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Research Article

A Morphometric and Morphological Analysis of Superior Border of Dry Scapulae

Duygu Akin Saygin[1], Fatma Nur Turkoglu[2], Anil Didem Aydin Kabakci[1], Serife Alpa[2], Mehmet Tugrul Yilmaz[1]

[1]Necmettin Erbakan University, Meram Medicine Faculty, Department of Anatomy, Konya, Türkiye
[2]KTO Karatay University, Faculty of Medicine, Department of Anatomy, Konya, Türkiye

Abstract

Aim: The recognition of the scapula anatomy and visible variations is important in surgical treatments and arthroscopic procedures in case of any diseases of the shoulder. The morphological and morphometric characteristics of the scapular notch on the superior margin are very important. Because compression of the suprascapular nerve extending inside the scapular notch causes entrapment neuropathy. Therefore, the present study was planned in order to contribute to us as well as practitioners about morphometric and morphological characteristics of the superior margin of the scapula.

Materials and Methods: Morphometric measurements (SL: scapula length; SW: scapula width; SI: scapula index; STD: superior transverse diameter of the scapular notch; MTD: medial transverse diameter of the scapular notch; VD: vertical diameter) were performed on 90 (50 left; 40 right) scapulae of Turkish population without unknown age and gender. Furthermore, the superior scapular margin and the scapular notch were categorized through observational classification as well as measurement.

Results: The mean scapular width was detected 98.87±7.71 mm on the right and 94.38±13.01 mm on the left. The scapula index was measured 67.51±4.40 mm on the right and 63.80±8.29 mm on the left. The SL, STD, and VT was larger on the left; the SW, SI, and MTD were larger on the right. The difference between right and left for the SW and SI measurements was statistically significant ($p<0.005$). The most common scapular notch appearance, the U shape (64.4%) was the most common scapular notch shape as VD>MTD (%48.9). The most common superior margin type was moderately oblique (41.1%).

Conclusion: We believe that the data obtained would be helpful for orthopedic surgeons in intramedullary nailing and radiologists in the differential diagnosis of some osteolytic lesions in that region. Furthermore, scapula measurements would help to identify the gender and race in forensic medicine and anthropology.

Keywords: Scapular notch, scapulae, variation, morphometry, anatomy

INTRODUCTION

The shoulder joint is one of the structures that performs important functions in the human body. Bone, joint, and muscle support the shoulder joint. The scapula is the basic bone of the shoulder. The scapula is a flat bone with three margins, three angles, and two surfaces at the level of the 2nd and 7th ribs (1). Recognition of the detailed anatomical information in order to understand the scapula, glenohumeral dislocation, rotator cuff injuries, arthritis, tumors and developmental anomalies on the shoulder region will facilitate the surgical and arthroscopic procedures performed on this region (1,2).

The thinnest and shortest margin of the scapula is the superior margin (SM). Important muscles such as the levator scapula and the supraspinatus for initiation of upper extremity movements attach to this margin.

A notch called the scapular notch scapulae exist on the superior margin. A ligament called the trasverse scapular ligament exist on this notch extending like a bridge and converts the notch into a foramen. The suprascapular nerve extends inside this foramen; the subscapular artery and vein exist over this nerve. The suprascapular nerve may be compressed through extension as a result of the structure of the foramen and compression of some structures in the region, and suprascapular entrapment

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Corresponding Author: Duygu Akın Saygin, Necmettin Erbakan University, Meram Medicine Faculty, Anatomy Department, Konya, Türkiye **E-mail**: d.akin.42@hotmail.com

neuropathy may develop (3). The orthopedic surgeons suggest that the suprascapular nerve entrapment and traction injuries are mostly caused by the scapular notch (4). The depth and size of the scapular notch varies among the individuals. Changing the width and depth of the notch causes varying degrees of compression of the nerve (3). The superior transverse scapular ligament ossificates in some cases and the foramen may completely convert into a formation surrounded by osseous formation.

In addition to investigating the morphometric feature of dry bone scapulae, determination of the differences between ethnic groups in the classification of bones according to their morphological features has been tried in recent years. The aim of the present study was to assess morphometric and morphological characteristics of the scapulae of Turkish population in Middle Anatolia region. Furthermore, another aim was to reveal the correlation between scapula measurements and the scapular notch.

MATERIAL AND METHOD

The present study was conducted on 90 (40 right, 50 left) scapula with unknown age and gender in the bone collection of Anatomy Departments of Meram Faculty of Medicine within Necmettin Erbakan University and Faculty of Medicine within KTO Karatay University. The permits required for the study were obtained by 0017 numbered decision of Research Ethics Committee of KTO Karatay University in 2019. The scapulae with variational and fracture deformity were excluded.

The scapulae of our study were examined under two titles including morphometric measurements and morphological classifications of the superior margin (SM) and the scapular notch (inc.). Morphometric measurements were performed by a digital caliper (Mitutoyo Dial caliper gauge, Tokyo, Japan, sensitivity 0.01 mm) and osteometric board (sensitivity 0.1 mm). The measurements were taken by the same person three times and the average of these measurements was obtained in order to have the highest level of measurement reliability in morphometric measurements. Morphological evaluations were performed by photographing from the same distance with a micrometer scale and by a single person both on the photograph and on the bone.

1. Morphometric Measurements (Figures 1A, B)

a) Scapula measurements

Scapula length (SL): The widest upper-lower distance between superior and inferior angles.

Scapula width (SW): The widest medio-lateral distance between the lateral angle and lower margin of the scapular trigon (Figure1A).

Scapula index (SI): It was calculated by SI:SW*100/ SL (5) formula.

a) Measurements of the scapular notch

Superior transverse diameter of the scapular notch (STD): The upper transverse diameter of the scapular notch.

Medial transverse diameter of the scapular notch (MTD): The medial transverse diameter of the scapular notch.

Vertical diameter of the scapular notch (VD): The vertical diameter of the scapular notch was measured (Figure 1B).

Figure 1. Morphometric evaluation of the scapula and scapular notch (SW: The width of scapula, SL: The length of scapula; STD: Upper transverse diameter of scapular notch, MTD: Middle transverse diamater of scapular notch, VD: Vertical diameter of scapular notch)

2. Morphological Classification (Figures 2, 3, 4)

a) Observational classification of the scapular notch: The classification of the scapular notch was performed by revising the classifications suggested by Rengachary et al. (6) and Okeke et al. (7).

Observational classification of the scapular notch (Figure 2);

Type 1: Arc-shaped or no scapular notch

Type 2: Blunt or large V shaped

Type 3: Deep U-shaped (superior transverse diameter of the scapular notch is smaller than vertical diameter of the scapular notch)

Type 4: Small v-shaped

Type 5: J-shaped which appears to be closed by a ledge

Type 6: Foramen-shaped

b) Measurement-based classification of the scapular notch: The classification was suggested under 5 groups through the classification made by Polguj et al. (8) according to the measurement data (Figure 3).

Type 1: VD>STD (maximum vertical depth)

Type 2: VD=STD (the vertical depth equals to the transverse diameter)

Type 3: STD>VD (the transverse diameter is larger than the vertical diameter)

Type 4: Foramen

Type 5: No notch

c) Shape-based superior margin typing: The superior margin of the scapula was revised and reclassified according to Singroha et al. (9).

Typing according to the superior margin (Figure 4)

Type 1: Moderately oblique

Type 2: Significantly oblique

Type 3: Saddle-shaped

Type 4: Corrugated

Type 5: Flat and on the medial

Type 6: Flat, saddle-shaped, oblique

Figure 2. Types of scapular notch according to the morphological evaluation (**Type 1:** Absence of scapular notch; **Type 2:** V shaped; **Type 3:** Deep"U" shaped; **Type 4:** Small"V" shaped; **Type 5:** J shaped; **Type 6:** Hole-shaped)

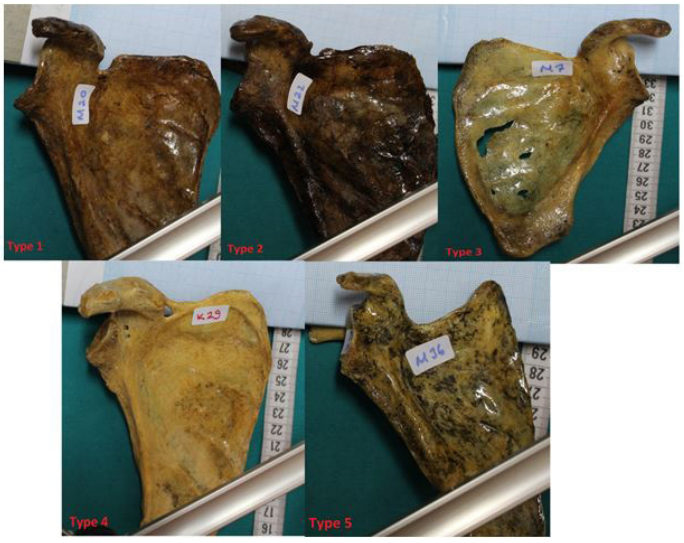

Figure 3. Types of scapular notch according to the scapular notch measurements (**Type 1:** VD>STD; **Type 2:** STD=MTD **Type 3:** STD>VD; **Type 4:** Foramen; **Type 5:** Absence of notch)

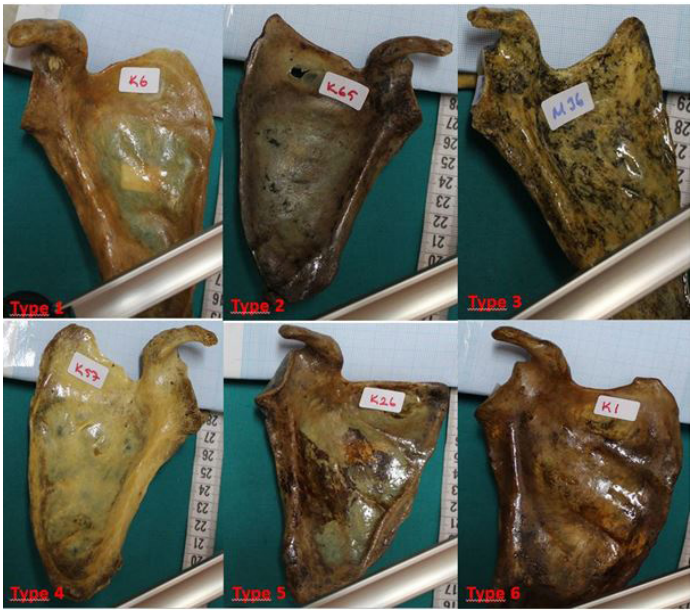

Figure 4. Morphological evaluation of the superior margin of the scapulae. (**Type 1:** Moderately oblique, **Type 2:** Markedly oblique, **Type 3:** Saddle shaped, **Type 4:** Wavy, **Type 5:** Straight, **Type 6:** Straight medially, saddle-shaped laterally)

Statistical analyses

Measurement parameters were evaluated statistically through SPSS 21.0 (IBM, New York, USA) program. The mean±SD (standard deviation), minimum (min.) and maximum (max.) values of all morphometric measurements were given. The association between the right and left parameters was evaluated by independent t test. The association between measurement parameters was analyzed by Pearson's Correlation test. Any p value below 0.05 ($p<0.05$) was accepted as statistically significant.

RESULTS

The present study was conducted on 90 human scapulae including 39.9 (44.4%) right and 50.04 (55.6%) right scapulae. The minimum, maximum, mean and standard deviation (Mean±SD) values of the total measurements of the scapulae and the scapular notch were given; however, the mean and standard deviation values were given for the measurement data of the right and left sides only (Table 1).

Total scapula width (SW) was 96.37±11.15 mm in our study. The scapular width was detected 98.87±7.71 mm on the right and 94.38±13.01 mm on the left. The scapula length (SL) was measured 146.92±13.63 mm on the left, 148.15±13.35 mm on the right, and 147.6±13.41 mm in total. The scapula index (SI) was 146.92±13.63mm on the right, 148.15±13.35 mm on the left, and 63.80±8.29 mm in total. The SW and SI were significantly larger on the right then the left. The SL measurements on the left were larger than the right; however, the difference was not statistically significant ($p>0.05$) (Table 1).

Mean values of STD, MTD, and VD parameters of all scapular notches were 9.90±3,38mm, 8.81±2.51 mm and

10.32±3.85 mm, respectively. Furthermore, results of such measurement data were similar for the right and left sides (Table 1) (p>0.05).

The percentage of distribution between the total, right and left sides of the scapular notch according to the observation and measurement values, and their comparison within the group according to the sides are presented in Table 2. In the observational classification of incisura scapulae, the most common shape was the 'U' shape (n=58, 64.4%); the others were arc-shaped (n=10, 11.1%), large 'V'-shaped (n=9, 10%), 'J'-shaped notch (n=9, 10%), respectively. The foramen-shaped (1%) type formed as a result of ossification of the superior transverse scapular ligament was determined as the least common type.

The most common type in the measurement-based classification of the scapular notch was Type 1 (n=44, 48.9%; VD>STD) the least common type was Type 5 as (n=1, 1.1%). The morphometric classification of the superior margin revealed that the most common type was moderately oblique (n=37, 41.1%) type; however, the saddle-shaped oblique type on the lateral side (1%) was observed as the least common (Table 2). The difference between the right and left sides was not statistically significant in the morphological classification of incisura scapuale and superior margin based on observation and measurement (p>0.05) (Table 2).

Table 1. Measurement values of scapula and scapular notch (mm)

		Total				Right	Left	
		n	Min.	Max.	Mean±SD	Mean±SD	Mean±SD	p
S	SW	90	19.69	119.94	96.37±11.15	98.87±7.71	94.39±13.02	0.046*
	SL	90	117.3	175.5	147.6±13.41	146.92±13.63	148.15±13.35	0.670
	SI	90	15.15	78.39	65.45±7.05	67.51±4.40	63.80±8.29	0.008*
Inc.	STD	76	4.63	18.97	9.90±3.38	9.81±3.58	9.98±3.26	0.832
	MTD	76	3.88	14.98	8.81±2.51	8.87±2.13	8.76±2.80	0.854
		76	2.19	19.95	10.32±3.85	10.19±3.57	10.42±4.11	0.790

(* Significant at the 0.05 level; Independent t-test; S; Measurements of scapulae, Inc.; Measurements of scapular notch, SW: Scapula width, SL: Scapula length, SI: Scapula index, STD: Scapular notch upper of transverse diameter, MTD: Middle transverse diameter of scapular notch, VD: Vertical diameter of scapular notch)

Table 2. Morphological classification distribution percentage of scapular notch and margo superior by sides (%)

	Variable	Combined N(%)	Right N(%)	Left N(%)	χ2	p
Scapular notch of the based on observation classification	Type 1	10 (11.1)	5 (12.5%)	5 (10%)	8.372	0.137
	Type 2	9 (10)	3 (7.5)	6 (12.2)		
	Type 3	58 (64.4)	22 (55)	36 (72)		
	Type 4	3 (3.3)	3 (7.5)	0		
	Type 5	9 (10)	6 (15)	3 (6)		
	Type 6	1 (1.1)	1 (2.5)	0		
Scapular notch of the based on measurement classification	Type 1	44 (48.9)	26 (43.3)	28 (45.9)	3.740	0.809
	Type 2	2 (2.2)	1 (1.8)	1(1.6)		
	Type 3	31 (34.4)	16 (29.1)	23 (37.7)		
	Type 4	1 (1.1)	1 (1.8)	-		
	Type 5	13 (14.4)	11 (20)	9 (14.8)		
Superor margin of the based on observation classification	Type 1	37 (41.1)	20 (50)	17 (34)	3.740	0.809
	Type 2	30 (33.3)	10 (25)	20 (40)		
	Type 3	7 (7.8)	3 (7.5)	4(8)		
	Type 4	5 (5.6)	1 (2.5)	4(8)		
	Type 5	10 (11.1)	5 (12.5)	5 (10)		
	Type 6	1 (1.1)	1 (2.5)			

(*Significant at 0.05 level; Chi-square analysis, STD: Upper transverse diameter of scapular notch, MTD: Mid-transverse diameter of scapular notch, VD: Vertical diameter of scapular notch)

Mean values of measurement data of observational and measurement-based scapular notch and SM were provided in Table 3. The SW and SL data in Type 6 were observed with the highest average. In the typing of the observational scapular notch, the STD and MTD data with the largest mean were found in Type 3, while the data with the smallest mean of measurement was found in Type 4.

The measurement-based incisura scapulae typing revealed that the group with the highest SW average was determined as Type 2, and the group with the lowest average was determined as Type 1. The SI with highest average was detected in Type 2; however, the SI with lowest average was detected in Type 4 (Table 3).

It was detected in the observational classification of the superior margin that the SW with the highest average was found in Type 4 whereas the SL with highest average was detected in Type 3. The SI data with highest average was observed in Type 6 (Table 3).

The association between parameters of the scapulae was evaluated through Pearson's Correlation test. A significant association was observed between many parameters (Table 4). The highest positive correlation was observed between SW and SI parameters on the left (r=0.767). The highest negative correlation was detected between SL and SI parameters on the right (r=-0.548). Although there was a negative association between STD and scapulae measurements (SW, SL, SI) both on the right and on the left, such association was not statistically significant (Table 4).

Table 3. Morphometric measurements of scapular notch and margo superior by sides (mm)

		N	SW	SL	SI	N	STD	MTD	VD
			Mean±SD	Mean±SD	Mean±SD		Mean±SD	Mean±SD	Mean±SD
Scapular notch of the based on observation classification	Type 1	10	97.19±7.88	146.3±14.12	66.71±5.66				
	Type 2	9	87.1±25.87	144.09±12.46	60.15±17.54	9	10.25±2.65	8.78±3.39	12.23±4.57
	Type 3	58	96.79±8.19	147.44±13.63	65.85±4.63	58	10.27±3.4	8.86±2.32	10.21±3.7
	Type 4	3	98.25±7.12	139.13±13.13	70.71±1.71	3	6.32±0.82	8.48±2.82	10.92±1.18
	Type 5	9	100.81±5.26	154.47±10.92	65.4±3.25	9	8.58±3.81	8.71±3.02	8.86±4.39
	Type 6	1	102.55	165.5	61.96				
Scapular notch of the based on measurement classification	Type 1	43	95.44±14.57	147.25±14.34	64.85±8.71	43	8.43±2.16	8.88±2.63	12.64±3.16
	Type 2	2	102.97±2.98	150.5±17.39	68.76±5.96	2	10.07±6.24	9.47±7.09	10.02±6.31
	Type 3	31	97.36±6.21	147.87±12.26	66.13±5.18	31	11.95±3.67	8.67±2.08	7.12±1.91
	Type 4	1	102.55±0	165.5	61.96				
	Type 5	13	95.64±8.09	146.32±13.55	65.59±5.36				
Superor margin of the based on observation classification	Type 1	37	97.19±7.82	145.52±13.07	66.95±3.9	35	9.83±3.71	8.71±2.78	10±3.73
	Type 2	30	94.33±15.98	148.37±14.06	63.59±10.17	30	9.76±2.84	8.89±2.3	10.82±3.98
	Type 3	7	97.41±7.19	153.8±15.6	63.76±6.67	2	10.07±6.95	7.31±4.12	6.92±1.51
	Type 4	5	98.67±8.02	150.6±9.24	65.54±4.02	2	15.55±0.81	11.19±1.37	11.42±4.84
	Type 5	10	97.12±8.65	148.95±12.98	65.33±4.53	6	9.61±2.79	8.82±2.03	11±4.68
	Type 6	1	101.98±0	130.1±0	78.39	1	7.21	8.44	7

(SW: Scapula width, SL: Scapula length, SI: Scapula index, STD: Scapular notch upper of transverse diameter, MTD: Middle transverse diameter of scapular notch, VD: Vertical diameter of scapular notch)

Table 4. Right and left measurement data of correlation relationship (%)

			LEFT					
			SW	SL	SI	STD	MTD	VD
RIGHT	SW	r	1	.534**	.767**	-.156	-.204	-.413**
		p		.000	.000	.322	.195	.007
	SL	r	.735**	1	-.127	-.184	-.069	-.223
		p	.000		.378	.244	.664	.156
	SI	r	.161	-.548**	1	-.049	-.199	-.327*
		p	.320	.000		.757	.206	.035
	STD	r	-.182	-.132	-.068	1	.425**	.033
		p	.302	.458	.700		.005	.838
	MTD	r	.276	.122	.184	.409*	1	.473**
		p	.114	.492	.296	.016		.002
	VD	r	.217	.220	-.053	-.070	.226	1
			.218	.211	.767	.693	.200	

(SW: Scapula width; SL: Scapula length; SI: Scapula index; STD: Scapular notch upper of transverse diameter; MTD: Middle transverse diameter of scapular notch; VD: Vertical diameter of scapular notch)

DISCUSSION

Shoulder pain is an important condition that is frequently encountered in the elderly and young population, restricting quality of life and daily activities. The incidence of this pain varies between 15% and 30% in adults. Shoulder pain is caused by degenerative diseases affecting the glenohumeral joint, the acromiocalavicular joint, and supporting soft tissue structures, inflammatory diseases such as rheumatoid arthritis, and suprascapular neuropathy which is the most important and most common entrapment of the suprascapular nerve (10).

Total scapula length (SL)

The total scapula length was detected as 147.06±13.41 mm in our study (Tables 1-5). Such length measurement was reviewed by different researchers on different populations. The longest scapula length was detected as 156+12.9 mm on German population by Prescher and Klümpen (11). Following the study above, the longest scapula length was detected as 151.16±10.32 mm on Egyptian population by El-din and Ali (12) (Table 5).Taser and Başaloğlu (13) who studied on dry scapulae of the Turkish population found an average SL of 141.5+14.2 mm; however, Coskun et al. (14) detected the average as 98.8±7 mm whereas Aydemir et al. (15) determined it as 147 mm. The SL average was detected as 148.08±13.61 mm in our study. When the length measurement data of the scapulae on dry bones of Turkish population are compared with each other, it is detected that the measurement data made by other researchers are close to our study, except for the studies conducted by Coskun et al. (14).

Total scapula width (SW)

Total scapula width (SW) was 96.37±11.15 mm in our study (Table 1-5). El-din and Ali (12) detected the mean SW as 107.22±9.74 mm in the Egyptian population; however, Kavita et al. (16) determined the mean SW on the Indian population as 105.5±7.6 mm. In Turkish populations, Taser and Basaloglu (13) detected 97.7±7.8 mm; Coskun et al. (14) as 99.29±7.6 mm, and Aydemir et al. (15) as 105 mm. The scapula width is observed as the least value among the studies.

Total scapula index

Limited number of researchers evaluated the SI parameter in the literature. In our study, total scapular notch index was found 65.45±7.05 (Tables 1-5). The following SI values were obtained in the following studies; average 70.93 mm in average on Egyptian population by El-din and Ali (13); 73.32±4.80 mm in average on Indian population by Chhabra et al. (17); 72±11.41mm in average on Northern India by Nazir et al. (18); 71.24±3.1 mm in average on Southern India by Rajeswari and Ramalingam (19); and 75.56±17.67 mm in average on Eastern India by Biswas et al. (5) (Table 5). Our results were found lower than other results.

Lateralization of the scapulae

There are limited studies in the literature that reveal the association between the scapula length and the sides (5,12,15).

Aydemir et al. (15) conducted a research on 40 scapulae of the Turkish population, and measured mean SL as 145 cm on the right side, 148 cm on the left side, and mean SW as 104 cm on the right side and 106 cm on the left side. Furthermore, Aydemir et al. (15) observed that mean SL and SW values were higher on the right scapulae. The mean SL was detected 147.6 mm (146.92±13.63 mm on the right; 148.15±13.35 mm on the left; p=0.670) and mean SW was detected 96.37 mm (98.87±7.71 mm on the right; 94.39±13.02 on the left; p=0.046) in this study (Table 1).

Table 5. The values obtained from the researchers' studies of the length, width and index parameters of the scapulae (mm)

			SL	SW	SI	N	STD	MTD	VD				
	N	Population	Total	N	Right	N	Left	Total	Right	Left	Total	Right	Left
Prescher and Klümpen (12)	214	Germany	156+12.9					104+12.9					
Taşer and Başaloğlu (13)	52	Turkish	141.5+14.2					97.7±7.8					
Coskun et al. (14)	90	Turkish	98.8 ± 7	44		46		99.29±7.6					
Kavita et al. (16)	129	India	145.1±11.7	67	144.6±12.2	62	145.7±11.3	105.5±7.6	104. ±7.7	106.5±7.5			
Singh et al. (20)	129	West India	141.7± 8.9	67	144.60±12.20	62	145.70±11.30	96.4 ± 7	104.60±7.70	106.50±7.50	68.5 ± 4		
El-dın and ali (12)	160	Egypt	151.16±10.32	80	151.05±8.42	80	151.20±9.47	107.22±9.74	107.43±8.07	107.01±9.00	70.93	71.12	70.77
Chhabra et al.(17)	126	India	141.94 ± 12.76	55	141.93±12.88	71	141.94±12.76	103.65 ± 6.82	103.64±6.41	103.67±7.16	73.32 ± 4.80		
Nazir et al.(18)	120	North India	137 ± 20.09					98.16 ± 11.60			72 ± 11.41		
Rajeswari and Ramalingam (19)	100	South India	141.34± 8.5					103.3 ± 6.9			71.24 ± 3.1		
Aydemir et al. (16)	40	Turkish	147	16	145	24	148	105	104	106			
Biswas et al. (5)	200	East Indıa	132.97± 18.00	100	130.61±21.51	100	135.40±13.05	97.96 ± 9.38	98.56±9.48	97.45±9.40	75.56 ± 17.67	78.91±23.5	72.28±6.53
Present study	99	Turkish	147.06±13.41		146.92±13.63		148.15±13.35	96.37±11.15	98.87±7.71	94.39±13.02	65.45±7.05	67.51±4.40	63.80±8.29

N: number of individuals, SW: Scapula width; SL: Scapula length; SI: Scapula index)

Table 6. Comparison of various studies on the suprascapular notch on Rengachary et al. (6) classification (%)

Student	Population	N	Type I (None)	Type II(V shape)	Type III (U shape)	Type IV (v shape)	Type V (J shape)	Type VI (Foramen shape)
Rengachary et al. (6)	Americans	211	8	31	48	3	6	4
Coskun et al. (14)	Turkish	100	5	23	38	13	11	6
Natsis et al.(21)	Greece	423	6	24	40	13	11	6
Sinkeet at al. (22)	Kenya	138	22.5	21	29.6	5.18	18	4
Wang et al. (23)	Chinese	295	9.5	58.16	28.23	-	-	4.08
Albino et al. (24)	Italy	500	12.4	19.8	22.8	31.1	10.2	3.6
Vandana and Patil (25)	India	134	4.5	4.5	35	5.2	34.3	12.5
Gopal ve at. (26)	India	120	15.83	41.66	25	12.5	1.67	3.33
Chhabra et al (17)	India	126	0.79		46	24.6	21.3	2.4
Boyan et al. (27)	Turkish	73	28.8	23.3	13.7	20.5	2.7	5.5
Adewale et al. (28)	Uganda	50	16.3	12.2	51	4	4	10
Okeke et al. (7)	Nigeria	193	3	22	71	1	3	0
Present study	Turkish	100	11.1	9	64.4	3.3	10	1.1

N: number of individuals

Despite the studies conducted by Aydemir et al. (15), the mean values of these parameters were found larger on the right side scapulae in our study.

Biswas et al. (5) carried out a study on 100 right and 100 left scapulae of Indian population and could not find a statistically significant association between SW (98.56 ±9.48 mm on the right; 97.45 ±9.40 mm on the left; p=0.059) and SL (130.61±21,51 mm on the right; 135.40±13.05 mm on the left; p=0.366). However, they detected a significance between sides for SI (78.91±23.5 on the right; 72.28±6.53 on the left; p=0.007) El-Din and Ali (12) detected SI average as 71.12 on the right, and 70.77 on the left. The SI value was detected 67.51±4.40 on the right, and 63.80±8.29 on the left in our study. Although the SI data obtained from our study were observed lower than other studies, we believe that this may be due to racial difference (Table 5).

The scapular notch

The scapular notch is the name of the notch existing on the base of the coracoid process on the superior margin. The suprascapular nerve may be commonly compressed and entrapped on STSL. Differences in the shape and size of the notch, congenital changes such as ossification and comminuted ossification of the STSL, and external mechanical effects are also important factors causing entrapment. Depending on the entrapment, individuals may experience shoulder pain and muscle atrophy on the supraspinatus and infraspinatus muscles (4, 33) (Table 6).

Natsis et al. (21) reported that the size and shape of the scapular notch were the most important factors in the etiopathology of suprascapular entrapment neuropathy. Rengachary et al. (6) reported that a narrow scapular notch may cause predisposition for entrapment neuropathy. Antoniadis et al. (34) stated that individuals with V-shaped scapular notch have higher incidence for entrapment neuropathy. Rengachary et al. (6) stated in their study that the shape of the scapular notch should be considered as the first factor that causes the entrapment of the suprascapular nerve to be supported. They reported that individuals with narrow and sharp incisura scapulae may be exposed to pressure during the passage of the nerve during upper extremity movements, and this may cause microtrauma as a result of injury to the nerve during bending. Albino et al. (24) also reported like Antoniadis et al. (34) that deep and narrow scapular notch may cause the injury of suprascapular nerve.

- **Upper and medial transverse diameter and vertical diameter pf the scapular notch**

Sharma et al. (31) determined the mean upper transverse diameter of the scapular notch as 5.55 mm (5.96 mm on the right; 6.36 mm on the left) on 100 dry scapulae from the Indian population. Similarly, Chhabra et al. (17) also found this length as 7.78±3.09 mm in average on Indian population. We believe that the difference in the results of the studies conducted on the same population may be caused by the difference in the age of the bone. Zhang et al. (35) determined the upper transverse diameter of 308 dry scapulae on 308 Chinese individuals as an average of 10.70 mm on the right side and 10.66 mm on the left side. Khattab et al. (36) determined the upper transverse diameter of the scapular notch as 4.4 mm on 100 dry scapulae from 100 Egyptians. Kastamonu et al. (37) found the mean upper transverse diameter of the scapula as 8.81 mm on dry scapulae of Turkish population. In our study, the mean upper transverse diameter of the scapular notch was determined as 9.90±3.38 mm (9.81±3.58 mm on the right, 9.98±3.26 mm on the left). We observed that the data obtained from this study were close to those obtained by Kastomoni et al. (37). However, the values were quite higher when compared to the researchers working in the Indian population, and lower than the Chinese and Egyptian populations.

Unlike the studies of other researchers, the median transverse diameter of the total scapular notch was determined as 8.81±2.49 mm (8.86±2.10 mm on the right side and 8.76±2.80 mm on the left side) in the present study. Khattab et al. (36) measured the mean transversus scapulae measurements as 2.69 mm on the Egyptian population. The median scapulae diameter data obtained in our study were found higher than the studies of Khattab et al (36). Furthermore, Polquj et al. (8), Polquj et al. (30), Gopal et al. (26), Ahmet et al. (32), provided mean values of measurement-based classification types rather than total mean values of median transverse diameter measurements. Ahmet et al. detected median transverse diameter in Type 1 determined as VD>STD as 3.69 ±0.97; however, they found the median transverse diameter in Type 3 determined as VD<STD 6.46 ± 1.79 mm. In our study, Gopal et al. (26)'s measurements of the scapular notch in Type 1 and Type 3 groups presented close results, while our data on Type 2 was found larger (Table 7).

In our study, the mean vertical diameter of the total scapular notch was found 10.3±3.85 mm (10.19±3.57 mm on the right, 10.42 ±4.11 mm on the left) (Table 1). Kastomoni et al. (37) found the mean upper transverse diameter of the scapula as 5.58 mm on Turkish population. Kale et al. (38) found the vertical diameter of the scapula as 5.5 mm. Sharma et al. (31) determined the mean value as 5.8mm (5.9 mm on the right; 5.9 mm on the left). Chhabra et al. (17) found the mean VD data as 6.39±2.65 mm in their study. Zhang et al. (35) detected scapula depth of 308 dry scapulae on 308 Chinese individuals as 5.63 mm on the right side and 6.28 mm on the left side. Kale et al. (38) found the vertical diameter of the scapula as 9.6 mm. It was determined that the data obtained in our study was larger than the studies conducted.

- **Classification according to the scapular notch**

The scapular notch has been morphologically classified differently by many researchers (8,14,21,39). The scapular notch is often classified under 6 groups in the literature (Table 8). The shape of the scapular notch which is frequently observed by most researchers has been determined as Type 3 ("U"-shaped) (Table 8). Coşgun et al. (14) and Boyan et al. (27) who have conducted researches

on the Turkish population in particular detected shape of the scapulae as Type 3 (38%) and Type 1 (28.8%), respectively. The scapular notch shapes were classified under six groups according to Rengahary (6). The most common scapular notch shape was detected as Type 3 (64.4%). However, the secondly most common scapular notch shape following Type 3 was detected as Type 3 (11.1%). Although there are racial differences, the prevalence of the "U"-shaped scapular notch shape is higher than many researchers.

Table 7. Comparison of studies of scapulae nothc according to measurement-based classification (%)

Student	Ethnicity	N	Type I	Type II	Type III	Type IV	Type V	Type VI
Natsis et al. (21)	German	423	41.85		41.85	7.3	8.3	0.75
Sinkeet et al. (22)	Kenya	135	29		21	4	22	2.9
Polquj et al. (8)	Poland	86	24.40	2.30	54.70	7.00	11.60	
Wang et al. (23)	Chine	295	58.16		28.23	3.00	28.00	
Mady and Shehab (29)	Egypt	132	43.93		45.45	3.03	6.06	1.5
Polquj et al. (30)	Poland	616	24.18	1.95	56.16	4.72	12.99	
Gopal et al. (26)	India	120	20	3.33	55.58	4.16	17.5	
Sharma et al. (31)	India	100	34		39	5	20	2
Ahmet et al. (32)	Egypt	65	39.99	1.54	47.68	3.08	7.69	
Vandana and Patil (25)	India	134	8	3.2	70.1	13.7	4.8	0
Present study	Turkish	100	48.9	2.2	34.4	1.1	0	0

N: number of individuals

Table 8. Mean STD, MTD and VD values according to measurement-based classification (mm)

	Type 1	Type 2	Type 3	Type 1	Type 2	Type 3	Type 1	Type 2	Type 3
Polguj et al. (8)	6.92±1.72	8.10±1.56	8.83±3.26	8.58±3.94	8.10±1.56	7.12±2.46	9.94±2.49	8.10±1.56	5.46±2.04
Polguj et al. (30)	7.01±3.19	8.02±2.28	12.46±3.66	7.68±2.34	7.98±2.29	9.17±2.63	10.33±2.74	8.0±2.29	7.02±2.71
Gopal et al. (26)	8.98 ± 2.76	5.92 ± 2.69	8.50 ± 1.98	9.08 ± 2.99	3.82 ± 1.50	8.06 ± 1.78	12.55 ± 4.07	5.92 ± 2.69	7.31 ± 2.02
Ahmet et al. (32)	5.79 ± 0.98		8.56 ± 1.80	3.69 ±0.97		6.46 ± 1.79	8.7 ± 1.43		5.86 ± 1.27
Present study	8.43±2.16	10.07±6.24	11.95±3.67	8.88±2.63	9.47±7.09	8.67±2.08	12.64±3.16	10.02±6.31	7.12±1.91

(STD: Scapular notch upper of transverse diameter; MTD: Middle transverse diameter of scapular notch; VD: Vertical diameter of scapular notch)

It was stated by Singh (20) that the most common variant of suprascapular entrapment neuropathy is the ossification of the scapular notch caused by the ossification of the scapulae. It was reported in the literature that the calcification incidence of the superior transverse scapular ligament varies between 0% and 12.79% (Table 8). The incidence of such variant was detected as 1.1% in our study. Similarly, Coskun et al. (14), Boyan et al. (27) and Bayramoglu et al. (39) who conducted research on Turkish population determined this rate as 6%, 5.5% and 12.5%, respectively.

Adewale et al. (28) examined the variation of SL and SW according to types in the classification of the scapular notch based on observation and detected the SL as 15.14 cm and the SW is 10.39 cm in Type 1; SL as 11.90 cm and SW as 8.18 cm in Type 2; SL as 14.37 cm and SW as 9.97 cm in Type 3, and SL as 15.55 cm and SW as 10.78 cm in Type 4. In this study, we detected the SL as 14.63 cm and the SW is 9.71 cm in Type 1; SL as 14.4 cm and SW as 8.7 cm in Type 2; SL as 14.7 cm and SW as 9.67 cm in Type 3, and SL as 13.9 cm and SW as 9.82 cm in Type 4.

The scapular notch has been classified based on observation as well as measurement by many researchers (8,21-23,25,29,32). In our study, the scapular notch was examined morphometrically and classified under 5 groups like in the study of Polquj et al. (31). In this study; the rate of Type 1 (VD>STD) was 48.9%, Type 2 (VD=STD) was 2.2%, Type 3 (VD<STD) was 34.4%, Type 4 (Foramen-shaped) was 1.1%, Type 5 (no notch) was 14.4% (Table 2).

Type 3 was detected as the commonly observed type by researchers in the literature (VD<STD) (8, 25,26,30-33). The incidence of Type 3 and Type 1 were determined equally by Natsis et al. (21).

Sinkeet et al. (22) stated that they frequently detected Type 1 on Kenyan population (29%) like Wang et al. (23) on Chinese population (58.16).

Classification of the superior margin

Singroha et al. (9) classified the superior margin in five types as follows; horizontal type (42%), moderately curved type (27%), significantly curved type (15%), saddle-shaped (12%)

and corrugated (6%). They reported that the most common superior margin shape in their study was the horizontal type (40%). In our study, the typing performed by Singroha et al. (9) was revised and classified under 6 groups. The most common superior margin shape on the right side was moderately oblique (50%) whereas significantly oblique (40%) on the left. There are a limited number of studies in the literature in which scapulae typing is done according to the shape of the superior margin. Therefore, we believe that further researches would support racial differences.

The association between parameters

Polquj et al. (3) reported that they have deeper notches in longer scapulae in their study. A negative but insignificant correlation was found between scapulae measurements and scapular notch measurements in this study (Table 4). A strong correlation (r=0.735 on the right; r=0.534 on the left) was found between SL and SW detected in our study.

Limitations of the Study

This study has two important limitations. The first of these is that our study was carried out only on dry scapulae. The second limitation is that genders of the scapulae is not known. Comparison of morphometric measurements by gender may be a guide for sexual dimorphism in future studies.

CONCLUSION

Recognition of the morphological structure of the scapulae is very important for the treatment of shoulder joint diseases, the design of suitable shoulder implants, understanding the shoulder pathologies that may occur in this region, for determining the insertion sites in shoulder arthroscopy, and surgical procedures planned to be performed on the region. In our study, morphometric and morphological examinations were carried out on scapulae of Turkish population. We believe that the data obtained would contribute to the literature.

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