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Role of fetal mid-thigh soft tissue thickness in predicting the fetal weight: Comparison with other ultrasound birth weight estimation formulae

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***Abstract*---Background:** Sonographic assessment of fetal growth for the estimation of fetal weight is a common practice in obstetrics, providing valuable information for planning the mode of delivery and management of labor. The aim of this study was to assess the role of fetal mid- thigh soft tissue thickness (MTSTT) in predicting fetal weight. **Methods:** This prospective observational study was conducted on 138 singleton pregnant women aged from 20 to 35 years admitted to the obstetric ward with gestational age from 37 to 40 weeks and normal amniotic fluid and planned for delivery within 48 hours. The ultrasound (US) parameters including bi-parietal diameter (BPD), head circumference (HC) abdominal circumference (AC), femur length (FL) and MTSTT were measured respectively. The estimated fetal weight (EFW) was assessed according to Scioscia's, Vintzileos', and Hadlock's formulae. **Results:** There was a significant strong positive correlation between ABW and both Scioscia's formula (r 0.787, P value <0.001) and Vintzileos' formula (r 0.739, P value <0.001) while a significant moderate positive correlation was observed between ABW and Hadlock's formula (r 0.434, P value <0.001). All the three EFW formulae were significant predictors for birth weight (P value <0.001) but the sensitivity, specificity, PPV, and NPV were higher in Scioscia's and Vintzileos' formulae compared with Hadlock's formula. **Conclusions:** MTSTT can be added to standard biometric parameters to improve fetal weight estimation by US at term before delivery.

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***Keywords*---**Fetal Mid- Thigh Soft Tissue Thickness, Estimated Fetal Weight, Actual Birth Weight, Scioscia's Formula, Vintzileos' Formula, Hadlock's formula.

Introduction

Estimation of fetal weight is crucial because proper evaluation and management can result in a favorable outcome. To date, two-dimensional ultrasound (2-D US) has become an essential tool for fetal weight estimation [1]. Sonographic assessment of fetal growth for the estimation of fetal weight is a common practice in obstetrics, providing valuable information for planning the mode of delivery and management of labor [2].

Underestimation of the potentially large baby is associated with labor abnormalities such as prolonged active phase, protracted decent of the presenting part, and shoulder dystocia, whereas overestimation of the small-sized baby may lead to iatrogenic premature delivery and neonatal problems due to low birth weight [3].

Thigh circumference could not only estimate the fetal birth weight, but it also can identify the soft tissue mass changes [4]. It has been documented that adding fetal thigh circumference to other sonographic parameters showed a more accurate estimation of the fetal weight [5].

Many equations are available for estimating fetal weight based on standard US fetal measurements and the most accurate include circumferential parameters, such as head circumference and abdominal circumference. Unfortunately, these parameters are more prone to intra and inter-observer variability, especially at term, when these measurements are technically more difficult to obtain [6, 7].
A previously published study by Scioscia et al. [8] proposed a novel formula for estimated fetal weight (EFW) using the linear measurements of femur length (FL) and mid-thigh soft-tissue thickness (MTSTT), involving adipose tissue plus lean mass. The aim of this study was to assess the role of fetal MTSTT in predicting fetal weight.

Patients and Methods

This prospective observational study was conducted on 138 singleton pregnant women aged from 20 to 35 years admitted to the obstetric ward with gestational age from 37 to 40 weeks and normal amniotic fluid and planned for delivery within 48 hours.

Exclusion criteria were maternal chronic or medical disorders with pregnancy (hypertension, diabetes mellitus, or heart diseases), women who were pregnant with twins, fetuses with congenital anomalies or oligohydramnios, or with breech presentation, and diagnosis of intrauterine fetal death, preterm delivery, or post-term delivery.

After giving consent to participate in our study, the studied women were subjected to detailed history taking including obstetric, menstrual, and contraceptive history, detailed clinical examination including abdominal examination to confirm cephalic presentation, and US examination to assess EFW 48 h or less before delivery.
All measurements were performed in the fetal US unit using a trans-abdominal US with 5.0 MHz convex probe (mindray DC-70, x-In sight).

Each fetus was examined on a single occasion. Gestational age had been determined from the last menstrual period and confirmed by US, it was given in exact weeks. The woman lied in flat position, and after good exposure, application of conducting gel, A rapid overview performed first to confirm positive fetal life, longitudinal lie and cephalic presentation then parameters like bi-parietal diameter (BPD), head circumference (HC) abdominal circumference (AC), femur length (FL) and mid-thigh soft tissue thickness (MTSTT) were measured respectively. The EFW was calculated as follow:

1. **Scioscia's formula** which uses FL and MTSTT as follow:
   $$EFW= -1687.47 + (54.1\times FL) + (76.68 \times MT\ STT)$$
2. **Vintzileos' formula** which uses BPD, HC, FL, and AC as follow:
   $$Log10\ BW = 2.144 + 0.004(HC \times FL) + 0.014(AC) - 0.00000001983(HC \times FL)^3 + 0.000006(BPD \times TC)^2$$
3. **Hadlock's formula** which uses BPD, HC, AC and FL and calculated by the machine programmed software.

The actual birth weight (ABW) of the infant was measured immediately after delivery and after cutting of the umbilical cord and clamping it 5 centimeters from the fetal abdomen without any towels or clothes. All fetuses were measured using the same calibrated scale.

Statistical analysis

Statistical analysis was done by SPSS v26 (IBM Inc., Armonk, NY, USA). Shapiro-Wilks test and histograms were used to evaluate the normality of the distribution of data. Quantitative data were presented as mean, standard deviation (SD), and range (minimum – maximum). Qualitative data were presented as frequency and percentage (%). Pearson's correlation was performed to estimate the degree of correlation between two quantitative variables. The overall diagnostic performance was assessed by ROC curve analysis, the area under the curve (AUC) evaluates the overall test performance (where the area under the curve >50% denotes acceptable performance and the area about 100% is the best performance for the test). A two tailed P value ≤ 0.05 was considered statistically significant.

Results

The age of the studied participants ranged from 20 to 35 years with a mean ± SD of 27.62 ± 4.63 years. The gestational age ranged from 37 to 40 weeks with a mean ± SD of 38.48 ± 1.18 weeks. **Table 1**

Table 1: Participants' characteristics

	n = 138
Age (years)	27.62 ± 4.63
Gestational age (weeks)	38.48 ± 1.18
Parity	
0	41 (29.71%)
1	40 (28.99%)
2	28 (20.29%)
3	27 (19.57%)

Data are presented as mean ± SD or frequency (%).

The mean ± SD of BPD was 88.92 ± 5.56 mm. The mean ± SD of HC was 319.19 ± 13.68 mm. The mean ± SD of AC was 327.04 ± 19.76 mm. The mean ± SD of FL was 70.55 ± 4.16 mm. The mean ± SD of MTSTT was 15.74 ± 1.72 mm. **Table 2**

Table 2: Fetal ultrasonographic measurements

	n = 138
BPD (mm)	88.92 ± 5.56
HC (mm)	319.19 ± 13.68
AC (mm)	327.04 ± 19.76
FL (mm)	70.55 ± 4.16
MTSTT (mm)	15.74 ± 1.72

Data are presented as mean ± SD. BPD: Bi-parietal diameter, HC: Head circumference, AC: Abdominal Circumference, FL: Femur length, MTSTT: Mid-thigh soft tissue thickness.

The mean ± SD of ABW was 3412.25 ± 339.22 gm. The mean ± SD of EFW by Scioscia's formula was 3335.98 ± 338.69 gm. The mean ± SD of EFW by Vintzileos' formula was 3440.31 ± 344.11 gm. The mean ± SD of EFW by Hadlock's formula was 3412.07 ± 337.33 gm. **Table 3**

Table 3: ABW and EFW by different formulae (n = 138)

	ABW (g)	EFW (g)		
		Scioscia's formula	**Vintzileos' formula**	**Hadlock's formula**
Mean ± SD	3412.25 ± 339.22	3335.98 ± 338.69	3440.31 ± 344.11	3412.07 ± 337.33
(Min – Max)	2880 - 3993	2795 - 3920	2895 - 4073	2883 - 4034

ABW: Actual birth weight, EFW: estimated fetal weight.

There was a significant strong positive correlation between ABW and both Scioscia's formula (r 0.787, P value <0.001) and Vintzileos' formula (r 0.739, P value <0.001) while a significant moderate positive correlation was observed between ABW and Hadlock's formula (r 0.434, P value <0.001). **Table 4**

Table 4: Correlation between ABW and the EFW formulae

	ABW	
	r	**P value**
Scioscia's formula	0.787	<0.001*
Vintzileos' formula	0.739	<0.001*
Hadlock's formula	0.434	<0.001*

ABW: Actual birth weight, EFW: estimated fetal weight, r: correlation coefficient, *: significant as P value < 0.05.

The Scioscia's formula had 92.31% sensitivity, 91.78% specificity, 90.9% PPV, and 93.1% NPV with an AUC of 0.896. The Vintzileos' formula had 89.23% sensitivity, 89.04% specificity, 87.9% PPV, and 90.3% NPV with an AUC of 0.871. The Hadlock's formula had 64.62% sensitivity, 80.82% specificity, 75% PPV, and 72% NPV with an AUC of 0.708. **Table 5** and **Figure 1**

All the three EFW formulae were significant predictors for birth weight (P value <0.001) but the sensitivity, specificity, PPV, and NPV were higher in Scioscia's and Vintzileos' formulae compared with Hadlock's formula. **Table 5** and **Figure 1**

Table 5: Sensitivity, specificity, PPV, and NPV of EFW formulae compared to ABW for less than 3300 gm

	Scioscia's formula	Vintzileos' formula	Hadlock's formula
AUC	0.896	0.871	0.708
Sensitivity	92.31	89.23	64.62
Specificity	91.78	89.04	80.82
PPV	90.9	87.9	75
NPV	93.1	90.3	72
P value	<0.001*	<0.001*	<0.001*

ABW: Actual birth weight, EFW: estimated fetal weight, AUC: Area under the curve, PPV: Positive predictive value, NPV: Negative predictive value, *: significant as P value < 0.05.

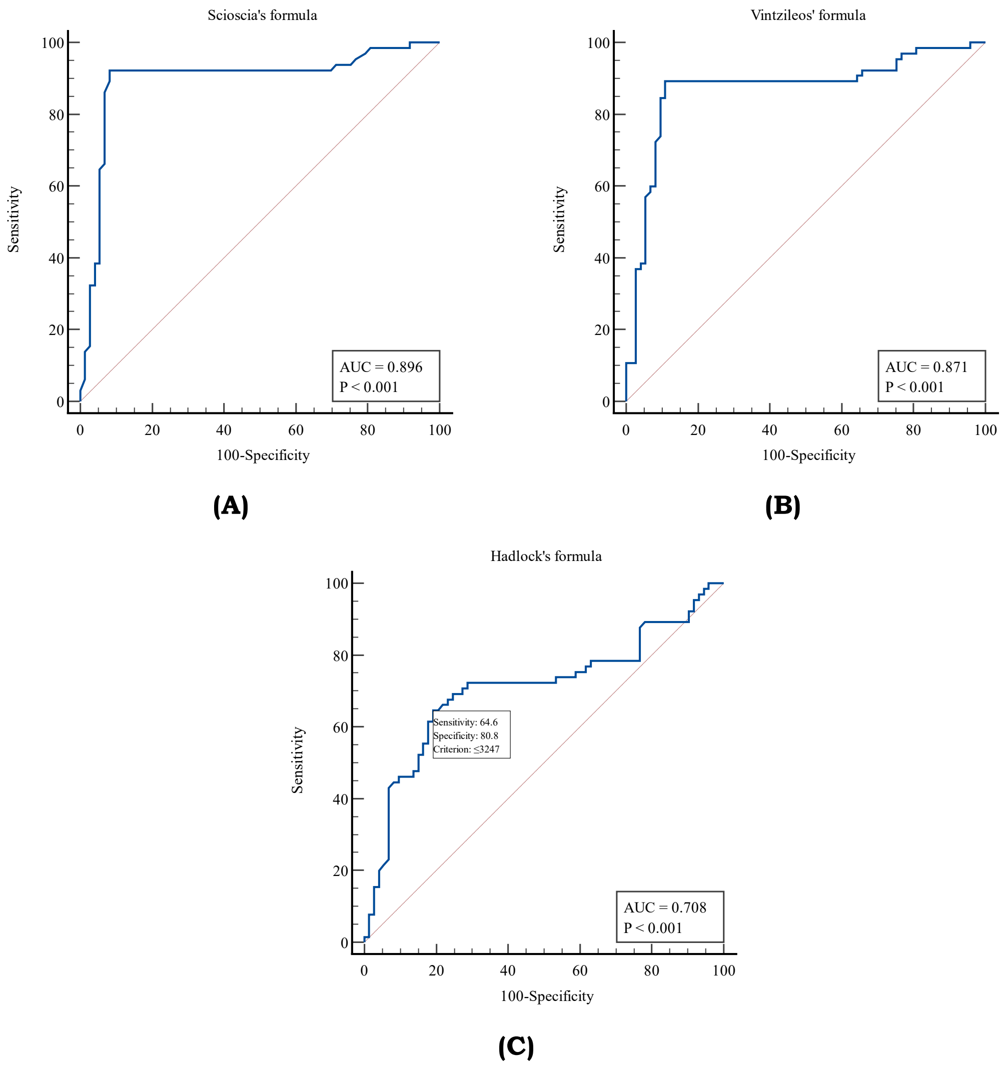

Figure 1: ROC curve analysis of (A) Scioscia's formula, (B) Vintzileos' formula, and (C) Hadlock's formula compared to ABW for less than 3300 gm

Discussion

Assessment of fetal weight in-utero leads to improved management of high-risk pregnancies. It is an independent factor to determine optimal survival of fetus; fetal weight is undoubtedly one of the most significant determinants of neonatal survival. Obstetric US with its diagnostic modality helps to predict fetal weight with a certain degree of precision. Many clinical methods substantiated by various US formulae have been used to estimate weight and growth in-utero [9].

The assessment of fetal weight has undergone a revolution since Prof. Ian Donald introduced US to obstetrics, and there is a wealth of material available on this application of US. Numerous fetal biometric parameters, including BPD, HC, AC, and FL, can now be measured, and multiple formulae have been developed by regression analysis with varying degrees of accuracy both in low BW and macrosomic babies [10].

These biometric assessments are based on linear or planar measurements of in utero fetal sections, and specific standards for measurement methodologies have been established [11]. A BW estimation formula with at least 90% correlation should have the fewest systematic and random errors. Therefore, ultrasonography equations utilizing standard biometric data have reached their diagnostic limits due to biological, ethical, geographical, and many other unknown aspects. This suggests that new factors are required to improve the accuracy of BW prediction [3].

In neonatology, the mid-arm circumference is commonly used to screen for low BW newborns. This can be extended to intrauterine measurements of body fat locations as mid-thigh mass, abdominal fat mass, subscapular fat, and cheek-to-cheek diameter [12].

In addition, Abdelgied et al. [13] assessed the use of antenatal estimation of fetal MTSTT as a predictor for the ABW after delivery by comparing both Scioscia's and Hadlock's formulae with the ABW and clarified that MTSTT in ultrasonography equations improves the accuracy of antenatal calculation of EFW. Researchers are paying close attention to the assessment of MTSTT among soft tissue parameters. Our study showed a significant strong positive correlation between ABW and both Scioscia's formula (r 0.787, P value <0.001) and Vintzileos' formula (r 0.739, P value <0.001) while a significant moderate positive correlation was observed between ABW and Hadlock's formula (r 0.434, P value <0.001).

In agreement with our findings, Mohamed et al. [14] evaluated the addition of fetal thigh circumference to predict fetal weight compared to two Hadlock's and Vintzileos methods and found a significant positive correlation between different US parameters and actual weight (all $p \leq 0.001$). The highest correlation was observed between TC and actual fetal weight ($r = 0.685$). Regarding both formulae, the correlation coefficient was higher in the Vintzileos formula than the Handlock formula (0.976 vs. 0.823). They also showed no statistically significant difference between weight estimated by Vintzileos formula and actual fetal weight or between actual fetal weight and weight estimated by fetal TC. There was a statistically significant difference between the actual weight and the weight estimated by the Hadlock formula ($p < 0.001$); the estimated weight was higher than the actual weight (3466.35 vs. 3204.31).

In contrary, Kurmanavicius et al. [6] used the formulae of Campbell and Wilkin, Shepard, 2 formulae of Hadlock and Merz for EFW and found the highest intraclass correlation coefficient and the most stable results in all birth weight groups were generated with both Hadlock formulae. Both Hadlock and Campbell formulae had the lowest percent errors in birth weight groups between <1500 g and 3500 g.

Similarly, Adarsh et al. [15] compared both MTSTT and Hadlock's method with ABW and revealed a moderate positive correlation was found between the EFW using MTSTT and Hadlock's method, and it was statistically significant ($P < 0.001$).

On the other hand, Barros at al. [16] assessed the EFW though the formula we used in Scioscia's method and found a significant low linear relationship between birth weight and EFW ($p < 0.001$; $r = 0.197$) with an absolute mean error of 10.6%. It is crucial to consider fetal weight while deciding on the best delivery method during obstetric care. The Hadlock formula, which was created in the early 1990s, continues to be the foundation of the standard equations used by contemporary US devices. Even with careful and repeated measurements, ultrasonically estimated BW can differ from actual BW by 10%-15%. This is due to the fact that soft tissue distribution has an impact on newborn body weight, and by including those into conventional formulae, these mistakes may be reduced [17].

To find the impact of soft tissue thickness on birth weight and develop a new predictive model, Kalantari et al. [18] conducted a prospective cohort study on this issue. In the same line with our results, they concluded that adding mid-thigh soft tissue thickness to the other variables in predictive models of fetal weight would provide a good estimation and in cases that measuring abdominal circumference is suboptimal MTSTT may be a good replacement.

In our study, the Scioscia's formula had 92.31% sensitivity, 91.78% specificity, 90.9% PPV, and 93.1% NPV with an AUC of 0.896. The Vintzileos' formula had 89.23% sensitivity, 89.04% specificity, 87.9% PPV, and 90.3% NPV with an AUC of 0.871. The Hadlock's formula had 64.62% sensitivity, 80.82% specificity, 75% PPV, and 72% NPV with an AUC of 0.708.

We found the all the three EFW formulae were significant predictors for birth weight (P value <0.001) but the sensitivity, specificity, PPV, and NPV were higher in Scioscia's and Vintzileos' formulae compared with Hadlock's formula. Supporting our study, Abdelgied et al. [13] demonstrated that the prediction of fetal weight was similar between the formulae, although estimate of the new algorithm (Scioscia's formula) was more accurate, showing positive predictive value of 94% compared with 91% for Hadlock's.

Also, Adarsh et al. [15] found MTSTT was more sensitive and specific than Hadlock's method in the estimation of fetal weight with actual birth weight as a gold standard in both 37 completed weeks and 38 completed weeks gestational ages.

The strength of our study was that we used both manually measured EFW formulae and the formula of Hadlock which was inserted into the US system, but the study was limited by its relatively small sample size and being performed in a single center.

Conclusions

The US detection of fetal weight using MTSTT was more accurate and more specific than Hadlock's method. MTSTT can be added to standard biometric parameters to improve fetal weight estimation by US at term before delivery.

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Conflict of Interest: Nil

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