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Measurement of the coracohumeral distance on magnetic resonance imaging in a large patient cohort

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Background: Coracoid impingement syndrome is an increasingly recognized etiology of anterior shoulder pain. Numerus studies have documented the coracohumeral distance (CHD) as a primary or secondary measurement in symptomatic individuals, but there lacks an evaluation of CHD in a large cohort of asymptomatic individuals. The purpose of this study was to quantify a normative distribution of the CHD in a large cohort of healthy, asymptomatic subjects with no history of impingement or shoulder instability.
Methods: Incoming first-year students in the United States Military Academy were offered enrollment in this study as part of a prospective cohort to assess the normal anatomic relationships of the shoulder girdle. Magnetic resonance images were obtained, and a board-certified, fellowship-trained musculoskeletal radiologist performed measurements of the smallest distance from the coracoid to the humeral head on axial images.
Results: Magnetic resonance images of 714 subjects were available for analysis, including 630 males and 84 females, with a total of 1120 individual shoulders with images of adequate quality. The mean CHD for all shoulders imaged was 13.7 mm. The mean CHD in male shoulders was 13.8 mm, and in female subjects the average was 12.4 mm.
Conclusions: This study is the largest of its kind to evaluate the CHD in asymptomatic, healthy shoulders to date and demonstrates a mean CHD of 13.7 mm for all subjects. This information can help to standardize "normal" ranges and act as a comparison for future work, when taken in the context of age and imaging in neutral rotation.
Level of evidence: Anatomy Study; Imaging

Keywords: Coracohumeral distance; coracohumeral interval; coracoid impingement; shoulder impingement; coracoid process; rotator cuff syndrome; anterior impingement; shoulder anatomy

Coracoid impingement syndrome is a known cause of anterior shoulder pain, first noted by Goldthwait in 1909.[12] Meyer and Bennett further validated the existence of impingement on nearby structures by the coracoid process in their articles in 1937 and 1941, respectively.[2,19] Since these early articles, many anatomic, biomechanical, and clinical studies can be found in literature that address various aspects of coracohumeral impingement.[5-8,10,13,17,18,20,22-24,26,28,29]

The mechanism of coracoid impingement has been demonstrated to be compression of the biceps tendon and/

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or subscapularis tendon between the coracoid process of the scapula and the lesser tuberosity of the humerus.[6,7,25] Multiple etiologies for the condition have been identified and include traumatic, iatrogenic, pathologic, and idiopathic.[9,10,25,30]

Cadaveric studies have noted impingement between the coracoid and the humerus to be reproducible dynamically with forward flexion, abduction, or internal rotation.[4,10,23] More recently, clinical studies have noted a correlation between the presence of coracoid impingement and rotator cuff tears, suggesting degenerative capabilities of long-standing impingement.[16,17,20,24] Richards et al[24] studied the coracohumeral distance (CHD) in patients with and without subscapularis tears and noted that the CHD was significantly smaller in those with a subscapularis tear (5 vs 10 mm).

Previously, anatomic studies evaluating the CHD in healthy and in symptomatic subjects have been published.[18] Gerber et al[10] studied the CHD of asymptomatic volunteers with their shoulder either in an adducted position or in forward flexion and internal rotation. They noted a significant decrease in the CHD with the arm in forward flexion and internal rotation. Richards et al[24] noted a mean CHD of 10 mm in patients without rotator cuff pathology and 5 mm in those with subscapularis tears. Tracy et al[27] noted CHD to be narrowed in patients with clinically diagnosed coracoid impingement than in healthy volunteers on ultrasonographic imaging.

Despite there being some studies that evaluate objective measurements of coracoid impingement in healthy individuals, few studies with a large patient population have been published demonstrating an acceptable "normal" range of CHD. The purpose of this study was to quantify a normative distribution of the CHD in a large cohort of healthy, asymptomatic subjects with no history of impingement or shoulder instability.

Methods

Enrollment was offered to all incoming freshmen entering the United States Military Academy in 2006 as part of a 4-year prospective cohort study intended to evaluate modifiable and nonmodifiable risk factors for acute traumatic glenohumeral instability. All subjects were queried about history of shoulder dislocation or instability at the time of entry into the study, as well as any symptoms consistent with coracohumeral impingement. Magnetic resonance (MR) images of the shoulder were obtained for each subject on enrollment.

All MR images were performed with the arm at the side in neutral rotation, using a 1.5-tesla imaging system (Intera, Philips Medical Systems, Andover, MA, USA), with a phased-array surface coil (Synergy Flex-M, Philips Medical Systems, Andover, MA, USA). Oblique coronal turbo spin-echo fat-suppressed T2-weighted images were obtained (time to echo [TE] / time to response [TR] 50/2000; field of view [FOV] 160-180 mm; slice 4 mm, interslice gap 0.4 mm, matrix 256×256; echo train length [ETL] 8-10; number of excitation [NEX] 2). An axial 3-dimensional fast field echo sequence was performed as well (TE/TR/ flip angle [FA] 9/18/15°; FOV 160-180 mm; slice 2.4 mm; slice overlap 1.2 mm; matrix 256×256; NEX 2), and was used to produce mutiplanar reformatted images in oblique coronal and oblique sagittal planes at 1.3-mm intervals.

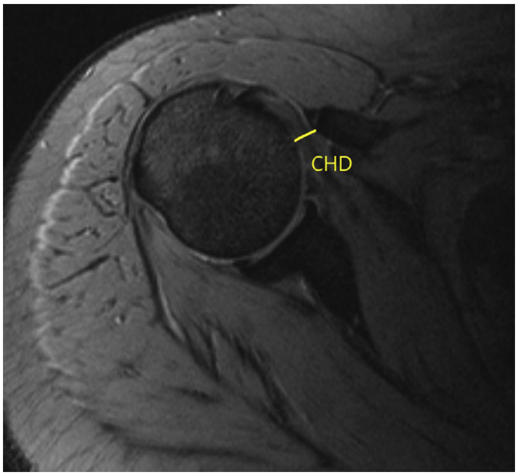

Figure 1 Representative axial magnetic resonance image demonstrating the measurement of coracohumeral distance as performed in this study. The yellow line labeled as "CHD" represents the coracohumeral distance, as measured in subjects included in this study.

The MR images obtained were interpreted by a board-certified, fellowship-trained musculoskeletal radiologist (S.E.C.) who was blind to patient information and clinical history and findings throughout the follow-up period. Measurements were performed using axial images at the level of the coracoid (Fig. 1). CHD was defined as the smallest distance between the cortex of the coracoid (typically at the posterolateral coracoid tip) and the cortex of the humeral head. Representative images of a small CHD and a large CHD are shown in Figure 2.

We conducted active surveillance within the study cohort following the initial enrollment and acquisition of MRI to identify all shoulder-related events. Because all subjects are required to participate in athletics, these injuries are documented in multiple electronic databases that were used for injury surveillance. Because of the closed health care system at the study institution and the available injury surveillance resources, our ability to detect any injuries during the 4-year study period was excellent. The subjects were not monitored at routine intervals but were at the study center during a 4-year period following the baseline MRI. Diagnosis of impingement or tear was determined by a single sports medicine fellowship-trained orthopedic surgeon (B.D.O.) who was blinded to all baseline data and MRI after injuries occurred.

Normative descriptive values including means and standard deviations (SDs) with 95% confidence intervals (CIs), medians and interquartile ranges, ranges, and percentiles were calculated for CHD for all subjects and for subjects stratified by sex.

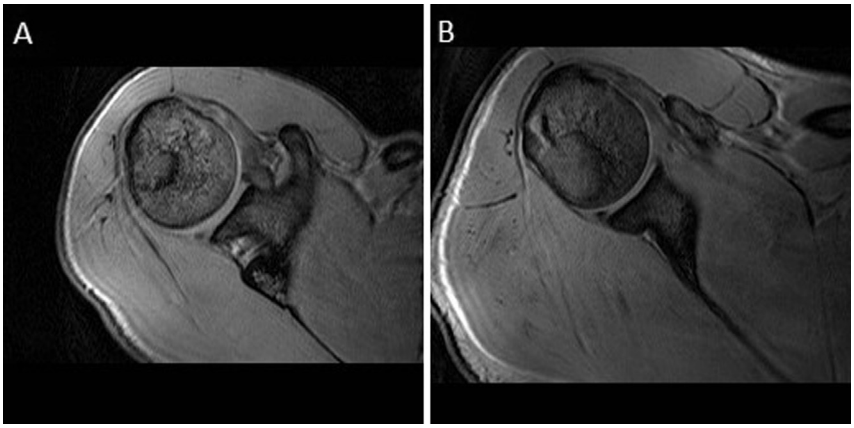

Figure 2 Representative images of a large coracohumeral distance (CHD) (**A**) and a small CHD (**B**).

Between-group differences in CHD by sex were evaluated using an independent *t* test. Statistical analysis was performed using Stata, version 10.1 (StataCorp LLC, College Station, TX, USA).

Results

Of the 714 subjects (1428 shoulders), 8 shoulders were excluded from the analyses, because of prior surgical stabilization for glenohumeral instability. This left 1420 shoulders, of which 118 shoulders had a self-reported history of instability. Of the remaining 1302 shoulders, 46 subjects had an instability event during the study surveillance period, and therefore, the affected shoulders were excluded from analysis. Of the remaining 1256 shoulders, we were able to obtain imaging for 1120 shoulders (998 males, 122 females) for analysis. Of the original 1256 eligible, we were unable to obtain imaging on 136 shoulders because of either motion artifact making it difficult to measure the CHD or logistical reason where the subjects were unavailable because of their military or school obligations or scheduling conflicts. The mean age of male subjects was 18.8 $\pm$ 1.0 years, and the mean age of female subjects was 18.7 $\pm$ 0.9 years.

The mean CHD for all shoulders was 13.7 mm (SD 3.0, 95% CI 13.5, 13.8). Shoulders of male subjects had a mean CHD of 13.8 mm (SD 3.1, 95% CI 13.6, 14.0), with a range of 6.3-25.6 mm. Female subjects had a mean CHD of 12.4 mm (SD 2.4, 95% CI 12.0, 12.8), with a range of 8.5-20.6 mm (Table I). Detailed normative data, including various percentiles and interquartile ranges, are reported for included subjections in Table I. Male shoulders had a significantly greater CHD when compared with female ($P < .001$).

During the 4-year study period, no subjects developed symptomatic coracoid impingement or subscapularis tears. Although there were no coracohumeral impingement events noted, there were 46 instability-related events documented post-enrollment, which has been reported elsewhere. These subjects were excluded from this study.

Discussion

The purpose of this study was to quantify a normative distribution of the CHD in a large cohort of healthy, asymptomatic subjects with no history of impingement or shoulder instability. As the understanding of the significance of CHD and its correlation with associated pathology continues to evolve, this study identified an average CHD of male subjects of 13.8 $\pm$ 3.1 mm, and the average CHD of female subjects of 12.4 $\pm$ 2.4 mm in shoulders without impingement or instability.

This study reports on a cohort of 1256 shoulders in 714 subjects, by far the largest cohort of measured CHD in the literature to date.

Diminished space between the coracoid and the humerus has been correlated with pathology. Although the natural history of subscapularis impingement is still uncertain, decreased CHD has been implicated in the impingement of the subscapularis muscle and its tendon. Li et al[15] found that in patients with known subscapularis tears, a smaller CHD correlated with worsening atrophy of the subscapularis muscle as well as a higher rate of associated tears in the other rotator cuff tendons. Similarly, Balke et al[1] reported their experience with patients with subscapularis tears. They classified the tears as either degenerative or traumatic and demonstrated that patients with degenerative tears had a significantly shorter CHD than patients with traumatic tears or controls (patients with supraspinatus tears). Richards et al[24] studied the CHD in patients with and without subscapularis tears and noted that the CHD was significantly smaller in those with a subscapularis tear (5 vs 10 mm). Zhang et al[31] also evaluated patients with subscapularis tears. In their cohort of 235 shoulders, they did not find a difference in the CHD

Table I Coracohumeral distance measured in subjects of this study

	Mean	SD	Range	10th %ile	25th %ile	50th %ile	75th %ile	90th %ile	IQR
Male patients (n = 998)	13.86	3.1	6.3-25.6	10.2	11.6	13.5	15.7	18.1	4.1
Female patients (n = 120)	12.49	2.41	8.5-20.6	9.8	10.7	12.2	14	15.4	3.3
All (n = 1120)	13.7	3.0	6.3-25.6	10.1	11.4	13.3	15.5	17.8	4.1

SD, standard deviation; *%ile*, percentile; *IQR*, interquartile range.
All values are in millimeters.

between patients who had an articular compared with bursal-sided tears. All of the included patients in that study did have a subscapularis tendon tear, without a control. However, they did find positive association between higher coracohumeral index (measured as the ratio between the coracoid length and the humeral head diameter on that axial MRI) and bursal-sided tears. Additionally, they showed that overlapping coracoids (with humeral heads on axial MRIs, which would generate a high coracohumeral index) and hook tips were also associated with bursal-sided subscapularis tears. Leite et al[14] also found an association with overlapping coracoids and subscapularis tendon, as well as long head of the biceps tendon pathology.

In this young, healthy, active, and predominantly male population, no coracoid impingement symptoms were observed over 4 years. This is despite the smallest CHD measured at 6.3 mm. Previously Balke et al[1] identified a mean CHD of 8.6 ± 2.0 mm in 44 patients with degenerative subscapularis tears and a mean of 10.2 ± 2.0 mm in 39 patients with traumatic subscapularis tears. The discrepancy between their findings and those reported here may be due to the difference in mean ages between the populations reported on (18.8 vs 63). To date, no literature has observed changes in the normative distribution of CHD between populations of different ages. Additionally, the study period was only 4 years, and it is possible that those with narrower CHD may develop impingement-type symptoms or subscapularis tear later in life, but earlier than their normal CHD counterparts.

Developing a standard and accepted measurement for CHD in healthy individuals continues to be difficult. A primary challenge is variability in imaging methodology. Some authors have preferred using ultrasonography,[21,27] whereas others have made measurements with MRI[1,11,24] or computed tomography.[3] Additionally, positioning has also been demonstrated to change the CHD, with the space decreasing in a position of forward flexion, cross-body adduction, and internal rotation.

Limitations do exist within this study. All images were obtained with the subjects' arms at rest in neutral rotation. Measuring the CHD at internal rotation and/or forward flexion may have provided further insight into dynamic subcoracoid impingement. In patients with suspicion of impingement or for future longer, prospective monitoring of the development of subscapularis pathology, MR sequences in internal rotation would be beneficial.

Additionally, this study is notable for being homogenous with regard to sex and age. Most of the subjects were relatively young, male, and members of the military, which likely meant that they were more muscular and physically fit compared with the general population, which may limit generalizability of the data presented. Although the female population presented here does present the largest collection of female subjects imaged for the purpose of measuring CHD, applying the population mean without taking sex into effect can lead to underestimating the average CHD for the male population or greatly overestimating the same for the female population. Similar differences between male and female subjects have been identified previously in the literature.[11]

Conclusion

This study measures CHD in the largest cohort reported to date. A mean of 13.8 ± 3.1 mm in male subjects and 12.4 ± 2.4 mm in female subjects was observed. This distance is in accord with a number of smaller, previously published studies. This information can help to standardize "normal" ranges and act as a comparison for future work, when taken in the context of age and imaging in neutral rotation.

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References

1. Balke M, Banerjee M, Greshake O, Hoeher J, Bouillon B, Liem D. The coracohumeral distance in shoulders with traumatic and degenerative subscapularis tendon tears. Am J Sports Med 2016;44:198-201. https://doi.org/10.1177/0363546515611653
2. Bennett GE. Shoulder and elbow lesions of the professional baseball pitcher. JAMA 1941;117:510.
3. Brunkhorst JP, Giphart JE, LaPrade RF, Millett PJ. Coracohumeral distances and correlation to arm rotation: an in vivo 3-dimensional biplane fluoroscopy study. Orthop J Sport Med 2013;1: 2325967113496059. https://doi.org/10.1177/2325967113496059
4. Burns WC, Whipple TL. Anatomic relationships in the shoulder impingement syndrome. Clin Orthop Relat Res 1993;(294):96-102.
5. Dines DM, Warren RF, Inglis AE, Pavlov H. The coracoid impingement syndrome. J Bone Joint Surg Br 1990;72:314-6.
6. Dumontier C, Sautet A, Gagey O, Apoil A, Augereau B, Robin H, et al. Rotator interval lesions and their relation to coracoid impingement syndrome. J Shoulder Elbow Surg 1990;8:130-5.
7. Ferrick MR. Coracoid impingement. A case report and review of the literature. Am J Sports Med 2000;28:117-9.
8. Friedman RJ, Bonutti PM, Genez B. Cine magnetic resonance imaging of the subcoracoid region. Orthopedics 1998;21:545-8.
9. Garofalo R, Conti M, Massazza G, Cesari E, Vinci E, Castagna A. Subcoracoid impingement syndrome: a painful shoulder condition related to different pathologic factors. Musculoskelet Surg 2011; 95(Suppl 1):S25-9. https://doi.org/10.1007/s12306-011-0142-7
10. Gerber C, Terrier F, Ganz R. The role of the coracoid process in the chronic impingement syndrome. J Bone Joint Surg Br 1985;67:703-8.
11. Giaroli EL, Major NM, Lemley DE, Lee J. Coracohumeral interval imaging in subcoracoid impingement syndrome on MRI. Am J Roentgenol 2006;186:242-6. https://doi.org/10.2214/AJR.04.0830
12. Goldthwait JE. An anatomic and mechanical study of the shoulder joint. J Bone Joint Surg 1909;s2-6:579-606.
13. Hughes PC, Green RA, Taylor NF. Measurement of subacromial impingement of the rotator cuff. J Sci Med Sport 2012;15:2-7. https://doi.org/10.1016/j.jsams.2011.07.001
14. Leite MJ, Sá MC, Lopes MJ, Matos RM, Sousa AN, Torres JM. Coracohumeral distance and coracoid overlap as predictors of subscapularis and long head of the biceps injuries. J Shoulder Elbow Surg 2019;28:1723-7. https://doi.org/10.1016/j.jse.2019.01.012
15. Li X, Fallon J, Egge N, Curry EJ, Patel K, Owens BD, et al. MRI study of associated shoulder pathology in patients with full-thickness subscapularis tendon tears. Orthopedics 2013;36:e44-50. https://doi.org/10.3928/01477447-20121217-17
16. Lo IKY, Burkhart SS. The etiology and assessment of subscapularis tendon tears: a case for subcoracoid impingement, the roller-wringer effect, and TUFF lesions of the subscapularis. Arthroscopy 2003;19: 1142-50. https://doi.org/10.1016/j.arthro.2003.10.024
17. Lo IKY, Parten PM, Burkhart SS. Combined subcoracoid and subacromial impingement in association with anterosuperior rotator cuff tears: an arthroscopic approach. Arthroscopy 2003;19:1068-78. https://doi.org/10.1016/j.arthro.2003.10.016
18. Masala S, Fanucci E, Maiotti M, Nardocci M, Gaudioso C, Apruzzese A, et al. Impingement syndrome of the shoulder. Clinical data and radiologic findings. Radiol Med 1995;89:18-21 [in Italian].
19. Meyer A. Chronic functional lesions of shoulder. Arch Surg 1937;35: 646.
20. Nové-Josserand L, Boulahia A, Levigne C, Noel E, Walch G. Coracohumeral space and rotator cuff tears. Rev Chir Orthop Reparatrice Appar Mot 1999;85:677-83.
21. Oh JH, Song BW, Choi JA, Lee GY, Kim SH, Kim DH. Measurement of coracohumeral distance in 3 shoulder positions using dynamic ultrasonography: correlation with subscapularis tear. Arthroscopy 2016; 32:1502-8. https://doi.org/10.1016/j.arthro.2016.01.029
22. Patte D. The subcoracoid impingement. Clin Orthop Relat Res 1990; (254):55-9.
23. Radas CB, Pieper HG. The coracoid impingement of the subscapularis tendon: a cadaver study. J Shoulder Elbow Surg 2004;13:154-9. https://doi.org/10.1016/j.jse.2003.12.007
24. Richards DP, Burkhart SS, Campbell SE. Relation between narrowed coracohumeral distance and subscapularis tears. Arthroscopy 2005;21: 1223-8. https://doi.org/10.1016/j.arthro.2005.06.015
25. Russo R, Togo F. The subcoracoid impingement syndrome: clinical, semeiologic and therapeutic considerations. Ital J Orthop Traumatol 1991;17:351-8.
26. Suenaga N, Minami A, Kaneda K. Postoperative subcoracoid impingement syndrome in patients with rotator cuff tear. J Shoulder Elbow Surg 2000;9:275-8.
27. Tracy MR, Trella TA, Nazarian LN, Tuohy CJ, Williams GR. Sonography of the coracohumeral interval: a potential technique for diagnosing coracoid impingement. J Ultrasound Med 2010;29:337-41. https://doi.org/10.7863/jum.2010.29.3.337
28. Wuelker N, Plitz W, Roetman B. Biomechanical data concerning the shoulder impingement syndrome. Clin Orthop Relat Res 1994;(303): 242-9.
29. Yamamoto N, Muraki T, Sperling JW, Steinmann SP, Itoi E, Cofield RH, et al. Contact between the coracoacromial arch and the rotator cuff tendons in nonpathologic situations: a cadaveric study. J Shoulder Elbow Surg 2010;19:681-7. https://doi.org/10.1016/j.jse.2009.12.006
30. Yel M, Parham M, Burkhead WZ. Old unreduced posterior sternoclavicular dislocation and coracoid impingement. Proc (Bayl Univ Med Cent) 2001;14:243-5.
31. Zhang H, Zhang Q, Li ZL. Coracohumeral index and coracoglenoid inclination as predictors for different types of degenerative subscapularis tendon tears. Int Orthop 2019;43:1909-16. https://doi.org/10.1007/s00264-018-4078-5