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Evaluation Of Fetal Thigh Circumference In Prediction Of The Birth Weight

[1]Dr. shivaprakash ,[2]Dr. Ashwin kumar patil , [3]Dr. Rahul s , [4]Dr. Jeevika M U, [5]Dr. Rahul k r , [6] Dr Adarsh H

[1]Junior Resident, [2] Associate Professor, [3,5,6]Assistant Professor, [4]Professor and HOD,
[1,2,3,4,5,6]Department of Radio-Diagnosis,
[1,2,3,4,5,6]JJMMC, Davangere, Karnataka, India

***Corresponding Author:**
Dr. Shivaprakash Kurgod
Junior Resident, Department of Radio-Diagnosis, JJMMC, Davangere, Karnataka, India

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Abstract

Background

Accurate antenatal estimation of fetal weight is essential for the identification of intrauterine growth restriction (IUGR), macrosomia and obstetric risk stratification. Conventional ultrasound-based formulas, such as Hadlock's formula, primarily rely on skeletal biometric parameters. Fetal thigh circumference (TC), a marker of fetal soft tissue mass, has been proposed as an additional parameter to improve the accuracy of fetal weight estimation. This study aimed to evaluate the usefulness of incorporating fetal thigh circumference in estimating fetal birth weight and to compare the performance of Hadlock's and Vintzileos' formulas.

Results

A prospective observational study was conducted on 100 singleton term pregnancies (37–40 weeks). The mean actual birth weight was 2746 ± 510 g, while the mean estimated fetal weights were 2890 ± 520 g and 2846 ± 515 g using Hadlock's and Vintzileos' formulas, respectively. Both methods showed a tendency to overestimate birth weight; however, Vintzileos' formula demonstrated closer agreement with actual birth weight across all weight categories. Estimated thigh circumference showed a strong positive correlation with actual neonatal thigh circumference. The incorporation of fetal thigh circumference improved the sensitivity, specificity, and overall predictive performance for fetal weight estimation, particularly in low-birth-weight and growth-restricted fetuses.

Conclusion

Fetal thigh circumference is a valuable adjunct sonographic parameter for fetal weight estimation. The Vintzileos formula demonstrated superior accuracy and closer agreement with actual birth weight compared with the conventional Hadlock formula. Incorporation of fetal thigh circumference into routine obstetric ultrasound assessment may enhance prenatal detection of fetal growth abnormalities and improve clinical decision-making.

Keywords: NIL

Introduction

Birth weight is a key determinant of neonatal survival and an important predictor of short- and long-term health outcomes. Both low birth weight (LBW) and fetal macrosomia are associated with significant maternal and neonatal morbidity and mortality, highlighting the need for accurate assessment of fetal growth during pregnancy. Reliable estimation of fetal weight assists in the diagnosis of intrauterine growth restriction (IUGR), prediction of macrosomia, assessment of fetopelvic disproportion, and planning of the optimal timing and mode of delivery[1,2,3,4]

Ultrasonography remains the most widely used and reliable imaging modality for fetal biometry and weight estimation. Several regression-based formulas have been developed using conventional biometric parameters such as biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL). Among these, Hadlock's formula is the most commonly employed and validated method for estimating fetal weight. However, these parameters primarily reflect fetal skeletal growth and may not adequately account for variations in fetal soft tissue mass. [5,16,19,20,21]

Fetal soft tissue plays a significant role in determining birth weight, particularly in fetuses affected by growth restriction or macrosomia. Human fetuses possess a relatively high proportion of body fat, and alterations in soft tissue composition may reflect important changes in intrauterine growth. Therefore, assessment of fetal soft tissue may provide additional information beyond conventional skeletal measurements and improve the accuracy of fetal weight estimation.[6,8,12]

To address this limitation, Vintzileos et al. introduced fetal thigh circumference (TC) as an additional sonographic parameter. Unlike traditional biometric measurements, thigh circumference reflects fetal soft tissue mass, including both muscle and adipose tissue. Previous studies have demonstrated that incorporation of thigh circumference into fetal weight estimation formulas can reduce prediction error and improve accuracy, particularly in fetuses with abnormal growth patterns. [6,8,12]

Population-specific differences in fetal growth have also been well documented. Indian fetuses generally exhibit lower birth weights and smaller biometric measurements compared with many Western populations, which may reduce the accuracy of formulas derived from non-Indian datasets. Consequently, evaluating the performance of fetal weight estimation models in the local population remains clinically relevant.[3,7,9,13]

Compared with clinical methods of fetal weight estimation, ultrasonography has consistently shown superior accuracy and reproducibility. Recent advances in fetal biometry suggest that combining conventional skeletal measurements with soft tissue parameters may further enhance predictive performance. Fetal thigh circumference represents a simple, reproducible sonographic measurement that may improve the assessment of fetal growth and birth weight prediction.[3,10,11,14]

The present study was undertaken to evaluate the role of fetal thigh circumference in ultrasound-based fetal weight estimation and to compare the predictive accuracy of Hadlock's formula and Vintzileos' formula in estimating birth weight.

Objectives Of The Study

Aim:

To evaluate the accuracy and usefulness of predicting birth weight by measuring fetal thigh circumference by ultrasound.

Specific Objectives:

1. Measurement of Femur Length (FL), Biparietal Diameter (BPD), Head Circumference (HC),Abdominal Circumference(AC), and Thigh Circumference(TC) of patients between 37 and 40 weeks with singleton pregnancy by ultrasound will be done.
2. Fetal birth weight will be calculated from two standard formulae:
    a. Hadlock's Formula: which does not use thigh circumference measurement
    b. Vintzileos' Formula: which uses thigh circumference measurement
3. The actual birth weight and thigh circumference of the newborn will be measured.
4. Comparison of the following will be done:
    a. Actual birth weight versus sonographically estimated fetal weight
    b. Neonatal versus ultrasonographically measured thigh circumference.
    c. Fetal weight estimated by the two ultrasound formulae.

The comparative analysis will be done using standard statistical techniques.

Materials And Methods

Source of Data

The study is conducted in the Department of Radiodiagnosis, JJM Medical College Davangere (Bapuji Hospital) over a period of 18 months (March 2024 -September 2025) and includes antenatal mothers attending the radiodiagnosis department for term scan.

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Type of study: Prospective longitudinal observational cohort study

Place of study: Department of Radiodiagnosis, J.J.M. Medical College Davangere (Bapuji Hospital).

Sample size: 100 cases

Study population: The study population comprised antenatal mothers attending the radiodiagnosis department for term scan, and subsequently getting admitted for safe confinement.

Method of Collection of Data (Including Sampling Procedures if any)

The main source of data for the study are patients recruited from teaching hospital attached to J.J.M. Medical College, Davangere.

Bapuji Hospital, Davangere, Chigateri General Hospital, Davangere, Women and Children Hospital, Davangere

Informed consent will be obtained (After clearance from ethical committee). Details of the study protocol will be explained to the subjects.

Following inclusion and exclusion criteria were used for selection of cases for the present study.

Inclusion Criteria:

1. The study population included clinically normal antenatal mothers with singleton intra uterine pregnancy and a viable fetus.

2. At term 37 To 40 Weeks

3. Uncomplicated pregnancy

Exclusion Criteria:

1. Antenatal mothers with twin pregnancies or higher order of gestation were excluded from the study.

2. Pregnant women with major congenital anomalies of the fetus detected by ultrasound or with nonviable fetus were not taken into the study.

3. Antenatal mothers with discrepancy of more than 4 weeks between their gestational ages calculated from the last normal menstrual period and from the dating ultrasound scan were not included in the study.

4. Women with severe preeclampsia necessitating immediate termination were excluded.

5. Hydrops or congenital anomalies

6. IUFD

Methodology

Technique:

1. All the patients underwent routine term scan using C1-6-D probe of2-5MHz. Additionally, the thigh circumference is calculated as follows.
    a. First whole length of femur from greater trochanter to the distal metaphysis is imaged.
    b. Transducer is then rotated by 90 degree to obtain a cross sectional profile of the middle of the thigh at a position that the bone profiles as round as possible and the boundary of the thigh profile will be well defined.
    c. Thigh circumference is determined with elliptical approximation three times and the average is taken as the final measurements.

Instrumentation:

- Sonographic evaluation with GE LOGIQ P5 Ultrasonography by curvilinear probe of resolution 3-5mgh

Method:

A thorough history was taken, paying particular attention to the mothers age, parity, gestational age, obstetric history, menstrual cycle and past medical histories.

Sonographic evaluation with GE LOGIQ P5 Ultrasonography by professional sonographer. The typical fetal biometric measures were included in ultrasound examination. Fetal anatomy and biometry (biparietal diameter, head circumference, femur length and abdominal circumference). During 48 hours following birth, the exact fetal weight was estimated.

Thigh Circumference (TC)

Thigh circumference is measured in a transverse section of the fetal thigh at the mid-femur level, where the femoral shaft appears centrally surrounded by soft tissues. The measurement is obtained by tracing the outer skin surface of the thigh using ellipse calipers. Thigh circumference reflects fetal muscle and fat mass, and studies have shown that it correlates

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strongly with birth weight and fetal growth, making it a useful adjunct parameter for estimating fetal weight.

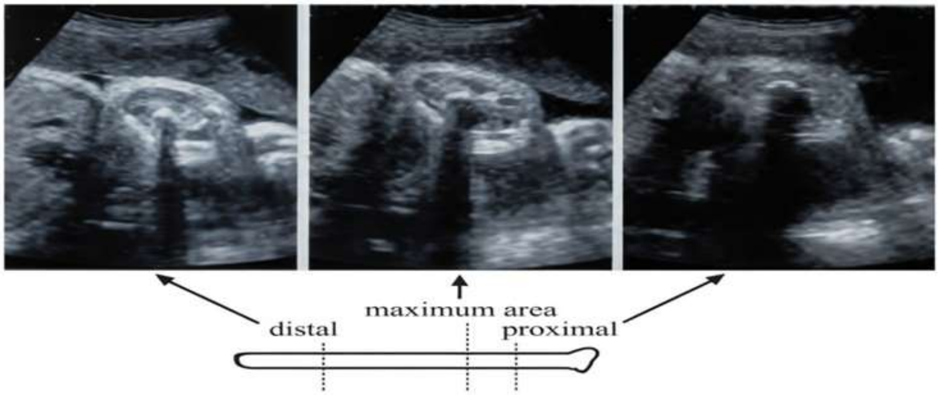

Fig.1 Standard sonographic measurement of fetal thigh circumference

A supine posture was used for all patients throughout the ultrasonographic test.

The first formula was the Hadlock's formula, which does not use thigh circumference as a parameter. The formula is as follows:

Log (Expected fetal weight)

=1.3596+0.0064(HC)+0.0424(AC)+0.174(FL)+0.00061(BPD×AC)−0.00386(AC×F)

The second formula used was the Vintzileos' formula, which uses the fetal thigh circumference as a parameter. The formula is as follows:

Log (EFW) = 1.897 + 0.015 x AC + 0.057 x BPD + 0.054 x FL + 0.011 x TC

Statistical Analysis:

Data obtained from the study were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) software version 26.0. Descriptive statistics were used to summarize the data and are presented as mean ± standard deviation (SD), median, proportions, and percentages.

Comparisons between groups were performed using appropriate inferential statistical tests. The independent sample t-test was used to compare the mean gestational age between IUGR and non-IUGR groups. Association between categorical variables was analyzed using the Chi-square (χ^2) test.

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The Pearson correlation coefficient (r) was used to evaluate the relationship between actual birth weight and ultrasound-derived fetal measurements including estimated thigh circumference, actual thigh circumference, and fetal weight estimated by Hadlock's and Vintzileos' formulas. Subgroup correlation analysis was also performed separately for IUGR and non-IUGR groups.

Agreement between Hadlock's and Vintzileos' formulas in predicting birth weight within ±10% of actual birth weight was assessed using the McNemar test. Diagnostic performance of the formulas for predicting IUGR was evaluated by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and 95% confidence intervals.

A p-value < 0.05 was considered statistically significant for all analyses.

Results

Data from 100 antenatal mothers were entered using Microsoft Excel spreadsheets. Analysis was performed with Statistical Package for the Social Sciences (SPSS) software version 26.0 (trial version), where the two ultrasonic birth weight formulae were integrated into an Excel worksheet for automatic fetal weight calculation upon parameter entry. Descriptive statistics, including mean, proportion, and standard deviation, were used for data interpretation

The study included 100 pregnant women, of whom the majority were multigravida (65%), while primigravida women accounted for 35%. All fetuses were in cephalic presentation with a longitudinal lie. Placental location was nearly evenly distributed, with posterior placentation observed in 35% of cases, anterior in 34%, and fundal in 31%.

Analysis of fetal biometric parameters showed that head circumference was below the normal range (<32.0 cm) in 58% of fetuses and within the normal range (32.0–35.0 cm) in 42%. Femur length exceeded the normal range (>7.3 cm) in 95% of cases, whereas only 5% fell within the normal limits (6.8–7.3 cm). Mid-thigh circumference was above normal (>13.0 cm) in 88% of fetuses, with 12% within the normal range (11.5–13.0 cm). Abdominal circumference was within the normal range (30.0–33.0 cm) in 64% of cases, while 36% showed values above normal (>33.0 cm).

With regard to birth weight, 26% of neonates were classified as Category 1 (≤2500 g), 48% as Category 2 (2501–3000 g), 17% as Category 3 (3001–3500 g), and 9% as Category 4 (>3500 g)

Table 1) Distribution of Neonates According to Birth Weight Category (n =100)

Birth Weight Category	Definition	Number of Neonates (n)	Percentage (%)
Category 1	≤ 2500 g	26	26.0
Category 2	2501–3000 g	48	48.0
Category 3	3001–3500 g	17	17.0
Category 4	> 3500 g	9	9.0
Total	—	100	100.0

Table 2. Distribution of IUGR in the study population

IUGR status	n (%)
Yes	26 (26.0)

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No	74 (74.0)
Total	100 (100.0)

Table 3. Comparison of gestational age between IUGR and non-IUGR groups

Variable	IUGR – Yes (Mean ± SD)	IUGR – No (Mean ± SD)	p-value
Gestational age (days)	272.69 ± 4.78	272.41 ± 5.29	>0.05

Table 4. Overall comparison of Actual Birth Weight and Estimated Fetal Weight by Hadlock's and Vintzileos' methods

Method	Mean ± SD (g)	Median (g)	95% CI (g)
Actual Weight	2746 ± 510	2800	2655 – 2837
Hadlock	2890 ± 520	2950	2796 – 2984
Vintzileos	2846 ± 515	2900	2753 – 2939

Table 5. Comparison of Actual Birth Weight and Estimated Fetal Weight by Hadlock's and Vintzileos' methods across Birth Weight categories

Birth Weight Category	Method	Mean ± SD (g)	Median (g)	95% CI (g)
Category 1 (≤2500 g)	Actual Weight	2110 ± 190	2115	2050 – 2170
	Hadlock	2275 ± 220	2310	2205 – 2345
	Vintzileos	2285 ± 230	2352	2210 – 2360
Category 2 (2501–3000 g)	Actual Weight	2775 ± 150	2800	2738 – 2812
	Hadlock	2945 ± 165	3000	2905 – 2985
	Vintzileos	2865 ± 160	2900	2826 – 2904
Category 3 (3001–3500 g)	Actual Weight	3190 ± 120	3200	3145 – 3235

	Hadlock	3360 ± 140	3300	3310 – 3410
	Vintzileos	3275 ± 135	3226	3228 – 3322
Category 4 (>3500 g)	Actual Weight	3725 ± 120	3730	3678 – 3772
	Hadlock	3850 ± 145	3805	3790 – 3910
	Vintzileos	3810 ± 150	3795	3750 – 3870

Discussion

Accurate fetal weight estimation is essential for identifying intrauterine growth restriction (IUGR) and macrosomia, both of which are associated with increased perinatal morbidity and mortality. This study compared the performance of Hadlock's and Vintzileos' formulas in estimating fetal weight and evaluated the contribution of fetal thigh circumference (TC) in improving prediction accuracy.

The majority of neonates weighed between 2501 and 3000 g (48%), while 26% were classified as low birth weight. IUGR was present in 26% of cases, with no significant difference in gestational age between IUGR and non-IUGR groups, suggesting that variations in birth weight were primarily related to fetal growth rather than gestational age.

Both Hadlock's and Vintzileos' formulas showed a tendency to overestimate actual birth weight. However, Vintzileos' formula demonstrated closer agreement with actual birth weight and a slightly stronger correlation (r = 0.953) than Hadlock's formula (r = 0.943). The discrepancy between estimated and actual birth weight was greatest in the low-birth-weight group and decreased with increasing birth weight, indicating reduced accuracy of sonographic estimation in growth-restricted fetuses.

Fetal thigh circumference showed excellent agreement between estimated and actual measurements (r = 0.977) and demonstrated strong positive correlations with actual birth weight. These findings support the role of thigh circumference as a reliable marker of fetal soft tissue mass and nutritional status. Incorporation of TC into fetal weight estimation may improve predictive accuracy by providing information beyond conventional skeletal biometric parameters.

Subgroup analysis revealed that Hadlock's formula performed slightly better in IUGR fetuses, whereas Vintzileos' formula showed superior performance in normally grown fetuses. Overall accuracy within ±10% of actual birth weight was high for both methods (84% for Hadlock and 87% for Vintzileos), with no statistically significant difference between the formulas.

The findings of this study are consistent with previous reports by Vintzileos et al., Grover et al., and other investigators, who demonstrated that inclusion of soft-tissue parameters enhances fetal weight estimation. Collectively, these results suggest that fetal thigh circumference is a valuable adjunct to conventional fetal biometry and may improve the accuracy of sonographic birth-weight prediction, particularly in fetuses with normal growth and higher birth weights.

Conclusion

The present study evaluated the role of fetal thigh circumference in estimating fetal weight and compared the accuracy of Hadlock's and Vintzileos' ultrasound formulas in predicting birth weight. The study demonstrated that both Hadlock's and Vintzileos' formulas show strong positive correlations with actual birth weight, indicating that ultrasonographic fetal weight estimation remains a reliable method for antenatal assessment of fetal growth. Although both formulas showed a tendency to slightly overestimate actual birth weight, their overall predictive accuracy remained high.

Among the two formulas evaluated, Vintzileos' formula demonstrated a slightly higher correlation

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with actual birth weight and marginally better overall accuracy in normally grown fetuses. However, Hadlock's formula showed slightly better sensitivity in identifying intrauterine growth restriction (IUGR).

Fetal thigh circumference showed a strong positive correlation with birth weight and demonstrated excellent agreement between estimated and actual measurements. These findings suggest that thigh circumference is a reliable soft tissue parameter reflecting fetal body composition and growth. The study also demonstrated a significant inverse relationship between the femur length to thigh circumference (FL/TC) ratio and birth weight, with higher ratios observed in growth-restricted fetuses. This indicates that the FL/TC ratio may serve as a useful indicator for identifying disproportionate fetal growth and detecting IUGR.

Overall, the findings of the present study support the use of fetal thigh circumference as an additional biometric parameter for improving the assessment of fetal growth and enhancing the accuracy of antenatal fetal weight estimation.

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