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Clinical Assessment of Anatomical Landmarks of the Shoulder for Safe Intramuscular Injections. A Cross-Sectional Study among Adult Patients

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ABSTRACT

Background: Standard deltoid intramuscular injection landmarks may not account for sex-specific anatomical variations, increasing the risk of subcutaneous injection, periosteal contact, or neurovascular injury.

Objectives: To quantify deltoid region anthropometry and tissue-depth biomarkers in Pakistani adults and assess sex differences to improve injection safety.

Methods: This cross-sectional study (June 2023–November 2024) enrolled 100 outpatients (50 men, 50 women; aged 18–65 years) at Nawaz Sharif Medical College and Aziz Bhatti Shaheed DHQ Hospital, Gujrat, following ethical approval and informed consent. Acromion–tuberosity distance and upper arm circumference were measured with a flexible tape; triceps skinfold thickness with Harpenden calipers; and deltoid muscle thickness using a 7.5 MHz ultrasound probe. Data were analysed with independent-samples t-tests and Pearson correlation in SPSS v26 ($p < 0.05$).

Results: Mean acromion–tuberosity distance was 53.2 ± 4.8 mm, higher in men (55.6 ± 4.2 mm) than women (50.8 ± 4.1 mm; $p < 0.001$). Upper arm circumference averaged 28.5 ± 2.9 cm (men: 30.2 ± 2.7 cm; women: 26.8 ± 2.3 cm; $p < 0.001$). Triceps skinfold thickness was greater in women (13.4 ± 4.0 mm) than men (11.8 ± 3.5 mm; $p = 0.014$), while deltoid muscle thickness was higher in men (19.2 ± 3.1 mm) than women (17.6 ± 3.0 mm; $p = 0.022$). Triceps skinfold showed strong correlation with BMI ($r = 0.65$; $p < 0.001$), and deltoid muscle thickness showed moderate correlation ($r = 0.42$; $p = 0.005$).

Conclusion: Although the 50 mm landmark generally identifies deltoid muscle, significant sex differences in muscle and fat warrant individualised needle selection using anthropometric or ultrasound guidance to minimise injection-related complications.

Keywords: Deltoid Muscle; Intramuscular Injection; Anatomical Landmarks; Shoulder Anthropometry; Ultrasound Measurement; Pakistan.

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INTRODUCTION

Intramuscular (IM) injections into the deltoid muscle are a mainstay of modern clinical practice as the most common route for the administration of a wide array of therapeutics, including routine vaccination, hormone therapy, antibiotic regimens, and biologic agents. For most adults, the deltoid muscle is the selected muscle because it is easily accessible and has favourable vascularity for rapid drug absorption and minimal overlying adipose tissue [1]. However, even though it is common, the procedure is not without risk. Local complications such as pain, swelling, hematoma, abscess formation, periosteal damage, and rarely axillary nerve bundle injury or injury of the humeral insertion can occur when the injection site is not properly identified [2].

Conventionally, the deltoid injection "safe zone" is described as a triangular region that is superiorly bounded by the acromion process, laterally by the midline of the arm, and inferiorly at approximately 5 cm below the acromion [3]. The deltoid muscle belly is thickest in this triangle, where it should be ideally located to ensure that maximal drug uptake occurs without causing damage to neurovascular structures. Yet, accumulating evidences from anthropometric and imaging studies argue that this standardized landmark is not always coincident with the muscular midpoint of all individuals. Measurable changes in muscle bulk and the spatial relationship of bony landmarks are due to variables including sex, age, body mass index (BMI), and ethnic background [4].

In particular, South Asian populations such as Pakistanis are known to have distinct anthropometric profiles with generally shorter stature, narrower shoulder breadths, and variable patterns of subcutaneous fat distribution [5]. These differences can also affect the palpation landmarks that clinicians depend on when making injections that may be too high and risk the subacromial bursa or too low, where the muscle tapers and gets closer to the humeral head. While these recognized variations exist, there is a lack of region-specific data to inform healthcare professionals on how to approach their technique to ensure safety and efficacy [6].

Additionally, the magnitude of vaccination campaigns, particularly those in the context of public health campaigns (e.g., polio eradication, COVID-19 immunization drive), emphasizes the need to minimize iatrogenic harm on a large scale [7]. When millions of doses are administered annually, even small percentages of injection-related complications can impose tremendous burdens on healthcare systems and patients' well-being. It is therefore critical to ensure that they have precise, evidence-based landmarks that the practitioners can use [8].

This study fills these gaps by systematically measuring the distances in the deltoid region of a representative cohort of adult patients in Lahore, Pakistan. The present study aimed to quantify the distance between the acromion process and the deltoid tuberosity and assess gender specific differences to further define the safe injection zone for our local context. These findings will inform clinical guidelines and training curricula and can inform broader efforts to improve patient safety and intramuscular injection practice generally in South Asia [9].

MATERIALS AND METHODS

The current study was a descriptive, cross-sectional investigation conducted between June 2023 and November 2024 at Nawaz Sharif Medical College and its affiliated Aziz Bhatti Shaheed DHQ Hospital, Gujrat, Pakistan, following approval by the Institutional Review Board (IRB). Adults aged

18–65 years attending general medicine and surgery outpatient clinics were screened, and those without a history of shoulder surgery or trauma, congenital musculoskeletal deformities, neuromuscular disorders, acute shoulder pathology or infection, pregnancy, or lactation were deemed eligible. Written informed consent was obtained from each volunteer—during which confidentiality safeguards and the right to withdraw without penalty were clearly emphasised—and 100 participants (50 men, 50 women) were enrolled.

An a priori power calculation ($\alpha = 0.05$; $1-\beta = 0.80$) predicated on detecting a 4 mm mean difference (SD ≈ 5 mm) in acromion-to-tuberosity distance determined that 92 subjects were required; the current study increased this to 100 to accommodate up to 10% nonresponse. Enrolled participants completed a structured questionnaire recording age, sex, height, weight, body mass index (kg/m^2), hand dominance, occupation (sedentary, light, moderate, heavy), and physical activity level (International Physical Activity Questionnaire short form).

To minimise inter-observer variability, all anthropometric and tissue-depth measurements were performed by a single ISAK-certified examiner. With participants seated upright and the dominant arm relaxed, the anterolateral edge of the acromion and the deltoid tuberosity were palpated; the linear distance between these landmarks was measured twice to the nearest millimetre using a flexible steel tape, and the mean value was recorded. The injection landmark was confirmed 50 mm inferior to the acromion. Upper arm circumference was measured at the midpoint between the acromion and olecranon, aligned parallel to the skin. Triceps skinfold thickness at the same point was assessed using calibrated Harpenden calipers (two readings averaged to the nearest 0.5 mm). Deltoid muscle thickness was quantified via ultrasonography: three transverse images were captured with a 7.5 MHz linear probe at the injection site, and the mean muscle thickness was recorded.

Quality assurance included a hands-on training workshop, monthly calibration of tapes and calipers, and fixed ultrasound gain and depth settings. Intra-observer reliability was assessed in 10% of participants re-measured one week later, yielding intraclass correlation coefficients > 0.90 for all parameters. Data were double-entered into Microsoft Excel for error checking and analysed in SPSS v.26. Continuous variables are presented as mean ± SD; categorical variables as frequencies and percentages. Between-sex comparisons employed independent-samples t-tests, and Pearson's correlation coefficients examined associations between BMI and tissue-depth metrics. Statistical significance was set at $p < 0.05$.

All procedures adhered to the principles of the Declaration of Helsinki. Ethical considerations included IRB approval, documented written informed consent, de-identification of data to ensure participant anonymity, and referral for clinical evaluation in the event of incidental shoulder pathology.

RESULTS

Therefore, 50 males and 50 females were enrolled as adult outpatients, and all measurements were completed. The ages of participants ranged from 18 to 65 years of age (mean 38.4 ± 12.7 years) and so constitute a middle-aged group. Mean height overall was 165.2 ± 8.7 cm, weight 67.1 ± 12.4 kg, and BMI 24.6 ± 3.2 kg/m^2. In 92 percent of subjects, right-hand dominance was observed. Sexes also did not differ concerning occupational activity levels (sedentary to heavy) or self-reported physical activity (IPAQ categories). These baseline characteristics indicate a moderate, balanced sample with little variance in body habitus or lifestyle factors, which provides a strong foundation for anatomically precise comparison.

Table 1's demographic characteristics shows that there is no demographic confounding between males and females, regarding age, BMI, and dominance.

Table-1: Demographic Characteristics of Study Participants (n = 100)

Variable	Overall (n=100)	Males (n=50)	Females (n=50)
Age (years), mean ± SD	38.4 ± 12.7	39.1 ± 13.0	37.7 ± 12.5
Height (cm), mean ± SD	165.2 ± 8.7	170.5 ± 6.5	160.0 ± 7.1
Weight (kg), mean ± SD	67.1 ± 12.4	72.3 ± 11.8	61.9 ± 10.9
BMI (kg/m²), mean ± SD	24.6 ± 3.2	24.9 ± 3.5	24.2 ± 2.8
Hand Dominance, n (%)			
Right	92 (92%)	46 (92%)	46 (92%)
Left	8 (8%)	4 (8%)	4 (8%)
Occupation Category, n (%)			
Sedentary	35 (35%)	18 (36%)	17 (34%)
Light activity	40 (40%)	20 (40%)	20 (40%)
Moderate activity	20 (20%)	10 (20%)	10 (20%)
Heavy activity	5 (5%)	2 (4%)	3 (6%)
Physical Activity Level (IPAQ), n (%)			
Low	30 (30%)	15 (30%)	15 (30%)
Moderate	50 (50%)	25 (50%)	25 (50%)
High	20 (20%)	10 (20%)	10 (20%)

Overall, there was a narrow BMI distribution (18.5–29.8 kg/m²) of the cohort and consistent hand dominance, preventing subsequent anatomical differences from being driven by these demographic factors.Table 2 provides core anthropometric measurements of the deltoid region. For all participants, the mean distance from anterolateral acromion to deltoid tuberosity was 53.2 ± 4.8 mm. The distances (55.6 ± 4.2 mm) of males were significantly greater than those of females (50.8 ± 4.1 mm; $p < 0.001$). On average, the upper arm circumference, a surrogate for the total muscle bulk, was 28.5 ± 2.9 cm, and males gave larger values (30.2 ± 2.7 cm) than females (26.8 ± 2.3 cm, $p < 0.001$). These results suggest that the deltoid muscle envelope of men is wider, giving a larger safety margin for intramuscular injections.

Table-2: Core Anthropometric Measurements

Variable	Overall (n=100)	Males (n=50)	Females (n=50)	p-value
Acromion–Tuberosity Distance (mm), mean ± SD	53.2 ± 4.8	55.6 ± 4.2	50.8 ± 4.1	< 0.001
Upper Arm Circumference (cm), mean ± SD	28.5 ± 2.9	30.2 ± 2.7	26.8 ± 2.3	< 0.001

Individual variability is evidenced by the 4.8 mm (4.8) overall standard deviation around the acromion–tuberosity distance that shows that reliance on a fixed 50 mm rule could place injections perilously close to the periosteum in smaller individuals, especially women.

The tissue depth biomarkers (triceps skinfold and ultrasound-measured muscle thickness) are detailed in Table 3. Overall, the mean triceps skinfold thickness was 12.6 ± 3.8 mm, and females had 13.4 ±3.0 mm vs males 11.8 ± 3.5 mm ($p = 0.014$). The difference of 1.6 mm is a 13.6% greater fat layer in women. Overall, the mean deltoid muscle thickness averaged 18.4 ± 3.2 mm, and males had a mean of 19.2 ± 3.1 mm and females 17.6 ± 3.0 mm ($p = 0.022$). Due to the thinner muscle and thicker fat pad in females, the effective intramuscular target zone is narrowed, and the risk of depositing subcutaneously or in a periosteal contact is higher if the needle depth is not adjusted appropriately.

Table-3: Tissue-Depth Biomarker Measurements

Variable	Overall (n=100)	Males (n=50)	Females (n=50)	p-value
Triceps Skinfold Thickness (mm), mean ± SD	12.6 ± 3.8	11.8 ± 3.5	13.4 ± 4.0	0.014
Deltoid Muscle Thickness (mm, ultrasound), mean ± SD	18.4 ± 3.2	19.2 ± 3.1	17.6 ± 3.0	0.022

In the clinic, the selection of needle length must include consideration of the muscle depth and adipose layer. For example, in the female patient with a fat layer of 13.4 mm and muscle of 17.6 mm, the standard 25 mm needle will penetrate approximately 11.6 mm into muscle, which is adequate but closer to periosteum than in the average male (penetration of 13.2 mm into muscle).

Local tissue biomarkers were correlated with BMI (Table 4). Triceps skinfold thickness correlated strongly with BMI ($r = 0.65$, $p < 0.001$), which is a good indication that adiposity is a good predictor of subcutaneous fat at the deltoid site. In contrast, BMI correlated moderately ($r = 0.42$; $p = 0.005$) with ultrasound-measured muscle thickness and is a less precise surrogate of muscle bulk.

Table-4: Correlation of BMI with Tissue-Depth Biomarkers

Biomarker	Pearson r	p-value
Triceps Skinfold Thickness (mm)	0.65	< 0.001
Deltoid Muscle Thickness (mm)	0.42	0.005

These correlations indicate that BMI may help to give an initial guesswork on fat thickness, but direct measurement of local tissue depth (either by calipers or ultrasound) is necessary for accurate needle selection and estimation of injection depth.

In summary, these detailed results demonstrate that the acromion standardized 50 mm landmark reliably penetrates all adult patients, but the anatomic margin varies between sexes. Wider muscular envelop, and shallower adipose layer of male patients, and narrower muscular depth and thicker fat pad in female patients, stress the need for precise landmark palpation and, if possible, individualized measurement of tissue depths to ensure the safety and efficacy of injections.

DISCUSSION

As far as the deltoid region is concerned, the present study offers comprehensive anthropometric and tissue depth data of a Pakistani adult population with important sex specific differences with direct implications for intramuscular injection practice [10]. This finding that males have much more acromion–tuberosity distance (55.6 mm vs. 50.8 mm) and larger upper arm circumference (30.2 cm vs. 26.8 cm) than females confirms that men have a larger muscle envelope with a greater safety margin for needle placement. On the other hand, females had a thinner deltoid muscle thickness (17.6 mm vs. 19.2 mm) and thicker subcutaneous fat layer (13.4 mm vs. 11.8 mm), which reduced the intramuscular target zone. These differences highlight that the ‘5 cm below acromion’ rule is generally valid but carries the danger of perilously close injections to the humeral periosteum in smaller or leaner patients (women in particular) if not individually assessed [11].

Our results are consistent with previous anthropometric studies in South Asian and other ethnic groups, which have shown shorter acromion–tuberosity distances (typically 60–65 mm) than are typically reported in Western populations and less muscle bulk of the deltoid muscle. Such variation underscores the need for population-specific rather than blanket application of landmarks derived from other groups [12]. Additionally, the high correlation of BMI with skinfold thickness (r = 0.65) but only a moderate correlation with muscle thickness (r = 0.42) implies that BMI is not sufficient to estimate muscle depth well. Better precision is provided by direct local measurements, whether via simple caliper assessment or, ideally, portable ultrasound for needle length and insertion angle [13].

These findings have large clinical implications. Failure to recognize individual and sex based anatomical differences may result in subcutaneous injection (reducing vaccine efficacy or drug absorption) or periosteal contact (causing obvious pain and patient reluctance for future injections) in mass vaccination settings or routine outpatient care [14]. These risks can be mitigated by training healthcare providers in palpating bony landmarks, but not only that, they should be trained to perform quick anthropometric assessments of arm circumference and skinfold thickness. Point-of-care ultrasound can provide even more refinement to injection depth, where resources allow, especially in high-stakes scenarios such as immunocompromised or pediatric patients [15].

Our study is limited to its single-center design and ambulatory outpatients and might not include the extremes of BMI and very elderly individuals with pronounced sarcopenia. Furthermore, intra-observer reliability, while high, would be strengthened by multi-observer validation, and all measurements were performed by a single examiner [16]. Future research should increase the sample to include patients of different BMI categories, older age groups, and those with comorbidities that affect muscle mass. Further investigation into the impact of dynamic factors (e.g., arm position, muscle contraction) on landmark accuracy would enhance injection safety [13, 17].

CONCLUSION

This cross-sectional study of 100 Pakistani adults showed sex based differences in deltoid anatomy, with males having larger muscle bulk, shorter fat layers, and females having narrower intramuscular target zones due to thinner muscle and thicker adipose tissue. For all subjects, the traditional landmark of 50 mm below the acromion lies within the deltoid belly, and individual measurement of anthropometric and tissue depth parameters is recommended for optimal needle selection and injection accuracy. Tailored landmarking protocols (perhaps augmented by portable ultrasound) can reduce iatrogenic complications and improve therapeutic efficacy for a wide variety of patients.

Conflict of Interest:

The authors declare that no conflicts of interest exist.

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Authors' Contributions:

All authors contributed equally to this work.

Data Availability:

De-identified data are available from the corresponding author upon reasonable request.

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