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# Diagnostic Performance of a Combined Fetal Soft-Tissue Index for Prediction of Macrosomia in Term Pregnancies: An Observational Study

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## Abstract

### Background

Accurate estimation of fetal weight is a crucial component of antenatal care, as deviations from normal fetal growth are associated with increased perinatal morbidity and mortality. Conventional ultrasound-based fetal weight estimation relies primarily on skeletal biometric parameters, which may not adequately reflect fetal nutritional status, particularly in cases of macrosomia. Sonographic assessment of fetal soft-tissue thickness provides additional information on fetal fat and muscle mass and may enhance the antenatal detection of macrosomia.

### Objective

To evaluate the diagnostic performance of fetal mid-thigh (MTSTT), mid-arm (MASTT), and abdominal (ASTT) soft-tissue thickness, individually and as a combined Soft Tissue Index (STI = MTSTT + ASTT), for the prediction of fetal macrosomia (birth weight >4000 g) in term pregnancies.

### Methods

This observational cross-sectional study was conducted over 18 months in the Departments of Radiodiagnosis, Obstetrics and Gynaecology, and Paediatrics at Hind Institute of Medical Sciences, Ataria, Sitapur, India. A total of 133 term singleton pregnancies (37–40 weeks) with cephalic presentation

were included. Ultrasound was performed within 48 hours of delivery (GE Logiq F8, 5 MHz convex probe). MTSTT, MASTT, and ASTT were each measured three times and averaged; estimated fetal weight (EFW) was calculated using Hadlock's formula from biparietal diameter, head circumference, abdominal circumference (AC), and femur length (FL). Receiver operating characteristic (ROC) and binary logistic regression analyses (SPSS version 23) were used to assess prediction of macrosomia.

**Results**

Mean gestational age was 38.2 ± 1.0 weeks and mean EFW was 3120 ± 395.6 g. Mean MTSTT, MASTT, and ASTT were 15.2 ± 2.0 mm, 13.1 ± 2.1 mm, and 12.3 ± 2.0 mm, respectively. All three parameters correlated significantly with EFW (MTSTT r = 0.72; ASTT r = 0.67; MASTT r = 0.64; all $p < 0.001$). On ROC analysis for macrosomia, MTSTT showed the highest individual accuracy (AUC 0.89; cutoff ≥17.5 mm; sensitivity 88.2%; specificity 84.1%), followed by ASTT (AUC 0.86; cutoff ≥15.5 mm; sensitivity 85.7%; specificity 80.4%) and MASTT (AUC 0.84; cutoff ≥16.0 mm; sensitivity 81.5%; specificity 77.6%; all $p < 0.001$). On logistic regression, MTSTT ≥17.5 mm was the strongest predictor of macrosomia (OR 5.20, 95% CI 2.1–11.8, $p < 0.001$), followed by AC ≥330 mm (OR 3.84, 95% CI 1.7–8.6, $p = 0.001$) and FL ≥75 mm (OR 2.96, 95% CI 1.3–6.9, $p = 0.007$). A combined Soft Tissue Index (STI = MTSTT + ASTT) at a cutoff of ≥30 mm gave the highest overall diagnostic performance (sensitivity 89.1%; specificity 85.4%; AUC 0.91; $p < 0.001$).

**Conclusion**

Fetal soft-tissue thickness, particularly MTSTT, showed strong correlation with EFW and good discriminative performance for macrosomia. A combined Soft Tissue Index (MTSTT + ASTT) outperformed individual parameters on point estimates of AUC, sensitivity, and specificity. These sonographic soft-tissue parameters may serve as adjuncts to conventional biometry for antenatal identification of macrosomia, although the small number of macrosomic cases in this cohort (n = 7) warrants cautious interpretation and external validation before clinical adoption.

**Keywords:** Fetal macrosomia; Soft tissue thickness; Mid-thigh soft tissue thickness; Soft Tissue Index; Ultrasound; Fetal weight estimation.

## 1. INTRODUCTION

Fetal growth monitoring is a cornerstone of antenatal care, and accurate estimation of fetal weight is central to identifying deviations from normal growth that are associated with adverse perinatal outcomes. Macrosomia predisposes to shoulder dystocia, birth trauma, operative delivery, and metabolic complications, making its timely antenatal recognition clinically important for delivery planning and surveillance.

Conventional ultrasound-based fetal weight estimation relies primarily on skeletal biometric parameters — biparietal diameter, head circumference, abdominal circumference, and femur length — as used in widely applied formulas such as Hadlock's model. These parameters predominantly reflect skeletal dimensions and may not adequately capture variation in fetal fat and muscle mass, a limitation that becomes particularly relevant when soft-tissue deposition is disproportionate to skeletal growth, as in macrosomia.

A body of literature reviewed in the source thesis has examined the addition of fetal soft-tissue parameters to conventional biometry. Joy et al. reported that mid-thigh soft-tissue thickness (MTSTT)-based estimation showed slightly better agreement with actual birth weight than the standard Hadlock formula in late third-trimester pregnancies, with minimal added scanning time.(1) O'Connor et al. found that combining EFW percentiles with soft-tissue thickness improved prediction of both macrosomia and growth restriction.(2) Scioscia et al. established an early regression model incorporating femur length and MTSTT with strong correlation to birth weight and good reproducibility,(3) and Abuelghar et al. reported high correlation coefficients and low prediction error using MTSTT-augmented models.(4)

Evidence specifically addressing macrosomia detection includes Sabbig et al., who examined thigh soft-tissue thickness in pregnancies at risk of macrosomia and reported strong correlation with birth weight and lower estimation variance than traditional formulas;(5) Chen et al., who found abdominal and subscapular subcutaneous tissue thickness strongly predictive of birth weight and macrosomia;(6) and Maruotti et al., who reported that third-trimester soft-tissue measurements improved sensitivity for macrosomia detection while maintaining high specificity.(7) A systematic review and meta-analysis by Kuhnert et al., cited in the source thesis, reported high pooled sensitivity and specificity of third-trimester soft-tissue thickness for detecting macrosomia across populations.(8)

Taken together, this literature — as reviewed in the source thesis — supports the premise that fetal soft-tissue thickness reflects fat and muscle deposition not captured by skeletal biometry alone, and that individual soft-tissue parameters, particularly MTSTT, show diagnostic promise for macrosomia. The source thesis does not explicitly articulate a distinct unmet research gap; rather, it frames sonographic soft-tissue assessment, including a combined index of two soft-tissue sites, as a logical extension of the single-parameter approaches described in this literature.

## OBJECTIVE

To evaluate the diagnostic performance of mid-thigh (MTSTT), mid-arm (MASTT), and abdominal (ASTT) soft-tissue thickness — individually and as a combined Soft Tissue Index (STI = MTSTT + ASTT) — for the prediction of fetal macrosomia (birth weight >4000 g) in term singleton pregnancies, using receiver operating characteristic and logistic regression analyses.

## MATERIALS AND METHODS

### Study Design and Setting

This was an observational cross-sectional study conducted in the Departments of Radiodiagnosis, Obstetrics and Gynaecology, and Paediatrics at Hind Institute of Medical Sciences and Hospital, Ataria, Sitapur, Uttar Pradesh, India.

### Study Duration

The study was conducted over a period of 18 months.

### Study Population

The study population comprised pregnant women at term (37–40 weeks of gestation) scheduled for delivery.

### Sample Size

A total of 133 pregnant women were enrolled.

Sample size was calculated using the formula for estimating a correlation coefficient: $n = 1 + 6r^2 + [Z^2_{1-\alpha/2} \times (1 - r^2)] / d^2$, with an anticipated correlation coefficient r = 0.49 (based on Scioscia et al., 2008),(3) significance level α = 5%, margin of error d = 0.15, and $Z_{1-\alpha/2} = 1.96$, giving a calculated sample size of 132.18, rounded to 133.

### Inclusion Criteria

- Pregnant women between 37 and 40 weeks of gestation, admitted for planned delivery within 48 hours
- Cephalic presentation
- Viable singleton fetus

### Exclusion Criteria

- Maternal comorbidities that could impair fetal growth (e.g., hypertension, diabetes)
- Oligohydramnios
- Congenital malformations
- Fetal growth restriction
- Maternal age <20 or >40 years
- Non-consenting participants

### Ultrasound Assessment

Ultrasound was performed within 48 hours prior to elective caesarean section, using a GE Logiq F8 ultrasound machine equipped with a 5 MHz convex transabdominal probe (Serial No. 46085UWX3).

### Standard Fetal Biometric Parameters

Biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) were recorded for all fetuses.

### Soft-Tissue Thickness Measurement Technique

#### *Mid-Thigh Soft Tissue Thickness (MTSTT)*

The femur was located in a cross-sectional view, and the measurement was taken perpendicular from the outer edge of the femur to the outer soft-tissue edge. This was repeated three times and the average recorded.

### *Mid-Arm Soft Tissue Thickness (MASTT)*

The humerus was located in a transverse section, and the measurement was taken perpendicular from the outer edge of the humerus to the outer soft-tissue edge. This was repeated three times and averaged.

### *Abdominal Soft Tissue Thickness (ASTT)*

In a transverse view at a standard level (umbilical vein level), the measurement was taken from the skin surface to the inner abdominal wall, just before the peritoneum. This was repeated three times and averaged.

### Estimation of Fetal Weight

Estimated fetal weight (EFW) was calculated using Hadlock's formula, incorporating FL, BPD, HC, and AC.(9)

### Definition of Macrosomia

Macrosomia was defined as birth weight >4000 g, as reported in the source thesis.

### Outcome and Predictor Variables

Outcome variable: macrosomia (birth weight >4000 g).

Predictor variables: MTSTT, MASTT, ASTT, the combined Soft Tissue Index (STI = MTSTT + ASTT), AC, and FL.

### Statistical Analysis

Statistical analysis was performed using SPSS version 23 (Student version). Descriptive statistics (mean ± SD, range) were computed for biometric and soft-tissue parameters. Pearson's correlation coefficient was used to assess the relationship between each soft-tissue parameter and EFW. Receiver operating characteristic (ROC) curve analysis was performed to evaluate the diagnostic performance (area under the curve, optimal cutoff, sensitivity, and specificity) of MTSTT, MASTT, ASTT, and the combined Soft Tissue Index for predicting macrosomia. Binary logistic regression was used to estimate odds ratios (OR) with 95% confidence intervals for macrosomia prediction from MTSTT, AC, and FL threshold values. A p-value <0.05 was considered statistically significant.

### Soft Tissue Index (STI)

The combined Soft Tissue Index was defined, exactly as reported in the source thesis, as: STI = MTSTT + ASTT.

### Ethical Considerations

Ethical clearance was obtained from the Institutional Human Ethical Committee (IHEC), Hind Institute of Medical Sciences, Mau, Ataria, Sitapur, Uttar Pradesh (Approval Reference No. IHEC-HIMSA/MD/MS-23/RD-42/07-24; protocol submission dated 24/07/2024), as documented in the approval certificate appended to the source thesis. Written informed consent was obtained from all participants using a bilingual (English and Hindi) participant information sheet and consent form.

## RESULTS

### Study Population

A total of 133 term singleton pregnancies were included. Mean gestational age at scan was 38.2 ± 1.0 weeks (range 37.0–40.0 weeks).

### Fetal Biometric and Soft-Tissue Measurements

Mean values for standard biometric parameters and soft-tissue thickness measurements are summarised in Table 1 and Table 2. Mean EFW was 3120 ± 395.6 g. Mean MTSTT, MASTT, and ASTT were 15.2 ± 2.0 mm, 13.1 ± 2.1 mm, and 12.3 ± 2.0 mm, respectively.

**Table 1. Baseline Gestational Age and Fetal Biometric Characteristics (n = 133)**

| Parameter | Mean ± SD | Min | Max |
|---|---|---|---|
| Gestational age (weeks) | 38.2 ± 1.0 | 37.0 | 40.0 |
| Biparietal diameter, BPD (mm) | 90.1 ± 4.9 | 80.2 | 100.5 |
| Head circumference, HC (mm) | 331.5 ± 14.2 | 300.1 | 360.4 |
| Abdominal circumference, AC (mm) | 301.4 ± 19.6 | 260.2 | 350.6 |
| Femur length, FL (mm) | 70.3 ± 5.1 | 60.3 | 80.2 |
| Estimated fetal weight, EFW (g) | 3120 ± 395.6 | 2300 | 4100 |

**Table 2. Fetal Soft-Tissue Thickness Measurements (n = 133)**

| Parameter | Mean ± SD (mm) | Min (mm) | Max (mm) |
|---|---|---|---|
| Mid-thigh soft tissue thickness (MTSTT) | 15.2 ± 2.0 | 10.1 | 20.3 |
| Mid-arm soft tissue thickness (MASTT) | 13.1 ± 2.1 | 9.2 | 18.5 |
| Abdominal soft tissue thickness (ASTT) | 12.3 ± 2.0 | 8.0 | 17.0 |

### Correlation Between Soft-Tissue Thickness and Estimated Fetal Weight

All three soft-tissue parameters correlated significantly and positively with EFW. MTSTT showed the strongest correlation ($r = 0.72$, $p < 0.001$), followed by ASTT ($r = 0.67$, $p < 0.001$) and MASTT ($r = 0.64$, $p < 0.001$) (Table 3).

**Table 3. Correlation Between Fetal Soft-Tissue Thickness and Estimated Fetal Weight (EFW)**

| Variable | Pearson's r | p-value |
|---|---|---|
| MTSTT | 0.72 | <0.001 |
| MASTT | 0.64 | <0.001 |
| ASTT | 0.67 | <0.001 |

### Prevalence of Macrosomia

Of the 133 fetuses, 7 (5.3%) met the >4000 g threshold used to define macrosomia in the source thesis, 114 (85.7%) fell within the 2500–4000 g range, and 12 (9.0%) were <2500 g.

### ROC Analysis and Combined Soft Tissue Index for Prediction of Macrosomia

On ROC analysis, MTSTT showed the highest individual diagnostic accuracy for macrosomia (AUC 0.89) at a cutoff of ≥17.5 mm, with sensitivity 88.2% and specificity 84.1%. ASTT (AUC 0.86; cutoff ≥15.5 mm; sensitivity 85.7%; specificity 80.4%) and MASTT (AUC 0.84; cutoff ≥16.0 mm; sensitivity 81.5%; specificity 77.6%) also showed good discriminative performance; all parameters were statistically significant ($p < 0.001$) (Table 4). A combined Soft Tissue Index (STI = MTSTT + ASTT) at a cutoff of ≥30 mm gave the highest overall performance of any parameter tested, with sensitivity 89.1%, specificity 85.4%, and AUC 0.91 ($p < 0.001$) (Table 4).

**Table 4. ROC Characteristics of MTSTT, MASTT, ASTT, and Combined Soft Tissue Index (STI) for Prediction of Macrosomia (Birth Weight >4000 g)**

| Parameter | Cutoff | Sensitivity (%) | Specificity (%) | AUC | p-value |
|---|---|---|---|---|---|
| MTSTT | ≥17.5 mm | 88.2 | 84.1 | 0.89 | <0.001 |
| MASTT | ≥16.0 mm | 81.5 | 77.6 | 0.84 | <0.001 |
| ASTT | ≥15.5 mm | 85.7 | 80.4 | 0.86 | <0.001 |
| Combined STI (MTSTT + ASTT) | ≥30 mm | 89.1 | 85.4 | 0.91 | <0.001 |

### Logistic Regression for Prediction of Macrosomia

On binary logistic regression, MTSTT ≥17.5 mm was the strongest independent predictor of macrosomia (OR 5.20, 95% CI 2.1–11.8, $p < 0.001$), followed by AC ≥330 mm (OR 3.84, 95% CI 1.7–8.6, $p = 0.001$) and FL ≥75 mm (OR 2.96, 95% CI 1.3–6.9, $p = 0.007$) (Table 5).

**Table 5. Logistic Regression Analysis for Prediction of Macrosomia (Birth Weight >4000 g)**

| Predictor | OR | 95% CI | p-value |
|---|---|---|---|
| MTSTT ≥ 17.5 mm | 5.20 | 2.1–11.8 | <0.001 |
| AC ≥ 330 mm | 3.84 | 1.7–8.6 | 0.001 |
| FL ≥ 75 mm | 2.96 | 1.3–6.9 | 0.007 |

## DISCUSSION

This study evaluated the diagnostic performance of fetal mid-thigh, mid-arm, and abdominal soft-tissue thickness, individually and as a combined Soft Tissue Index, for prediction of macrosomia in term pregnancies. All three soft-tissue parameters correlated significantly with EFW, MTSTT showed the highest individual discriminative accuracy for macrosomia, and the combined STI (MTSTT + ASTT) showed the highest overall point-estimate performance (AUC 0.91) among all parameters assessed.

### Interpretation of MTSTT

The correlation coefficient between MTSTT and EFW in the present study (r = 0.72) is consistent with the association reported by Scioscia et al., in whose cohort the coefficient of determination between thigh soft-tissue thickness and birth weight was $r^2 = 0.46$ ($p < 0.001$).(3) The mean MTSTT observed here is comparable to the 14.2 ± 3.0 mm reported by that group.(3) This concordance is consistent with the concept that fetal soft-tissue mass contributes to overall fetal weight in a manner not fully captured by circumferential skeletal measurements alone. Scioscia et al. also observed that conventional formulas tend to underestimate fetal weight when soft-tissue mass is increased, particularly in macrosomic fetuses;(3) the present findings, where higher soft-tissue thickness values were associated with improved detection of macrosomia relative to individual conventional parameters, are directionally consistent with this observation.

### Interpretation of MASTT and ASTT

MASTT showed a statistically significant but comparatively weaker correlation with EFW than MTSTT, consistent with its lower AUC for macrosomia prediction in this study. ASTT showed a moderate but significant correlation with EFW (r = 0.67) and the second-highest AUC among individual parameters (0.86). This pattern is broadly consistent with Bhat et al., who reported a positive correlation between fetal abdominal subcutaneous tissue thickness and birth weight (r = 0.418) and identified a cutoff for large-for-gestational-age prediction with high negative predictive value but limited sensitivity for growth-restricted fetuses.(11) Taken together with the present findings, this supports abdominal soft-tissue thickness as a useful adjunctive, rather than primary, parameter for macrosomia detection.

### Interpretation of the Combined Soft Tissue Index

The combined Soft Tissue Index (STI = MTSTT + ASTT) achieved the highest sensitivity, specificity, and AUC of all parameters evaluated in this study. This suggests that summing two anatomically distinct soft-tissue measurements may capture complementary information on fetal adiposity that is not fully represented by either site alone. However, the source data do not indicate that the STI cutoff of ≥30 mm was derived in one dataset and independently tested in another; it therefore should be regarded, at this

stage, as an internally derived and internally tested threshold rather than an externally validated diagnostic cutoff (see Strengths and Limitations, and AUTHOR VERIFICATION REQUIRED BEFORE SUBMISSION).

### Comparison with Other Studies Cited in the Source Thesis

Mohammed et al. reported a correlation between soft-tissue thigh thickness and fetal weight of r = 0.731 ($p < 0.01$), within the same range as observed in the present study, and found that combined models incorporating abdominal circumference and biparietal diameter substantially increased explained variance in fetal weight.(10) Sankar et al. similarly reported that mid-thigh soft-tissue thickness showed the highest overall diagnostic accuracy among soft-tissue parameters for identifying large-for-gestational-age fetuses, with superior performance for large- compared to small-for-gestational-age classification.(12) Both observations are concordant with the hierarchy of individual-parameter performance (MTSTT > ASTT > MASTT) observed in the present study. Joy et al. reported closer agreement with actual birth weight using a soft-tissue-augmented (Scioscia) formula compared with Hadlock's formula in term pregnancies, with a higher area under the ROC curve for the soft-tissue-based approach (0.965).(1) While that comparison addressed continuous weight estimation rather than binary macrosomia classification, it is broadly consistent with the present finding that soft-tissue parameters carry diagnostic information beyond conventional biometry.

### Clinical Relevance

Consistent with the framing in the source thesis, these findings support fetal soft-tissue thickness measurements — and a combined index of two soft-tissue sites — as complementary, adjunctive tools alongside conventional biometry for antenatal identification of macrosomia, rather than as a replacement for standard biometric assessment. The statistically significant discrimination demonstrated by ROC analysis (AUC values 0.84–0.91) indicates diagnostic association with macrosomia in this cohort; it does not, on its own, establish clinical utility in a different population or the causal contribution of soft-tissue mass to macrosomia risk, and should not be interpreted as such.

### Implications and Future Research

These findings suggest a potential role for soft-tissue thickness measurements, including a combined two-site index, as adjuncts to conventional fetal biometry for antenatal macrosomia screening. Given the limitations discussed below — in particular the small number of macrosomic cases in this cohort — prospective validation in larger, independent cohorts, ideally with a pre-specified derivation/validation split, would be required before the reported cutoffs could be recommended for routine clinical use.

## STRENGTHS AND LIMITATIONS

This study’s primary strengths lie in its **rigorous measurement protocol**, which used triplicate scans to achieve **excellent interobserver reliability** across all fetal soft-tissue parameters. This methodological precision is bolstered by a **statistically justified sample size** calculated *a priori* and a **narrow 48-hour scan-to-delivery window** that effectively minimized interval fetal growth error.

Conversely, the study's scope is restricted by its **single-centre, cross-sectional design**, which limits wider generalisability and prevented the evaluation of longitudinal growth trends. Methodologically, it relied

entirely on **manual, operator-dependent measurements** while omitting advanced Doppler or 3D volumetric assessments. Its clinical applicability is further narrowed by the **exclusion of high-risk pregnancies** and an exclusive focus on **term fetuses**, leaving findings unverified against actual postnatal neonatal adiposity. Finally, the statistical power is heavily constrained by **underpowered subgroup analyses**—particularly a tiny macrosomia cohort (n = 7)—an **unvalidated, exploratory Soft Tissue Index cutoff**, and **missing confidence intervals** for key diagnostic accuracy metrics.

## Conclusion

In this cohort of term singleton pregnancies, fetal soft-tissue thickness — particularly mid-thigh soft-tissue thickness — showed a strong, statistically significant correlation with estimated fetal weight and good discriminative performance for macrosomia on ROC analysis. A combined Soft Tissue Index (STI = MTSTT + ASTT) at a cutoff of ≥30 mm showed the highest point-estimate sensitivity, specificity, and AUC among the parameters evaluated, suggesting that combining two soft-tissue sites may enhance antenatal detection of macrosomia beyond individual measurements or conventional biometry alone. These sonographic soft-tissue parameters may have value as adjuncts to, rather than replacements for, conventional fetal biometry. Given the small number of macrosomic cases (n = 7) informing the diagnostic-performance analyses in this study, these findings should be regarded as exploratory, and independent, adequately powered validation is warranted before the reported cutoffs are applied in clinical practice.

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