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ORIGINAL PAPER

Anthropometric Cadaveric Analysis of the Quadrangular Space and Deltoid Region: Anatomical Perspectives for Clinical Applications in the Indian Population

Sundip Hemant CHARMODE[a], Abhishek Kumar MISHRA[b], Simmi MEHRA[a]

[a]Department of Anatomy, All India Institute of Medical Sciences, Rajkot, Gujarat, India

[b]Department of Orthopedics, All India Institute of Medical Sciences, Rajkot, Gujarat, India

ABSTRACT

Background: *Neurovascular structures beneath the deltoid, particularly the axillary nerve and posterior circumflex humeral artery, are vulnerable to injury from intramuscular injections or compression in the quadrangular space, especially in overhead athletes. Studies by Kakati* et al *(2013) and Desai* et al *(2019) report intramuscular injection-related nerve injury rates of 1.5% to 15% and 82.5%, respectively. However, there is a lack of cadaveric studies in the Indian population, prompting this anthropometric study.*

Aims and objectives: *This study aims to assess the dimensions of the quadrangular space and examine the branching pattern of the axillary nerve and its relationship with the posterior circumflex humeral artery.*

Methods: *This two-year cross-sectional study, approved by the Institutional Ethical Committee (Protocol ID: F-IM/15/2023), was conducted at AIIMS Rajkot in collaboration with Orthopaedics. Anthropometric measurements of the quadrangular space (height, width, and depth), deltoid muscle, distances of the axillary nerve and posterior circumflex humeral artery from the origin point and AXN-PCHA relationship patterns were obtained from 12 (seven male and five female) cadavers using vernier callipers.*

Results: *Among the 24 specimens, type 1 branching pattern was the most common, observed in 12 specimens (50 %), followed by type 2 in six specimens (25%), type type-3 in five specimens (21%), and type 4 in one specimen (0.041%). The dimensions of quadrangular space varied, with height ranging from 4.28 mm to 5.57mm, width from 10.57 mm to 13.75 mm, and depth from 9.97 mm to 12.84 mm.*

Conclusion: *The mean dimensions (in mm) of the quadrangular space in males and females were 4.77 for height, 11.79 for width, and 11.01 for depth. The type-1 branching pattern was the most frequently observed.*

Keywords: quadrangular space syndrome, axillary nerve, posterior circumflex humeral artery, anthropometry, neurovascular structures, deltoid muscle.

Address for correspondence:
Dr. Sundip Charmode
Department of Anatomy, All India Institute of Medical Sciences, Rajkot, India
Postal address: Department of Anatomy, AIIMS Rajkot, Gujarat-360110
Tel.: 9633239685; email: sundip.charmode@yahoo.com

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INTRODUCTION

Intramuscular (IM) medication administration has traditionally been done in the deltoid muscle, mainly in Southeast Asia (1). Southeast Asian populations vary in the deltoid muscle and its subjacent neurovascular structures, especially the axillary nerve and posterior circumflex humeral artery (2-4). Indian studies like Kakati *et al* (2013) and Desai *et al* (2019) found peripheral nerve damage rates of 1.5% to 15% and 82.5% after deltoid intramuscular injections (5, 6). These anatomical distinctions are clinically significant. Since only two anthropometric studies – Patra *et al* (2018) and Gurushantappa PK (2015) (7, 8) – have examined the neurovascular architecture beneath the deltoid muscle in Indians, region-specific anatomical data is scarce. Orthopaedic surgeons must understand this area's anatomy whether operating on the shoulder joint, proximal humerus, or the clinically relevant but rare Quadrangular space syndrome. Only Gurushantappa PK and Kuppasad S have performed a morphometric evaluation of the quadrangular space in the Indian population. Elizabeth C *et al* (2015) and Damian McClelland and Paxinos A (2008) have provided limited global cadaveric data on its dimensions and contents in their 30- and 16-shoulder specimen studies (9, 10). Charmode *et al*'s 2022 systematic study found flaws in international and Indian intramuscular injection guidelines (11). The current cross-sectional cadaveric observational study measured the quadrangular space's dimensions, identified the topographical relationships of related neurovascular structures, and systematically quantified the deltoid muscle's anthropometric parameters due to the lack of region-specific anatomical information. ❑

MATERIALS AND METHODS

Study design and population

The Department of Anatomy at AIIMS Rajkot and the Department of Orthopaedics collaborated on this two-year observational cross-sectional study using cadavers from the Saurashtra region in the dissecting hall. The Institutional Ethical Committee of AIIMS Rajkot approved this intramural financed project under Protocol ID: F-IM/15/2023 (O.W.No./AIIMS Rajkot/IEC/54/2023) dated 13 September 2023. It involved 12 donated cadavers and 24 shoulder specimens. The goal was to measure the deltoid muscle's length and thickness, then the axillary nerve (AXN) and posterior circumflex humeral artery (PCHA) in relation to nearby bone and surface landmarks. The cadavers' quadrangular spaces were measured as a secondary goal. This article summarizes the research on twelve cadavers dissected in the second year. Each corpse was donated to the department voluntarily. All cadavers died naturally, with no signs of medicolegal issues, physical trauma, organ transplantation, malignancy, or major or minor surgical treatments. None of the cadavers showed physical trauma or trauma involvement, especially in the area of concern. The study had a first-year pilot and a second-year continuation. The pilot phase findings on six cadavers were published (12). The twelve corpses included seven men and five women.

Sample size

The study used 12 embalmed cadavers (seven males, five females), comprising 24 specimens, throughout two years. In each of the two years, six of the 12 cadavers were dissected. The institute's corpse donation program provided all cadavers.

Sample size calculation

Only six cadavers were available in the department when this research project proposal was presented to the Research Review Board and Institutional Ethical Committee. So it became a PILOT project. Only two Indian cadaveric investigations on the subject exist: Patra A. *et al*. 2018 and Gurushantappa P. *et al* (2015) (7, 8). Sample size was calculated using Surraj S *et al* (2022), AIIMS Bibinagar (13). This reference study estimated 5% symptomatic axillary nerve compression. Another study, Pourhoseingholi MA *et al* (2012 Iran), proposed the sample size formula for cross-sectional medical investigations (14).

Based on prevalence, the following factors were determined.

P (prevalence) = 5; Q = 1-P = 95;
L (precision) = 5%; confidence level = 95%;
confidence interval = 5 for 0-60-year-olds.

The study power was 80.0.

$N = Z^2 PQ/L^2 (1.96)^2 2.5 \times 95/ (5)^2$;

$n = 3.8416 \times 475/25$.

73 cadavers.

Based on cadaver availability, the study will begin with six available cadavers and continue for two years with any additional cadavers. Twelve cadavers were analysed over two years.

Eligibility criteria

Eligible cadavers were selected based on the following criteria: 1. Cadavers were embalmed using normal procedures; 2. Specimens lacking congenital/acquired deformities, metabolic problems, cancer, or other debilitating diseases; 3. Those lacking humerus, scapula, or pectoral girdle fractures; 4. Humerus, scapula, and pectoral girdle specimens without operation history and 5. Arm and shoulder joint specimens without scars, injuries, or deep wounds.

Cadavers were excluded if they were: 1. An unembalmed human body; 2. Samples with congenital/acquired deformities, metabolic problems, cancer, or other severe diseases; 3. Humerus, scapula, or pectoral girdle fracture specimens; 4. Samples having humerus, scapula, or pectoral girdle surgery histories and 5. Arm and shoulder joint specimens with scars, injuries, or deep wounds.

Ethical considerations

The Institutional Ethical Committee of AIIMS Rajkot approved this intramural sponsored project under Protocol ID: F-IM/15/2023 (O.W.No./AIIMS Rajkot/IEC/54/2023) dated 13 September 2023. The Departments of Anatomy and Orthopaedics collaborated on it. No written or oral agreement was needed because the study participants were donated cadavers. The data was anonymous.

Registration of clinical trial

After IEC approval, the study proposal was submitted to the Clinical Trial Registry of India (CTRI) and registered on September 27, 2023. Reference code REF/2023/09/072948; CTRI website: https://www.ctri.nic.in/. Cadaveric studies are excluded from the Clinical Trial Registry India (CTRI); hence, registration could not be completed.

Data collection procedure

Initial stage of dissection: Traditional dissection methods were used in the study (15). After designating the bony landmarks, such as the acromial process, with dissection pins, the skin and subcutaneous tissue were carefully removed from the shoulder and proximal arm, retaining the fascia over the deltoid. This study examined the acromial deltoid muscle (DM) and ignored its clavicular and scapular origins.

- Digital vernier callipers and measuring tape were used to measure the DM after exposure. Triple measurements were taken, and the average was taken as the final reading. The lead investigator measured everything to eliminate interobserver bias.
- Marked the anterior and posterior lateral border of acromion (AP) and mid-acromial point (OP) with dissection pins following skin removal. The origin point was the mid-acromial point(DP), the middle of the x-axis linking the AP and the posterior acromial point (PP). From the origin point to the distal point, which denotes muscle insertion, a vertical line (y-axis) was drawn (16).
- Deltoid muscle length: The length of DM was measured from OP to DP using vernier callipers (type: MarCal 16 ER, resolution 0.01 mm/0.0005", Insize 1108-150: Digital caliper, range 0–300 mm/12", accuracy ± 0.01 mm) (16) (Figure 1).

A study assessed the thickness of the deltoid muscle without skin and soft tissue using digital callipers and a dissecting needle at 3, 5, and 7 cm from the OP (16).

Dissection and recording of the anterior branch of the axillary nerve (AXN) and posterior circumflex humeral artery (PCHA) branches revealed their connection pattern. The upper borders of AXN and PCHA were measured from the OP, then DP. The upper borders of AXN and

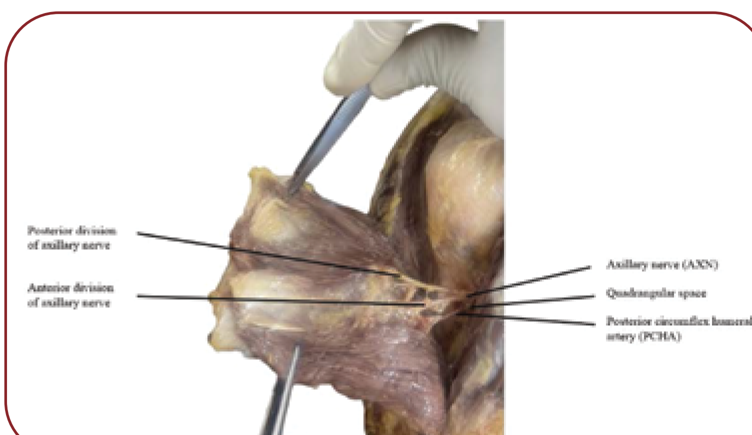

FIGURE 1. Bony landmarks for reference line measurements (Courtesy – The image was captured and edited by junior residents of the Anatomy Department.)

PCHA were also measured from the deltoid muscle midpoint (Figure 2).

• AXN and PCHA relationship patterns – Four types of relationship patterns were identified by dissecting their branches. Type-1: AXN goes above PCHA and branches twice. Type-2: AXN passes above PCHA, giving more than two branches. Type-3: AXN splits below PCHA into many branches. Type 4: AXN crosses PCHA downward (Figure 3).

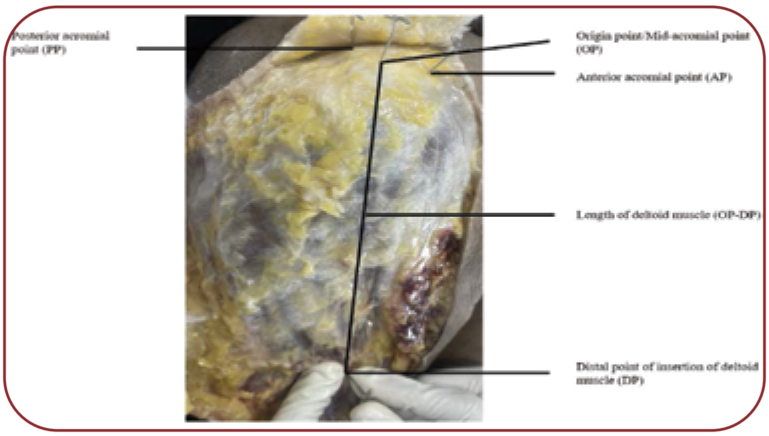

FIGURE 2. Neuro-vascular structures underlying to the Deltoid muscle (Courtesy – The image was captured and edited by junior residents of the Anatomy Department.)

The dimensions of the quadrangular space (height, breadth, and depth) were measured using digital vernier callipers. We measured height from the lower border of the teres minor to the higher border of the teres major and breadth from the lateral border of the long head of the triceps to the surgical neck of the humerus (8).

Data categorization

The cadavers provided reference line measurements (OP-DP, AP-DP, PP-DP, AP-PP), deltoid muscle thickness (3, 5 and 7 cm from OP), AXN and PCHA distances from OP, quadrangular space dimensions (height, width, depth) and relationship patterns. Descriptive variables were tabulated, graphed, and statistically analysed by gender.

Risk assessment

Two researchers independently analysed and documented each parameter. Measurements were taken with digital vernier callipers, anthropometric tape and thread, and discrepancies were assessed. After measuring each specimen, the investigators discussed their findings to reduce interobserver bias. If measurement discrepancies surpassed 5%, a third investigator was called to

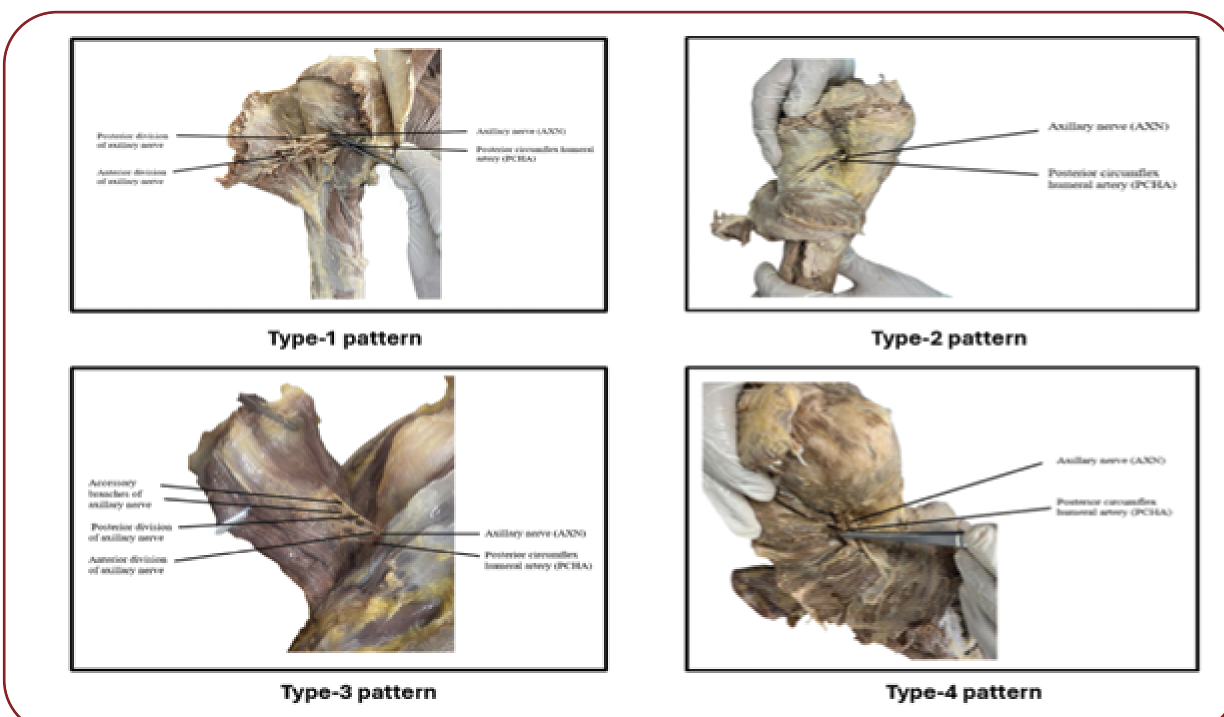

FIGURE 3. Types-1, -2, -3 and -4 relation patterns of axillary nerve and posterior circumflex humeral artery (Courtesy – The image was captured and edited by junior residents of the Anatomy Department.)

remeasure or remark. Two measurements of each variable were taken and averaged to reduce intraobserver variability. The average was calculated from morning, afternoon, and evening data to account for environmental factors.

Data collecting instruments

Digital Vernier callipers, dissection needles, measuring tape, skin marking pens, case record form, plastic triangle ruler, pins, stationery.

Data analysis procedure

Statistics were analysed using IBM SPSS 25.0 (17). Data were spread on excel and a master chart was created. Tables and graphs were made from the master chart. Calculating mean and standard deviations for quantitative data analysis. The variables of interest were compared by gender and side using un-paired t-tests with P-values below 0. 05 was important. ❑

RESULTS

The two-year experiment examined 12 embalmed cadavers (24 specimens). In the first year, six corpses are dissected. Six more cadavers were dissected in the second year. Data was in a master chart, statistically analysed, and presented in tables and graphs. Tables 1, 2 and 3 show descriptive statistics on deltoid muscle anthropometric variables, spatial measurements of the axillary nerve (AXN) and posterior circumflex humeral artery (PCHA) from the origin point (OP), quadrangular space morphometric dimensions and AXN–PCHA relational patterns. Tables 4 and 5 meticulously compare these factors across sexes and sides.

As shown in Table 1, the deltoid had a mean length of 175.81 mm and a range of 157.6 to 205.0 mm, and its thickness was the highest at 5 cm from the origin point. In our investigation, the thickness of the deltoid muscle was assessed without skin or subcutaneous tissue. Also, Table 1 shows that AXN is proximate to PCHA, with the mean distances from the origin point being 68.13 and 73.31 mm.

Table 2 summarizes the mean dimensions of the quadrangular space, with a height of 4.77, a width of 11.79 and a depth of 11.01 mm.

As shown in Table 3, type-1 was the most common AXN-PCHA connection pattern, occurring in 11 of 24 instances (45%), followed by type-2 and type-3. Type-1 had the axillary nerve pass above the PCHA and split into two.

As shown in Table 4, the present study found no statistically significant difference in the mean values of right-sided variables between genders (P>0.05).

As seen in Table 5, the present study found no statistically significant difference in the mean values of left-sided variables between genders (P>0.05). ❑

Variables (mm)	Minimum	Maximum	Mean	SD
Deltoid length (mid-acromial point-DP)	157.6	205.0	175.81	11.40
Length of lateral acromion border (anterior point-posterior point)	40.2	66.0	46.66	6.22
Anterior acromial point-DP distance	153.8	210.0	173.87	11.91
Posterior acromial point-DP distance	156.0	205.0	177.06	13.20
Deltoid thickness at 3 cm from OP	4.6	20.8	14.02	5.79
Deltoid thickness at 5 cm from OP	9.2	27.2	19.16	6.44
Deltoid thickness at 7 cm from OP	11.9	24.0	17.57	3.19
OP-AXN	60.4	97.0	68.13	8.42
OP-PCHA	62.5	106.0	73.31	9.36
DP-AXN	90.0	122.3	108.03	7.66
DP-PCHA	85.0	109.1	98.39	6.63
Midpoint of deltoid-AXN	9.0	23.0	18.82	3.08
Midpoint of deltoid-PCHA	4.0	21.0	14.32	3.41

OP=origin point; DP=distal point; AXN=axillary nerve; PCHA=posterior circumflex humeral artery; SD=standard deviation

TABLE 1. Descriptive statistics of anthropometric variables of deltoid muscle

Variables (mm)	Minimum	Maximum	Mean	SD
Quadrangular space dimensions of height (mm)	4.3	5.6	4.77	0.31
Quadrangular space dimensions of width (mm)	10.6	13.8	11.79	0.76
Quadrangular space dimensions of depth (mm)	9.9	12.8	11.01	0.71

SD=standard deviation

TABLE 2. Descriptive statistics of dimensions of quadrangular space

TABLE 3. Descriptive statistics of AXN and PCHA relationship patterns

Type	Description of relationship pattern	Number of specimens (Nos)	Percentage (%)
1	AXN runs above PCHA and splits into two branches	11	45.00
2	AXN runs above PCHA and splits into more than two branches	07	30.00
3	AXN runs beneath PCHA and splits into two branches	05	20.0
4	AXN transitions from a position above the PCHA to one below	01	5.0
Total		**24**	**100.0**

AXN=axillary nerve; PCHA=posterior circumflex humeral artery

TABLE 4. Comparison of variables of right-side specimen with gender

Variables (mm)	Males (N=7)	Females (N=5)	Un-paired t-test value, P-value
	Mean ± SD	Mean ± SD	
Deltoid length (OP-DP)	170.19 ± 8.98	176.00 ± 9.16	t = 1.09, P = 0.299, NS
Lateral acromial border (AP-PP)	48.23 ± 9.16	45.94 ± 5.33	t = 0.479, P = 0.642, NS
OP-AXN	70.35 ± 13.82	65.83 ± 4.00	t = 0.703, P = 0.498, NS
OP-PCHA	75.13 ± 15.05	71.70 ± 4.55	t = 0.488, P = 0.636, NS
DP-AXN	103.08 ± 7.95	109.35 ± 8.85	t = 1.286, P = 0.227, NS
Distal point-PCHA distance (mm)	94.58 ± 5.81	100.38 ± 5.01	t = 1.796, P = 0.227, NS
Midpoint of deltoid-AXN distance (mm)	16.42 ± 4.22	19.77 ± 0.98	t = 1.716, P = 0.103, NS
Midpoint of deltoid-PCHA distance (mm)	14.31 ± 3.80	13.71 ± 3.01	t = 0.287, P = 0.780, NS
Anterior acromial point-DP distance (mm)	168.80 ± 11.09	173.60 ± 8.56	t = 0.806, P = 0.439, NS
Posterior point-DP distance (mm)	172.50 ± 11.34	175.78 ± 9.30	t = 0.531, P = 0.607, NS
Deltoid thickness at 3 cm from OP	14.84 ± 4.64	11.56 ± 6.17	t = 1.004, P = 0.339, NS
Deltoid thickness at 5 cm from OP	19.92 ± 5.41	16.95 ± 7.70	t = 0.791, P = 0.447, NS
Deltoid thickness at 7 cm from OP	18.38 ± 3.98	15.94 ± 2.76	t = 1.172, P = 0.268, NS
Quadrangular space dimensions of height (mm)	4.62 ± 0.24	4.78 ± 0.25	t = 1.105, P = 0.295, NS
Quadrangular space dimensions of width (mm)	11.41 ± 0.60	11.80 ± 0.61	t = 1.097, P = 0.299, NS
Quadrangular space dimensions of depth (mm)	10.66 ± 0.56	11.02 ± 0.57	t = 1.097, P = 0.298, NS

OP=origin point; DP=distal point; AXN=axillary nerve; PCHA=posterior circumflex humeral artery; SD=standard deviation; AP=anterior acromial point; PP=posterior acromial point.

TABLE 5. Comparison of variables of left side specimen with gender

Variables	Males (N=7)	Females (N=5)	Un-paired t-test value, P-value
	Mean ± SD	Mean ± SD	
Deltoid length (OP-DP)	177.86 ± 14.56	180.64 ± 11.50	t = 0.353, P = 0.731, NS
Lateral acromial border (AP-PP)	46.75 ± 5.44	45.04 ± 1.73	t = 0.673, P = 0.516, NS
OP-AXN	68.43 ± 6.48	66.89 ± 4.98	t = 0.443, P = 0.667, NS
OP-PCHA	73.83 ± 8.58	71.63 ± 4.40	t = 0.521, P = 0.614, NS
DP-AXN	109.03 ± 5.10	112.24 ± 7.54	t = 0.885, P = 0.397, NS
DP-PCHA distance (mm)	100.27 ± 6.28	99.08 ± 9.01	t = 0.273, P = 0.791, NS
Midpoint of deltoid-AXN distance (mm)	19.07 ± 2.34	20.86 ± 1.55	t = 1.479, P = 0.170, NS
Midpoint of deltoid-PCHA distance (mm)	13.57 ± 4.41	16.03 ± 1.33	t = 1.185, P = 0.263, NS
AP-DP distance (mm)	176.72 ± 16.85	177.23 ± 7.70	t = 0.063, P = 0.952, NS
Posterior point-DP distance (mm)	181.63 ± 16.36	178.34 ± 15.63	t = 0.350, P = 0.733, NS
Deltoid thickness at 3 cm from OP	15.27 ± 5.59	13.06 ± 7.55	t = 0.441, P = 0.669, NS
Deltoid thickness at 5 cm from OP	20.24 ± 6.42	18.78 ± 8.01	t = 0.353, P = 0.732, NS
Deltoid thickness at 7 cm from OP	17.96 ± 3.18	17.51 ± 2.69	t = 0.256, P = 0.803, NS
Quadrangular space dimensions of height (mm)	4.83 ± 0.39	4.90 ± 0.31	t = 0.356, P = 0.729, NS
Quadrangular space dimensions of width (mm)	11.93 ± 0.97	12.11 ± 0.77	t = 0.354, P = 0.731, NS
Quadrangular space dimensions of depth (mm)	11.14 ± 0.91	11.31 ± 0.72	t = 0.352, P = 0.732, NS

OP=origin point; DP=distal point; AXN=axillary nerve; PCHA=posterior circumflex humeral artery; SD=standard deviation; AP=anterior acromial point; PP=posterior acromial point.

DISCUSSION

In a study of 40 specimens from 22 Korean cadavers, Ye-Gyung Kim *et al* discovered that the mean lateral acromial border (AP-PP) distance was 4.7 ± 0.7 cm, while the mean vertical length of the deltoid muscle (OP-DP) was 16.1 ± 1.0 cm. At 3, 5 and 7 cm, the thickness of the deltoid muscle was 0.62 ± 0.9 cm, 0.73 ± 0.7 cm and

1.3 ± 1.1 cm, respectively (16). In the study, the mean AP-PP and OP-DP distances were 4.66 ± 0.54 cm and 17.58 cm, respectively, whereas deltoid muscle thickness was 1.40, 1.91 and 1.75 cm at 3, 5 and 7 cm. Nicholson *et al* (USA) found considerable lateral acromion border length differences between males and females. In their study, acromial dimensions (L x W x T) averaged 48.5 x 19.5 x 7.7 mm in men and 40.6 x 18.4 x 6.7 mm in women. In our study, the mean length of the lateral acromial border (AP-PP) in males and females was 48.23 ± 9.16 mm and 45.94 ± 5.33 mm, respectively. Our results reflect the findings of the two studies cited above (18).

Regarding the AXN and PCHA distances, Nakatani *et al* (Japan) found that males and females had 6.4 cm (5.8-7.4) and 5.7 cm (4.9-7.1) distances from mid-acromial lateral border to AXN from 31 specimens in 21 cadavers (19). In our study, male and female OP-AXN distances were 6.93 ± 1.01 and 6.63 ± 0.44 cm, respectively. Our results were similar to theirs. According to Nakajima *et al* (Japan), deltoid IM is safest in the tuberosity's periphery (20). This region had the thinnest deltoid muscle and was quite close to the periosteum. The PCHA was located differently from the values reported by Nakajima *et al*, who found 7.6 ± 1.0 (5.5-9.2) cm below mid-acromion lateral border in males and 6.2 ± 0.8 cm (5.1-7.7) in females (20). In our research, we found the same structure (7.44 ± 1.18 cm and 7.16 ± 0.44 cm below the landmark) in males and females, respectively. According to Gurushantappa PK (India), AXN was 7.46 cm ± 0.99 cm from the midpoint of the postero lateral border of the acromion process (8), while in our study it was 6.81 cm ± 0.84 cm. Patra A. *et al* (India) found that AXN was 5.22 cm and 4.17 cm from the front and posterior acromion borders (7). In our research, the mean AXN-OP distance was 6.81 cm ± 0.84 cm. In the cases where the shoulder was abducted 60 degrees, Cheung K. *et al* (USA) found that the anterior branch of AXN travelled 1.3 to 1.4 cm nearer the 16 acromia (21), while we discovered that AXN and PCHA moved 1.1 cm. According to Ye-Gyung Kim *et al*, the mean distance of AXN and PCHA (0.5 cm below) from the mid-acromial point was 5.8 ± 1.0 cm and 6.3 ± 0.9 cm, respectively; the deltoid muscle had a mean length of 16:1 ± 1:0 cm and was the thickest at 7 cm (16). In our study, the mean deltoid length was 17.58 cm, 1.5 cm longer. The deltoid muscle was the thickest at 5 cm. Also, AXN measured 6.81 ± 0.84 cm and PCHA 7.33 ± 0.93 cm. Axillary nerve anatomy varies. Standard textbooks place it 5 cm from the acromion (22, 23). Kontakis GM *et al* found it 4.3-6.3 cm from the acromion's front margin and 4.1-6.3 from its posterior edge (24). Burkhead *et al* observed it 3.1 cm to 7.7 cm from the lateral edge of acromion, with 20% of patients measuring less than 5 cm (25). Kulkarni *et al* found it 2.2–2.6 cm above the deltoid centre and 5 cm below the acromion (26).

In a cadaveric investigation by Gurushantappa and Kuppasad (India), quadrangular space dimensions were found to be 2.23 ± 0.40 cm in height, 2.19 ± 0.22 cm in breadth and 1.25 ± 0.14 cm in depth (8). In our study, these variables measured 0.47 ± 0.03, 1.17 ± 0.07, and 1.10 ± 0.07 cm. Gurushantappa PK *et al* found that the mean distance of the axillary nerve from the antero-medial tip of the coracoid process, postero-lateral acromion process, midpoint of deltoid insertion and midpoint of deltoid muscle was 3.56 ± 0.51, 7.4 ± 0.99, 6.7 ± 0.47 and 2.45 ± 0.48, respectively. In our study, we did not measure AXN's distance from the tip of the coracoid process or the posterolateral aspect of the acromion process, but we did measure 10.80 ± 0.76 cm and 1.88 ± 0.30 cm. Ye-Gyung Kim *et al* (Korea) found that type-1 (60%), in which AXN gave two branches, one above and one below the PCHA, was the most prevalent axillary nerve branching pattern (16). In our investigation, type-1 pattern was seen in 45% of all dissected specimens.

The Centers for Disease Control and Prevention (2021), National Immunization Technical Advisory Groups (NITAGs) Ireland (2020) and New Zealand (2020) recommend injecting deltoid intramuscularly in the central and thickest portion of the muscle, approximately two inches (5.08 cm) below the mid-acromion (27). The Handbook of Safe Injection Practices, the National Centre for Disease Control (NCDC) and the Government of India recommend deltoid IM one to two inches (4.4 cm) below the acromion process (28). Deltoid IM should be performed 2-3 fingerbreadths below the acromion process and above the upper arm armpit, according to the US Department of Health and Human Sciences Centres for Disease Control and Prevention (2017) (29).

For deltoid intramuscular injections, Davidson *et al* (2007) suggested a position 1-3 fingerbreadths (5 cm) below the mid-acromion (30). The apex of a triangular injection site should be at the intersection of the upper ends of the anterior and posterior axillary lines and the base should be a horizontal line 1-3 fingerbreadths (5 cm) below the mid-acromion (31, 32). In their 2005 nursing manual, Funnell *et al* (Australia) suggested a position in whites at the middle 1/3rd of deltoid muscle, with mid-acromion as its origin and deltoid tuberosity as its insertion (33). According to Kim *et al*, 2017 (Korea), the safest site for deltoid IM in Asians is a mid-deltoid site with the acromion as the muscle's origin and the tuberosity as its insertion (34). We found that AXN and PCHA were 6-8 cm and 7-9 cm from the mid-acromial point, respectively, and the mean mid-deltoid point was 8.79 cm. Our study suggests deltoid IM at any site distal to the mid-deltoid point or 9 cm distal to the mid-acromial point. Similar results were reported in our systematic review (35).

Study limitations

This study's main drawback was the limited number of cadaveric specimens available, which led to a small sample size. Consequently, the statistical analysis did not produce significant results, which limited the findings' applicability to the broader population. ❑

CONCLUSION

The current study provides valuable morphometric information on the deltoid region, emphasizing differences in deltoid muscle length, acromial border dimensions and neurovascular structure locations based on gender. The results show that males have a thicker deltoid muscle than females, with the thickest muscle located about 5 cm below the mid-acromial point. The posterior circumflex humeral artery and axillary nerve were consistently found 6-7.5 cm below the mid-acromial point, highlighting the necessity of avoiding intramuscular injections in the upper half of the deltoid to prevent iatrogenic injury. The type-1 pattern was the most prevalent anatomical relationship between the artery and axillary nerve. A safe injection location is suggested to be about 9 cm (four fingerbreadths) below the mid-acromion based on the anatomical landmarks that have been observed. Safer vaccination administration is also ensured by placing the recipient's hand on the hip to abduct the shoulder, which improves accessibility to the mid-deltoid region. The developed linear regression formulas provide predictive value for acromial or deltoid length estimation, which may support customized clinical evaluations. ❑

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