USA) (Fig. 1). Measurements were taken by touching the specific bony landmarks. Data were directly entered into an excel sheet.

We measured (Fig. 2):

- The distance from the base of the scapular spine to the supra-glenoidal tubercle (L_0) [1, 27].
- The projection parallel to L_0 from the base of the scapular spine to the most lateral edge of the acromion process (L_{max}) [1, 27].
- The distance between the supra-glenoidal and infra-glenoidal tubercles, i.e., the height of the glenoid cavity [31].

First an intra-observer and inter-observer reliability tests were carried out to assess the validity of the methodology. Same measurements were taken on a random selection of ten separate specimens by the same researcher (one junior and one senior) for the intra-observer test and by three researchers for the inter-observer test (one supplementary resident trained for the study).

We defined the LOA as the difference between the length of the scapula (L_{max}) and the length of supra-scapular fossa (L_0). To standardize the lateral extension of the acromion (regarding inter-individual height variations) we expressed this measurement in percentage of the maximal length of the scapula, corresponding to $((L_{max} - L_0)/L_{max}) \times 100$. We also standardize this characteristic with the use of the height of the glenoid fossa $((L_{max} - L_0)/L_1 \times 100)$.

Statistical analysis

All the data were collected in an Excel sheet (Microsoft corporation, v14.3.2). All statistical analyses were performed using xlstat 2007 (Addinsoft, Paris, France). Mean, median and standard deviation were calculated for each specimen.

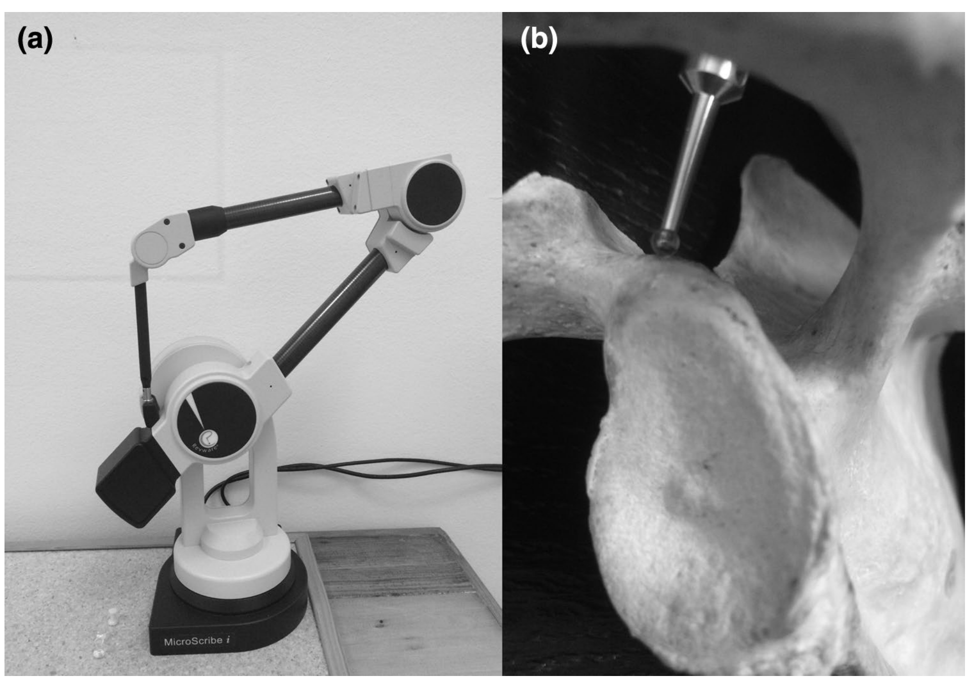

Fig. 1 **a** MicroScribe 3D digitizer (Immersion Corporation, San Jose Ca, USA), **b** closed view of the pointer

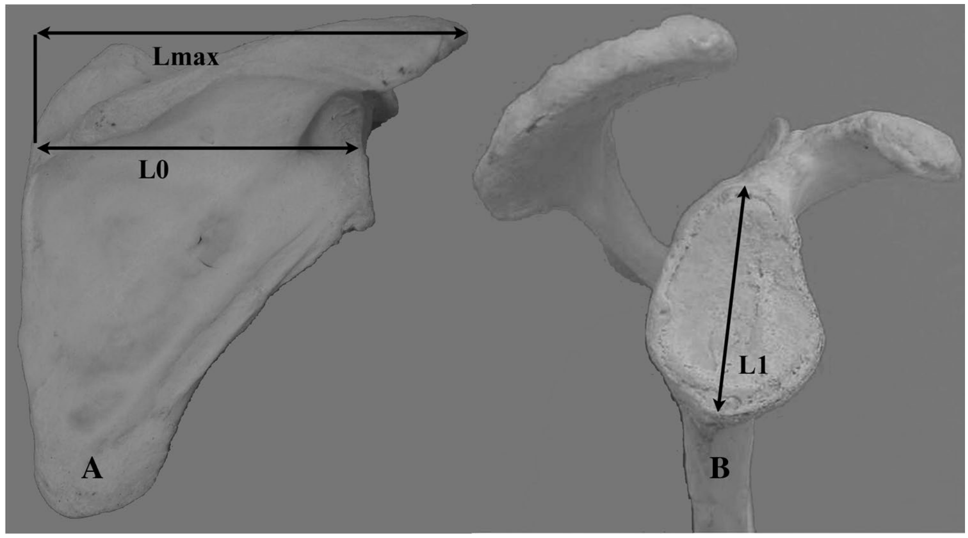

Fig. 2 Representation of measures made on the posterior aspect of the scapula (**a**) and at the level of the glenoid cavity (**b**)

The non-normal distributions of the different values were assessed by the use of the Shapiro–Wilk test.

The Cronbach reliability coefficient for the intra-observer and inter-observer reliability tests was compared (0.9—excellent, 0.8—good, 0.7—acceptable, 0.6—questionable, 0.5—poor, and < 0.5—unacceptable).

Results

Cronbach's coefficients for the intra-observer and inter-observer tests were 0.92 and 0.89, respectively. Both results indicate that there was a good to an excellent internal consistency.

The average distance L_{max} was 137.46 mm (min: 115.2, max: 159.3 mm, SD: 9.66 mm). The average length of the supra-scapular fossa L_0 was 105.71 mm (90.5–123.1 mm, SD 7.52 mm). From these data, we found a LOA ($L_{max} - L_0$) average of 31.76 mm (20.5–41.6 mm, SD in 4.04). This corresponded to 23.07% of L_{max} (SD 2.19%). The analysis of the variance of these measures was 0.661338.

The distribution of the LOA is represented in the Fig. 3. This corresponds to a non-Gaussian distribution, with two very different peaks being situated in 29.5 mm and in 35 mm.

The average height of the glenoid cavity (L_1) was 37.57 mm (SD 3.10 mm). The ratio $((L_{max} - L_0)/L_1) \times 100$

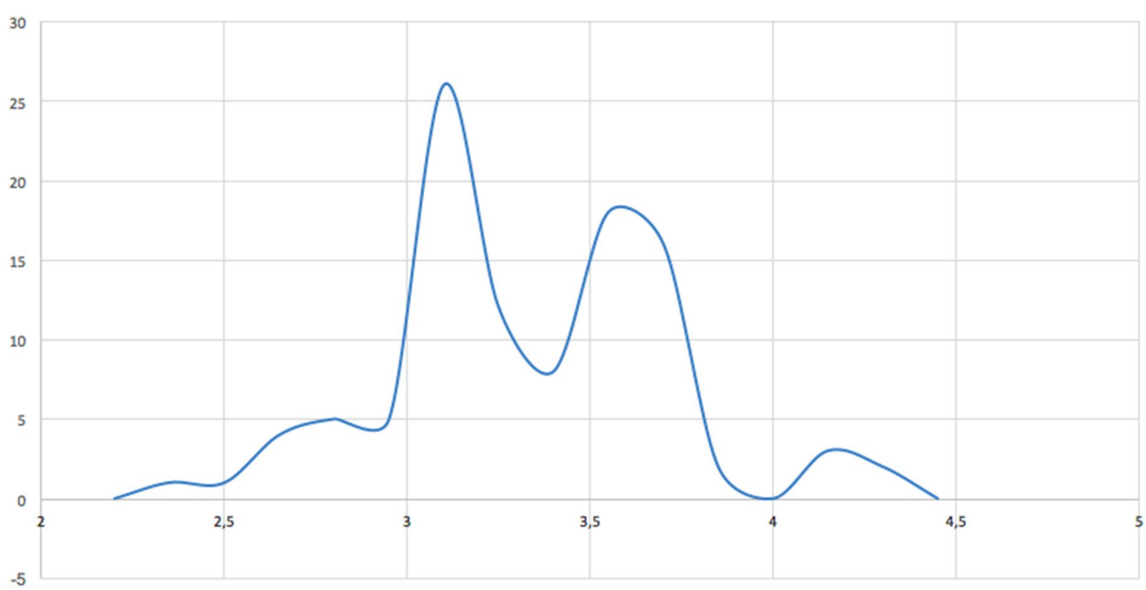

Fig. 3 Distribution of the side backwardations of the acromion. *X* axis lateral offset of the acromion (cm), *Y* axis number of scapulae

also showed a non-Gaussian distribution with in two peaks, identical to those already described above.

Discussion

Through our study we showed that there are two populations of scapula characterized by the lateral extension of the acromion process (Fig. 3). A group presents a short offset (on average: 29.5 mm), and a group a large offset (on average: 35 mm), whether we consider absolute values or ratio. The strength of our anatomical study is that our measurements are more precise than those made on X-rays because they are dependent neither on the magnification nor on the quality of X-rays in terms of incidence. Furthermore, we propose a new protocol of measures, which does not require either the plan of the glenoid surface or the humeral head diameter and which can be realized with routine CT scans.

The physiopathology of the lesions of rotator cuff tendons is complex and not clearly understood yet. The disruption of the histological architecture contributes to the tendinous degeneration that leads to degenerative ruptures [14]. In 1934, Codman [9] noted a natural fragility of the enthesis of the rotator cuff tendons. Further, based on anatomical, histological and micro-angiographies studies, the tendinous fragility was explained by a low development of the microvascular network in the distal part of the tendons and by a natural age-related degeneration of the fibers of collagens [16, 29, 32, 33]. This is responsible for a progressive metaplasic replacement of the tenocytes by chondrocytes [32]. Those intrinsic factors are worsened by extrinsic factors. For Meyer et al. [18], the bursal side of the acromion would be at the origin of irritations and erosion of the underlying tendons by friction; it is the impingement syndrome described by Neer [21–23]. This impingement is located under the first third of the antero-inferior part of the acromion, the coracoacromial ligament and the acromio-clavicular joint. The concept of impingement with the acromial arch is based on numerous studies trying to demonstrate a relation between morphology of the acromion and tendinous ruptures. Nicholson et al. [24] pointed out that the morphology of scapula evolves in time and that spurs of the undersurface of the acromion appear, but the question of their implication as cause or consequence of the tendinous pathology remains discussed [13, 26, 28, 32]. First, Bigliani has classified acromion in three types: type 1: flat, type 2: curved and type 3: hooked; the type 3 being more often associated with pathologies of the cuff [5, 6]. Bigliani and Morrison suggested a decision-making process in case of chronic tendinopathy of the cuff [5]. Those morphologies were confirmed by Natsis et al. [20]. Those authors added a fourth type of acromion with existence of enthesophytes that might be responsible of rotator cuff tears. Then Aoki et al. [2] introduced the notion of the "slope of the acromion". They found that a flattening of the acromial slope with regard to the horizontal plan on "Y"view increased the impingement of the cuff by the acromion. Banas et al. [4] determined the "lateral angle of the acromion" on MRI in the frontal plan. This corresponds to the angle between the lower face of the acromion and the glenoid surface. The authors state that if it decreases, a higher incidence of tendinous lesions is observed. All those theories remain questionable [15].

Finally, more recently, Nyffeler et al. [25] and Moor et al. [19] introduced a new hypothesis concerning the implication of the anatomy of the acromial process in the pathogeny of tendinous lesions. They studied the association existing between large extensions of the acromion measured on plain X-rays "= the critical shoulder angle" and the tendinous lesions of the supra-spinatus. They determined the acromial index as being proportional in the lateral extension of the acromion. This theory has been confirmed by clinical studies [3, 8, 11, 17]. All confirm that the hypothesis that the acromial morphology of patients with degenerative supraspinatus tendon tears differs from patients with traumatic tears. They not only demonstrated that the lateral extension of the acromion favors the supra-spinatus rupture, but their results also suggested that a short lateral extension of the acromion is a predisposing factor of osteoarthritic changes of the shoulder [12]. This difference in terms of pathogenic evolution may be related to the direction of forces applied by the mid-deltoid muscle [7, 10]. It results in a narrower subacromial space. Thus, the results of this study support the theory of external impingement as a cause for degenerative rotator cuff tears. As this study demonstrates that there are two main morphology of acromion we can infer that rotator cuff tears are manly related to intrinsic factors.

Limitations of this study lie on that our anatomical specimens are not referenced regarding the gender, the age, the height, dominant side, or the occupation of the donor. Thus, we cannot evaluate if male/female variations exist and/or if the LOA is correlated with the size of the humeral head. It was also not possible to determine if dominant side or occupation of the donor may have influenced the bony geometry.

Conclusion

In this study, we focused on the LOA to determine its variability. According to our results, there are clearly two morphological types of acromial offset: a short and a large one, confirming the existence of important inter-individual variations. As it has been shown in the literature that this plays a role in rotator cuff pathology, this would allow surgeons to include this data in the pre-operative planning of rotator factor repair. It would seem possible to us to finalize an imaging protocol allowing the shoulder surgeon to estimate the LOA in a reliable way.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no direct conflict of interest in relation with this research protocol. P. Clavert is a consultant for Wright-Tornier and is associated editor of Orthopaedics and Traumatology: Surgery and Research. There is outside funding for this research protocol.

Ethical approval As the study was conducted on cadaveric material, relevant consent had been obtained at the time of body donation in accordance with the Human Anatomy (Scotland) Act 2006.

References

1. Alobaidy M, Soames R (2016) Evaluation of the coracoid and coracoacromial arch geometry on Thiel-embalmed cadavers using the three-dimensional MicroScribe digitizer. J Shoulder Elbow Surg 25:136–141. https://doi.org/10.1016/j.jse.2015.08.036
2. Aoki M, Ischii S, Usui M (1986) The slope of the acromion and rotator cuff impingement. Orthop Trans 10:228
3. Balke M, Liem D, Greshake O, Hoeher J, Bouillon B, Banerjee M (2016) Differences in acromial morphology of shoulders in patients with degenerative and traumatic supraspinatus tendon tears. Knee Surg Sports Traumatol Arthrosc. 24:2200–2250. https://doi.org/10.1007/s00167-014-3499-y
4. Banas M, Miller R, Totterman S (1995) Relationship between the lateral acromion angle and rotator cuff disease. J Shoulder Elbow Surg 4:454–461
5. Bigliani L, Morrison D, April E (1986) The morphology of the acromion in its relationship to rotator cuff-tears. Orthop Trans. 10:228
6. Bigliani L, Ticker J, Flatow E, Soslowsky L, Mow V (1991) The relationship of acromial architecture to rotator cuff disease. Clin Sports Med 10:823–838
7. Biluart F, Gagey O, Skalli W, Mitton D (2006) Biomechanics of the deltoideus. Surg Radiol Anat 28:76–81
8. Blonna D, Giani A, Bellato E, Mattei L, Caló M, Rossi R et al (2016) Predominance of the critical shoulder angle in the pathogenesis of degenerative diseases of the shoulder. J Shoulder Elbow Surg 25:1328–1336. https://doi.org/10.1016/j.jse.2015.11.059
9. Codman E (1934) Rupture of the supraspinatus tendon. In: Codman E (ed) The shoulder. Thomas Todd Publishing Company, Boston, pp 123–177
10. Gagey O, Hue E (2000) Mechanics of the deltoid muscle. A new approach. Clin Orthop Relat Res 375:250–257
11. Garcia G, Liu J, Degen R, Johnson C, Wong A, Dines D et al (2017) Higher critical shoulder angle increases the risk of retear after rotator cuff repair. J Shoulder Elbow Surg 26:241–245. https://doi.org/10.1016/j.jse.2016.07.009
12. Heuberer P, Plachel F, Willinger L, Moroder P, Laky B, Pauzenberger L et al (2017) Critical shoulder angle combined with age predict five shoulder pathologies: a retrospective analysis of 1000 cases. BMC Musculoskelet Disord 15:259. https://doi.org/10.1186/s12891-017-1559-4
13. Hirano M, Ide J, Takagi K (2002) Acromial shapes and extension of rotator cuff tears: magnetic resonance imaging evaluation. J Shoulder Elbow Surg 11:576–578
14. Kannus P, Jozsa L (1991) Histopathological changes preceding spontaneous rupture of a tendon. A controlled study of 891 patients. J Bone Jt Surg 73:1507–1525
15. Ketola S, Lehtinen J, Arnala I (2017) Arthroscopic decompression not recommended in the treatment of rotator cuff tendinopathy: a final review of a randomised controlled trial at a minimum follow-up of ten years. Bone Jt J 99:799–805. https://doi.org/10.1302/0301-620X.99B6.BJJ-2016-0569.R1
16. Lindblom K (1939) On pathogenesis of ruptures of the tendon aponeurosis of the shoulder joint. Acta Radiol 20:563–577
17. Mantell M, Nelson R, Lowe J, Endrizzi D, Jawa A (2017) Critical shoulder angle is associated with full-thickness rotator cuff tears in patients with glenohumeral osteoarthritis. J Shoulder Elbow Surg 26:e376–e381. https://doi.org/10.1016/j.jse.2017.05.020
18. Meyer A (1931) The minuter anatomy of attrition lesions. J Bone Jt Surg. 13:341–360
19. Moor B, Bouaicha S, Rothenfluh D, Sukthankar A, Gerber C (2013) Is there an association between the individual anatomy of the scapula and the development of rotator cuff tears or osteoarthritis of the glenohumeral joint? A radiological study of the critical shoulder angle. Bone Jt J 95:935–941
20. Natsis K, Tsikaras P, Totlis T, Gigis I, Skandalakis P, Appell H et al (2007) Correlation between the four types of acromion and the existence of enthesophytes: a study on 423 dried scapulas and review of the literature. Clin Anat 20:267–272
21. Neer C (1972) Anterior acromioplasty for the chronic impingement syndrome in the shoulder: a preliminary report. J Bone Jt Surg Am 54:41–50
22. Neer C (1983) Impingement lesions. Clin Orthop 173:70–77
23. Neer C, Craig E, Fukuda H (1983) Cuff-tear arthropathy. J Bone Jt Surg Am 65:1232–1244
24. Nicholson G, Goodman D, Flatow E, Bigliani L (1996) The acromion: morphologic condition and age-related changes. A study of 420 scapulas. J Shoulder Elbow Surg 5:1–11
25. Nyffeler R, Werner C, Sukthankar A, Schmid M, Gerber C (2006) Association of a large lateral extension of the acromion with rotator cuff tears. J Bone Jt Surg 88:800–805
26. Ogata S, Uhthoff HK (1990) Acromial enthesopathy and rotator cuff tear: a radiologic and histologic postmortem investigation of the coracoacromial arch. Clin Orthop 254:39–48
27. Owaydhah W, Alobaidy M, Alraddadi A, Soames R (2016) Three-dimensional analysis of the proximal humeral and glenoid geometry using MicroScribe 3D digitizer. Surg Radiol Anat. https://doi.org/10.1007/s00276-016-1782-y
28. Ozaki J, Fujimoto S, Nakagawa S, Mashuara K, Tamai S (1988) Tears of the rotator cuff of the shoulder associated with pathological changes in the acromion: a study in cadavera. J Bone Jt Surg 70:1224–1230
29. Rathbun J, Macnab I (1970) The microvascular pattern of the rotator cuff. J Bone Jt Surg 52:540–553
30. Shah N, Bayliss N, Malcolm A (2001) Shape of the acromion: congenital or acquired—a macroscopic, radiographic, and microscopic study of acromion. J Shoulder Elbow Surg 10:309–316
31. Strauss E, Roche C, Flurin P, Wright T, Zuckerman J (2009) The glenoid in shoulder arthroplasty. J Shoulder Elbow Surg 18:819–833. https://doi.org/10.1016/j.jse.2009.05.008
32. Uhthoff H, Lohr J, Sarkar K (1990) The pathogenesis of rotator cuff tears. In: Takagishi N (ed) The shoulder. Professional Postgraduate Services, Tokyo, pp 211–212
33. Yamanaka K, Fukuda H, Hamada K, Mikasa M (1983) Incomplete thickness tears of the rotator cuff. Orthop Traumatol Surg 26:713