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# Ultrasonographic Assessment of Deltoid Muscle Echogenicity for Type 2 Diabetes Screening.

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## Abstract

***Background:*** Type 2 diabetes mellitus (T2DM) is frequently underdiagnosed due to its insidious onset, and there is growing interest in non-invasive imaging biomarkers for early detection. Deltoid muscle echogenicity on ultrasound has emerged as a potential screening tool, given its correlation with intramuscular fat infiltration seen in insulin-resistant states. ***Methods:*** This cross-sectional observational study was conducted at ESIC Medical College, Kalaburagi, over 3 months and included 100 participants. Deltoid muscle echogenicity was graded qualitatively (hypoechoic/isoechoic vs hyperechoic) and quantitatively using grayscale pixel intensity and correlated with fasting blood glucose, HbA1c and BMI. ***Results:*** Of 100 participants, 52 were diabetic and 48 non-diabetic. Hyperechoic deltoid appearance was observed in 41 of 52 diabetics (78.8%) versus 9 of 48 non-diabetics (18.7%). Mean echo intensity was significantly higher in diabetics (142.6 ± 18.3) than non-diabetics (98.4 ± 15.1). Deltoid echogenicity showed sensitivity of 78.8% and specificity of 81.3% for detecting T2DM, with a strong positive correlation with HbA1c (r=0.71). ***Conclusion:*** Deltoid muscle echogenicity is a simple, accessible, and reasonably accurate non-invasive ultrasonographic marker that correlates well with glycemic status and may serve as an adjunct screening tool for T2DM.

**Keywords:** deltoid muscle; echogenicity; type 2 diabetes mellitus; ultrasound screening.



## INTRODUCTION

Type 2 diabetes mellitus (T2DM) has become a major public health issue globally. India has a large share of the diabetes population, a considerable proportion of whom go undiagnosed till complications develop.[1] Conventional diagnostic modalities rely on blood sampling which though quite accurate, may not be useful for screening the population because of cost, accessibility and patient comfort.[2] Musculoskeletal ultrasound has emerged as a new non-invasive alternative for T2DM screening. Several studies have shown that the deltoid muscle in patients with diabetes has a characteristic hyperechoic appearance due to deposition of intramuscular fat and glycogen.[3]

This is difference from the generally hypoechoic to isoechoic appearance in non-diabetics. It has been proposed that this altered echogenicity is useful surrogate marker representing the metabolic derangement caused by chronic hyperglycemia at the tissue level.[4] Earlier work including studies assessing this with quantitative sonography quantified have shown that deltoid echogenicity has clinically useful sensitivity and specificity for predicting T2DM, and may also pick up prediabetics who have not yet progressed to overt disease.[1,5 ]However, most of the above studies originate from the west. Data from Indian tertiary care centres is limited.

The rising burden of T2DM in India and the need for simple, reproducible and low-cost screening tools have stimulated interest in this study. The present study has been taken up to evaluate deltoid muscle echogenicity as a screening marker for T2DM in patients attending a tertiary care centre. Furthermore, we aimed to correlate the ultrasonographic findings with fasting blood glucose, HbA1c and BMI.

## MATERIALS AND METHODS

### Study Design and Setting

This cross-sectional observational study was conducted over a 3-month period in the Department of Radiodiagnosis at ESIC Medical College, Kalaburagi. The study protocol was formally approved by the Institutional Ethics Committee prior to initiation. Written informed consent was obtained from all participating individuals following a detailed explanation of the study objectives and ultrasound procedures, adhering strictly to the ethical principles of the Declaration of Helsinki.

**Participant Selection and Group Stratification**

A total of N = 100 adult participants aged 30 to 65 years attending the outpatient department were enrolled sequentially. Based on established clinical diagnostic criteria for diabetes mellitus (fasting plasma glucose [FPG] ≥ 126 mg/dL and/or glycated hemoglobin [HbA1c] ≥ 6.5%), participants were stratified into two cohorts:

Diabetic Group (Cases, n = 52): Comprising 52 individuals with confirmed Type 2 Diabetes Mellitus meeting the diagnostic thresholds for FPG or HbA1c.

Non-Diabetic Control Group (Controls, n = 48): Comprising 48 age-matched, normoglycemic individuals with FPG < 100 mg/dL and HbA1c < 5.7%.

Exclusion Criteria: Individuals with known primary myopathies, prior shoulder trauma or surgery, active or recent systemic corticosteroid therapy, neuromuscular disorders affecting the upper extremities, or localized dermatological lesions over the shoulder that could interfere with acoustic coupling or alter deltoid muscle architecture were excluded.

**Ultrasound Imaging Protocol**

All sonographic evaluations were performed using a high-resolution color Doppler ultrasound scanner equipped with a high-frequency linear-array transducer (7–12 MHz). To minimize inter-individual variance and technical artifacts, all scans were performed by experienced radiologists adhering to a standardized imaging protocol:

**Patient Positioning:** Participants were seated comfortably in a relaxed, upright position with the arm resting neutrally at the side and the forearm resting on the lap to avoid involuntary muscular contraction.

**Transducer Orientation:** The linear probe was placed longitudinally over the mid-deltoid muscle belly, approximately midway between the acromion process and the deltoid tuberosity of the humerus.

**System Standardization:** System settings—including time-gain compensation, depth (3 to 4 cm), overall gain, and focus—were standardized at the beginning of the study and kept constant across all participant scans to ensure consistency in grayscale echogenicity measurements.

**Qualitative and Quantitative Echogenicity Assessment**

Deltoid muscle echotexture was evaluated utilizing both qualitative grading and quantitative grayscale analysis:

**Qualitative Assessment:** Grayscale images of the mid-deltoid was visually graded blinded to the participant's glycemic status. Echogenicity was categorized relative to the underlying hyperechoic humeral bone cortex and adjacent subcutaneous fat: (1) Normal Grade (Hypoechoic/Isoechoic): Muscle parenchyma appearing predominantly hypoechoic with distinct, clearly visible hyperechoic fibroadipose septa. (2) Abnormal Grade (Hyperechoic): Diffuse increase in echogenicity (brightening of the muscle parenchyma) approaching or matching the echogenicity of surrounding adipose tissue, with blurring or loss of distinct fibroadipose septal architecture.

**Quantitative Assessment:** A standardized region of interest (ROI) was manually placed within the mid-deltoid muscle belly, carefully avoiding major fascial planes, humeral bone cortex, and artifactual acoustic shadowing. Grayscale histogram analysis was performed within this ROI utilizing image analysis software to derive a quantitative mean echo intensity value (measured on a scale of 0 [black] to 256 [white] pixels). Deltoid muscle thickness (mm) was also measured perpendicularly from the superficial subcutaneous fascia to the deep bone-muscle interface.

**Clinical and Glycemic Variables**

Concurrently with ultrasound imaging, baseline demographic and clinical variables were documented for each participant. Recorded parameters included age, sex, body mass index (BMI, calculated as $kg/m^2$), duration of diabetes (in years, where applicable), fasting plasma glucose (mg/dL), and HbA1c percentage (%).

**Statistical Analysis**

Compiled data were verified and analyzed using standard statistical software. Continuous variables were assessed for normal distribution using the Shapiro-Wilk test and expressed as mean ± standard deviation (SD). Categorical data were presented as absolute frequencies and percentages (%). Intergroup comparisons between the diabetic and non-diabetic cohorts were conducted using Student's independent two-tailed t-test or the Mann-Whitney U test for continuous variables, and Pearson's $\chi^2$ test or Fisher's exact test for categorical variables. The diagnostic performance of qualitative echogenicity grading was evaluated by calculating sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Pearson's correlation coefficient (r) or Spearman's rank correlation (ρ) was utilized to evaluate linear associations between quantitative mean echo intensity values and continuous glycemic parameters (FPG and HbA1c). A two-tailed p-value < 0.05 was considered statistically significant for all analyses.

## RESULTS

A total of 100 participants were evaluated, comprising 52 diabetics and 48 non-diabetics.

**Table 1: Baseline Demographic and Clinical Characteristics**

| Parameter | Diabetic (n=52) | Non-Diabetic (n=48) | p-value |
|---|---|---|---|
| Mean age (years) | 54.2 ± 8.6 | 48.7 ± 9.3 | 0.002 |
| Male:Female ratio | 30:22 | 26:22 | 0.68 |
| Mean BMI (kg/m²) | 27.8 ± 3.4 | 24.9 ± 2.8 | <0.001 |
| Mean duration of DM (years) | 6.4 ± 4.1 | — | — |
| Mean fasting blood glucose (mg/dL) | 168.3 ± 32.5 | 91.2 ± 9.6 | <0.001 |
| Mean HbA1c (%) | 8.1 ± 1.4 | 5.4 ± 0.5 | <0.001 |

Table 1 shows that the diabetic group (n=52) was significantly older (54.2 vs 48.7 years, p=0.002) and had a higher BMI (27.8 vs 24.9 kg/m², p<0.001) than the non-diabetic group (n=48). As expected, fasting blood glucose and HbA1c were markedly elevated in diabetics (p<0.001 for both), while sex distribution was comparable between groups (p=0.68). The mean duration of diabetes in the case group was 6.4 ± 4.1 years.

**Table 2: Deltoid Muscle Echogenicity Findings**

| Echogenicity Pattern | Diabetic (n=52) | Non-Diabetic (n=48) |
|---|---|---|
| Hyperechoic | 41 (78.8%) | 9 (18.7%) |
| Isoechoic/Hypoechoic | 11 (21.2%) | 39 (81.3%) |
| Mean echo intensity (grayscale units) | 142.6 ± 18.3 | 98.4 ± 15.1 |
| Mean deltoid thickness (mm) | 14.2 ± 2.1 | 16.8 ± 2.4 |

Table 2 demonstrates that a hyperechoic deltoid pattern was seen in 78.8% of diabetics compared to only 18.7% of non-diabetics, while the reverse pattern (isoechoic/hypoechoic) predominated in non-diabetics (81.3%). Mean echo intensity was substantially higher in diabetics (142.6 vs 98.4 grayscale units), reflecting increased intramuscular fat infiltration. Diabetics also showed slightly reduced deltoid thickness (14.2 vs 16.8 mm), suggestive of early muscle atrophic changes.

**Table 3: Diagnostic Performance of Deltoid Hyperechogenicity for T2DM**

| Metric | Value |
|---|---|
| Sensitivity | 78.8% |
| Specificity | 81.3% |
| Positive predictive value | 82.0% |
| Negative predictive value | 78.0% |
| Correlation with HbA1c (r) | 0.71 |
| Correlation with fasting glucose (r) | 0.66 |

Table 3 summarizes the diagnostic accuracy of deltoid hyperechogenicity for detecting T2DM, showing good sensitivity (78.8%) and specificity (81.3%), with positive and negative predictive values of 82.0% and 78.0% respectively. Echo intensity correlated strongly with HbA1c (r=0.71) and moderately-strongly with fasting glucose (r=0.66). These findings support deltoid echogenicity as a reasonably accurate non-invasive screening marker for T2DM.

## DISCUSSION

According to the results obtained from this study, the hyperechoic appearance of the deltoid muscle on ultrasound is significantly correlated with T2DM with a sensitivity of 78.8% and specificity of 81.3%, which are similar to previous sonographic studies of delta muscle. According to Rosen et al. [1], quantitative deltoid ultrasound assessment was both sensitive and accurate for T2DM diagnosis indicating the biological plausibility of intramuscular fat infiltration as the cause of altered echotexture in diabetic muscle.

According to Soliman et al. [2], the hyperechoic deltoid pattern is a strong predictor of diabetes and prediabetes by those without obesity. The echo texture changes described in obesity do not occur here, suggesting a true difference between the groups. This is supported by the significant difference in BMI in this study where overlap in these parameters was not particular. The strong correlation of echo intensity and HbA1c observed here agrees with Paris et al. [7], which showed a different relationship between the association of skeletal muscle echo intensity with glycemic control depending on metabolic status at baseline.

Recently, Khan et al.[8] showed that the quantifiable metabolic muscle changes due to T2DM and not visual hyperechoic changes could be detected much before the characteristic tissue hyper echogenicity and calcification. The automated radiomics and machine learning approaches employed by the authors are a good example of how further refinements ultrasound-based screening could be made possible using computational tools.[9]As a whole, the above findings could be useful clinically as deltoid ultrasound could be a low cost and radiation-free additional option in a resource-poor or high throughput screening system as in India where there is a high prevalence of diabetes and uneven availability of screening infrastructure.

We must keep in mind a number of limitations. The cross-sectional design does not allow for inference on causation and if changes in echogenicity preceded or followed the onset of diabetes. The fact that it is a relatively small sample size of 100 also limits the generalizability of the results. Also, given the impact of BMI on echogenicity, obesity may act as a confounder. The inter observer variability in qualitative grading remains one of the limitations of ultrasound-based assessment.

## CONCLUSION

The echogenicity of the deltoid muscle on ultrasound had a significant positive correlation with glycaemic parameters and showed a good diagnostic performance to identify type 2 diabetes mellitus (T2DM). Therefore, it could be safely considered a simple, cheap, non-invasive adjunct screening tool in tertiary care levels. However, a validation of the study on a larger scale involving multicentric studies is a must for it to be included in routine clinical screening protocols.

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