ORIGINAL ARTICLE

The Rotator Cuff Footprint in Filipinos: A Cadaveric Study

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ABSTRACT

Introduction. Rotator cuff tears are one of the common etiologies of shoulder pain. Rotator cuff repair is recommended for a patient who failed conservative treatment. Proper knowledge of the rotator cuff footprint is needed in restoring correct anatomy during the repair. The size of the footprint is important in determining the kind of repair.

Objective. This study aimed to define the average measurements of the rotator cuff footprint on the humerus in Filipino cadavers.

Methods. This is a descriptive, cross-sectional study of preserved human cadaver upper extremity specimens. We measured the length, width, and shape of the supraspinatus, infraspinatus, subscapularis, and teres minor.

Results. We obtained 27 upper extremity specimens. The median age of the source cadavers was 50.5 years with the equal male-to-female distribution. The mean measurement of the supraspinatus is 22.92 mm in length and 10.17 mm in width. The shape of the supraspinatus was found to be trapezoidal. The infraspinatus length was found to be 17.20 mm and the width at 10.72 mm. Its shape was found to be trapezoidal. The teres minor length was measured at 15.15 mm and the width at 11.04 mm. The shape was mostly trapezoidal but some were triangular. Finally, the subscapularis length was 17.68 mm while the width was 11.26 mm. The shape was trapezoidal or comma-shaped.

Conclusion. The average measurement of the rotator cuff footprint was found to be smaller in our study than reported in terms of length and width. The footprint shape was similar to the studies reported.

Keywords: rotator cuff, footprint, supraspinatus, infraspinatus, teres minor, subscapularis, Filipino, anatomic, cadaveric

INTRODUCTION

Shoulder pain is one of the most common musculoskeletal conditions, occurring in 7 to 26% of the population,[1] more so in the aging population. Rotator cuff tears are one of the common etiologies of shoulder pain, occurring more commonly in the elderly. However, not all rotator cuff tears are symptomatic. In a study by Minagawa, symptomatic rotator cuff tears occur in 34.7% of patients while 65.3% of tears remain asymptomatic.[2] Symptomatic rotator cuff tears can be a significant burden that needs surgical intervention.

Rotator cuff repair is dependent on the size of the tears. It can be classified as partial or full thickness. For partial-thickness rotator cuff tears, an accurate measurement of the rotator cuff footprint is needed to determine if it is an articular-sided or bursal-sided partial rotator cuff tear.[3] Full-thickness rotator cuff tears are classified based on the size of the tear (anterior-posterior measurement)[4] and the

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degree of retraction[5]. Surgical management is guided by the size of the tear. These measurements have been conducted in Caucasian shoulders[6–8] which may not be applicable to Asian, particularly Filipino, shoulders.

There are no published studies on the average anatomy of the rotator cuff in Filipino cadavers. Most studies have been conducted on Caucasian populations; this does not translate to our population. Poor landmarks can lead to non-anatomic reconstruction, which can lead to improper surgical management.

This study aimed to define the average measurements of the rotator cuff footprint on the humerus in Filipino cadavers, including the length, width, and shape.

METHODS

Study Design

This is a descriptive, cross-sectional study on preserved human cadaver upper extremity specimens at the Department of Anatomy, College of Medicine, University of the Philippines Manila.

Sample Size Computation

We used Meurs'[9] calculations to estimate a sample size of fifty-two, assuming to achieve a Power (1-β) of 0.90 and an α of 0.05.

Selection of Specimens

We obtained pre-dissected, formalin-preserved upper extremity specimens containing the humerus and rotator cuff. The scapula was not included in the specimens. The cadavers were all of Filipino race and donated to the Department of Anatomy, usually coming from the Philippine Center for Mental Health, by Section 15.2 of the IRR of PD 856 (PD 856).[10] Each donated body has death certificates that are duly signed by in-house physicians. Requirements on the use of remains for scientific purposes are in accordance with ethical, legal, and regulatory requirements.

The cadavers were previously used by UP College of Medicine 1st year students for Gross Anatomy dissection sessions during the academic year 2018-2019. We excluded specimens with existing fractures, or muscle or tendon tears. Formalin-preserved specimens were considered suitable for our study since they have similar gross morphometric properties (e.g., length, width, cross-sectional area, etc.) to Thiel and frozen cadavers.[11]

Preparation of Specimens

The specimens were mounted onto a vice. The skin and superficial tissues were stripped off. The rotator cuff muscles were identified and isolated, tracing to their insertion on the humerus. The rotator cuff was separated from each other starting medially. The supraspinatus and subscapularis were separated from the rotator interval. The same was done for the infraspinatus and teres minor going from medial to lateral dissection to separate the muscles. Dissection was done by two investigators (KG, a board-certified orthopedic surgeon, and JA, a resident trainee in Orthopedics) (Figure 1).

Measurements

We measured the length, width, and shape of the following:

1. supraspinatus insertion
2. infraspinatus insertion
3. subscapularis insertion
4. teres minor insertion

The laterality of the specimens was recorded. Age and sex variables for the entire batch of cadavers (N=40) from where the specimens were obtained.

The tendons were cut close to their insertions and the footprints of each muscle were outlined in permanent ink. All soft tissues were stripped from the humeral head, leaving the ink outlines. The length and width of each footprint were measured with a digital vernier caliper and recorded up to 1 decimal place. The insertion outline was traced with a permanent marker to record the shape (Figure 1). All measurements were done three times by two investigators (Figure 2), and the average measurement was taken. Inter-rater reliability was measured to determine the degree of agreement between two orthopedic surgeons.

Data Analysis

The average of three measurements, in millimeters, of the length and width of rotator cuff muscle insertions by each of the two raters for each cadaver was recorded. The inter-rater reliability between two investigator combinations for the measurement of the length and width of rotator cuff muscle insertions was determined by intraclass correlation analysis. The degree of agreement was considered high for ICC of 0.80 and higher; moderate for ICC=0.60 to 0.79; weak for ICC= 0.40 to 0.59, and minimal for ICC=0.40 and lower. These measurements from twenty-seven cadavers were summarized as means and standard deviations. Data analysis was performed using Stata version 17. There were no missing data from the dataset. Intraclass correlation and mean estimates were accompanied by 95% confidence intervals.

Ethical Considerations

As this is a study on preserved cadavers, an exemption was secured from the Research Ethics Board (UPMREB 2022- 0495-EX). Permission from the Department of Anatomy was obtained. We adhered to the Data Privacy Act of 2012 to maintain the privacy of all data. All cadavers were deidentified of any personal information (name, address, contact number). All data were stored on a password-protected computer accessible only to the investigators. All data will be wiped out after two years of dissemination or publication of the study.

Figure 1. Tracing insertion with permanent marker.

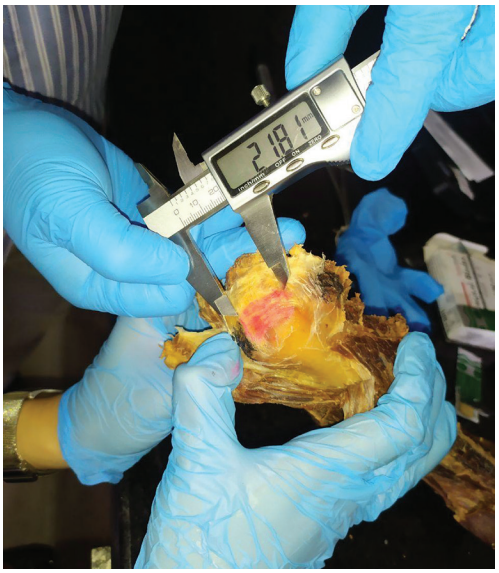

Figure 2. Measurement of the supraspinatus footprint between the biceps groove and the bare area using a calibrated caliper in a trapezoidal fashion.

RESULTS

We obtained 40 upper extremity specimens (humerus and rotator cuff) but excluded 13 due to fractures or muscle/tendon tears. The median age of the cadavers in the cadaver pool was 50.5 (range, 24, 75), with a male: female ratio of 1.1:1. Out of 27 specimens, 15 were left upper extremity and 12 were right upper extremity.

The measurements are shown in Table 1. The mean measurement of the supraspinatus is 22.92 mm in length and 10.17 mm in width. The shape of the supraspinatus was found to be trapezoidal. The infraspinatus length was found to be 17.20 mm and the width at 10.72 mm. Its shape was found to be trapezoidal. The teres minor length was measured at 15.15 mm and the width at 11.04 mm. The shape was mostly trapezoidal but some were triangular. Finally, the subscapularis length was 17.68 mm while the width was 11.26 mm. The shape was trapezoidal or comma-shaped (Figure 3).

There was a high inter-rater agreement for all measurements (ICC of 0.89 to 0.99) (Table 2). Inter-rater reliability was measured to evaluate the degree of agreement between two individuals. High inter-rater agreement showed that the method used was reproducible and has higher accuracy.

DISCUSSION

The exact anatomy of the rotator cuff footprint is crucial when performing rotator cuff repair. Classification is based on the size, in particular the anterior to posterior length (AP length). In our study, the average AP lengths of the rotator cuff muscle were 22.92 mm for the Supraspinatus, 17.2 mm for the Infraspinatus, 15.5 mm for the Teres Minor, and 17.68 mm for the Subscapularis. The combined length of the supraspinatus and infraspinatus was 40.12 mm. Our results are similar to studies conducted on Asian shoulders (Table 3). In a study by Mochizuki et al.[12], the average length of the supraspinatus footprint was 12.6 mm. The infraspinatus footprint has an average maximum length of 32.7 mm. The combined length of the supraspinatus and infraspinatus was 45.3 mm.

Table 1. Mean Measurements for Length and Width of Insertions of Rotator Cuff Footprint

Muscle	Length		Width		Footprint Area	
	Mean [95% CI]	SD	Mean [95% CI]	SD	Mean [95% CI]	SD
Supraspinatus	22.92 [21.46, 24.39]	3.70	10.17 [9.69, 10.65]	1.21	275.98 [247.60, 304.36]	71.75
Infraspinatus	17.20 [15.93, 18.47]	3.20	10.72 [10.09, 11.35]	1.59	215.48 [197.13, 233.83]	46.39
Teres minor	15.1 [14.49, 15.81]	1.66	11.04 [10.42, 11.65]	1.56	193.51 [179.80, 207.21]	34.64
Subscapularis	17.68 [16.35, 19.00]	3.35	11.26 [10.54, 11.97]	1.80	228.53 [207.40, 249.65]	53.40

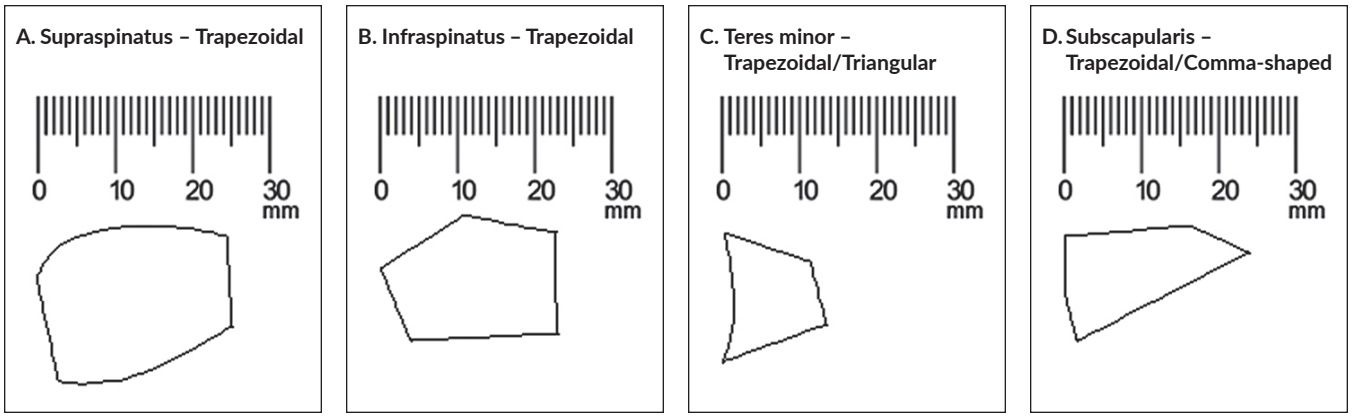

Figure 3. Representative tracing of Insertion shapes **(A)** Suprasinatus, **(B)** Infraspinatus, **(C)** Teres Minor, and **(D)** Subscapularis (Specimen #1).

Table 2. Inter-rater Reliability in Measuring the Length and Width of Rotator Cuff Muscle Insertions between Two Raters

Muscle	Investigators 1 and 2			
	Length		Width	
	ICC	95% CI	ICC	95% CI
Supraspinatus	0.8944	0.7683, 0.9519	0.9693	0.9327, 0.9860
Infraspinatus	0.9895	0.9770, 0.9952	0.9658	0.9249, 0.9844
Teres minor	0.9460	0.8815, 0.9754	0.9734	0.9416, 0.9879
Subscapularis	0.9905	0.9791, 0.9957	0.9677	0.9290, 0.9853

**moderate agreement; **weak agreement; ***minimal agreement*

The mean measurements in our study were also similar to those of an unpublished study conducted in another Philippine medical school,[13] except for the infraspinatus insertion length, which was around 5 mm shorter in our study (17.20 vs 23.95 mm) and the length of the supraspinatus insertion length, which was 5 mm longer in our study (22.92 vs 15.3 mm). Garrido[13] noted that there was a slight overlap of the anterosuperior portion of the infraspinatus on the posteroinferior portion of the supraspinatus. If we were to combine the lengths and widths of the supra and infraspinatus muscles, the sum from this study would be comparable to Garrido's (2012) study (40.12 mm vs 39.25 mm). Curtis has previously noted an overlap zone between the infraspinatus and supraspinatus, which may account for the difficulty in isolating these muscles.[8]

Our results are much smaller than the results reported by Curtis. In his study, the average supraspinatus AP length is 23 mm and the infraspinatus is 29 mm. The combined length of supraspinatus and infraspinatus is 52 mm.

The supraspinatus and infraspinatus length has been the basis of most classifications on rotator cuff tears.

The classification of rotator cuff tears by Cofield[4] takes into account the anterior-posterior length of the tear. This classification has been widely used in literature. He classified tears as small if the tear is less than 1 cm, medium if it is 1 to 3 cm, large if it is 3 to 5 cm, and massive if it is greater than 5 cm. Massive tears were denoted as a full tear of both the supraspinatus and infraspinatus. Based on our study, the combined length of supraspinatus and infraspinatus is only 40.12 mm.

The mediolateral width of the rotator cuff is important when considering the size of partial rotator cuff tears. Ellman[14] devised a classification of partial rotator cuff tears based on the mediolateral width of the rotator cuff. In his classification, partial tears greater than 6 mm is considered large which accounts for more than 50% of the mediolateral thickness. It was based on a study by Ruotolo[15] which showed that the mean width of the supraspinatus was at 12.1 mm mid-tendon. In our study, the mean width of the supraspinatus was 10.17 mm while for the infraspinatus it was 10.72 mm. This is similar to the study of Dugas[7] which measured the width of the supraspinatus at 12.7 mm and the infraspinatus at 13.4 mm. In the study by Curtis[8], the mean width is larger with the supraspinatus width at 16 mm and the infraspinatus width at 19 mm.

Compared to some foreign literature, our measurements were smaller, particularly the subscapularis (mean 17.68 x 11.26 mm). In literature, the subscapularis is 80% longer in the study by Curtis[8] at 40 mm and Ide[16] at 39 mm. It is wider at around 20 mm width based on the study by Curtis[8] and Naidoo[17]. However, our results are similar to the study done by Naidoo at 22.57 mm and Dugas at 24.3 mm. It seems race

Table 3. Comparison of Measurements from Previous Studies

Author		Supraspinatus	Infraspinatus	Teres minor	Subscapularis
Current study	Measurement	Anteroposterior: 22.92 mm Mediolateral: 10.17 mm	Anteroposterior: 17.2 mm Mediolateral: 10.72 mm	Anteroposterior: 15.15 mm Mediolateral: 11.04 mm	Anteroposterior: 17.68 mm Mediolateral: 11.26 mm
	Shape	Trapezoidal	Trapezoidal	Trapezoidal/ triangular	Trapezoidal/ comma-shaped
Garrido 2012 Philippines unpublished (40 unspecified cadavers)	Measurement only	Anteroposterior: 15.3 mm Mediolateral: 12.15 mm	Anteroposterior: 23.95 mm Mediolateral: 14.9 mm	Anteroposterior: 14.58 mm Mediolateral: 13.58 mm	Anteroposterior: 17.38 mm Mediolateral: 12.05 mm
Curtis 2006 Boston, USA (20 fresh frozen cadavers)	Measurement	23 x 16 mm	29 x 19 mm	29 x 21 mm	40 x 20 mm
	Shape	Trapezoidal	Trapezoidal	Triangular	Comma-shaped pattern
Dugas 2002 New York, USA (20 fresh frozen cadavers)	Measurement only	Anteroposterior: 16.3 mm Mediolateral: 12.7 mm	Anteroposterior: 16.4 mm Mediolateral: 13.4 mm	Anteroposterior: 20.7 mm Mediolateral: 11.4 mm	Superoinferior: 24.3 mm Mediolateral: 17.9 mm
Naidoo 2016 South Africa (40 formalin cadavers)	Measurement	Mediolateral distance: 20.14 ± 5.38 mm Superoinferior: 15.20 mm	Mediolateral distance: 19.07 ± 4.74 mm Superoinferior: 19.49 mm	Mediolateral: 15.33 mm Superoinferior: 19.02 mm	Superoinferior: 22.57 mm
	Shape	Rectangular and round	Oval and triangular	Round	Oval and triangular
Lumsdaine 2015 Australia (27 Genelyn™-embalmed cadavers)	Measurement	Anteroposterior (medial): 20.4 mm Anteroposterior (lateral): 6.3 mm Maximal mediolateral width: 6.6 mm	Anteroposterior (medial): 22.6 mm Anteroposterior (lateral): 25.4 mm Maximal mediolateral width: 12 mm	-	-
	Shape	Trapezoidal	Circular	Wider attachment	-
Mochizuki 2008 Tokyo, Japan (64 unspecified cadavers)	Measurement	Anteroposterior: 12.6 mm Mediolateral: 6.9 mm	Anteroposterior: 32.7 mm Mediolateral: 10.2 mm	-	-
	Shape	Triangular	Trapezoid	-	-
Ide 2008 Japan (56 unspecified cadavers)	Measurement	-	-	-	Anteroposterior: 39.5 mm Mediolateral: 16 mm
	Shape	-	-	-	Comma-shaped
Addesi 2006 Pennyslyvania, USA (14 embalmed cadavers)	Measurement only	-	-	-	Superoinferior: 25.8 mm Mediolateral: 18.1 mm
Ruotolo 2004 California, USA (48 unspecified cadavers)	Measurement only	Anteroposterior: 25 mm Superoinferior: 12 mm	-	-	-
Minagawa 1998 Japan (52 embalmed cadavers)	Measurement only	Anteroposterior: 22.5 mm	Anteroposterior: 12.9 mm		

is not a factor for the subscapularis length since Ide's study is also done on Asian shoulders.

The footprint shape was described by Curtis[8] in his study. The supraspinatus and infraspinatus were both trapezoidal. The teres minor was triangular and the subscapularis was comma-shaped. The subscapularis was described to have a wider proximal end and a narrow distal end in a shape of a comma. In our study, almost all the footprint shapes were trapezoidal. We did note some samples with similar comma shapes for the subscapularis. Since most subscapularis tears occur in the proximal end of the muscle, this gives surgeons more space to repair the tear with anchors.

Summary of all previous studies are shown in Table 3.

CONCLUSION

The average measurement of the rotator cuff footprint was found to be smaller in our study than reported in terms of length and width. The footprint shape was similar to the studies reported. This study will serve as a guide for shoulder surgeons on how to estimate the degree of tear and how to recreate the native footprint in Filipino during rotator cuff repair.

Recommendations

Further studies using newer embalming methods or fresh frozen cadavers may be undertaken to confirm the measurements gathered from our study of formalin-preserved cadavers. Because of the pandemic, cadavers for dissection in the anatomy courses of the UP College of Medicine and preservation methods using the Thiel were limited. Another limitation is majority of the cadavers used were pre-dissected, formalin preserved prior to the start of the study, hence we were not able to determine the age and sex of each humerus which could affect the size of the rotator cuff footprint. For future studies, we recommend to correlate the age and sex to the size of the rotator cuff footprint.

Statement of Authorship

All authors certified fulfillment of ICMJE authorship criteria.

Author Disclosure

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