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Evaluation of the Fetal Thigh Cross-Section to Predict Fetal Birth Weight in Normal-Term Pregnant Women

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ABSTRACT

Background: Fetal weight is an important factor in assessing fetus growth, and arranging for delivery. Different parameters and different models were used to estimate fetal weight, and the 3-dimensional ultrasound plays a crucial role in many aspects, including assessing the fetus's weight.

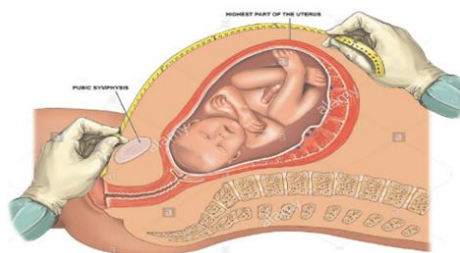
Aim of the study: To precisely assess third-trimester ultrasound using fetal limb cross-section area by 3D ultrasound to predict birth weight of the fetus versus sonographic parameters for predicted fetal weight by two-dimensional ultrasound.

Materials and methods: This Prospective-cohort study recruited one hundred pregnant women with a normal pregnancy in their late third trimester. They were taken from the antenatal clinic and had their fetal weights estimated by two-dimensional ultrasound by Modified Hadlock (MH) and three-dimensional ultrasound by measuring the thickness of the soft tissue of thigh, assessment of fetal weight, and follow up to delivery to measure the actual birth weight of the infant and comparing the results. A study was done in the department of Obstetrics and Gynecology at Al-Yarmouk Teaching Hospital.

The Ethical Committee code was obtained after getting the scientific approval.

Results: One hundred pregnant women were enrolled in this study, their mean age of the women was 32.6 years old, their mean BMI was 25.6 kg/m², and most of them had a cephalic presentation (92%); in the current study, Modified Hadlock overestimate fetal weight 159.9 g, while mid thigh soft tissue thickness (MTSTT) underestimates the fetal weight - 67.3 gm. Modified Hadlock was non significantly different from zero. In terms of systemic errors, there was a non-significant difference between MH from zero, whereas MTSTT significantly differs from MH, and in terms of absolute error, the 3D model was significantly different from MH. **Conclusion:** This study found that compared with using the traditional Hadlock's formula, the fetal thigh soft tissue thickness measured by the novel method of three-dimensional ultrasonography is more precisely and specifically related to the antenatal anticipated birth weight.

GRAPHICAL ABSTRACT



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Introduction

Fetal weight

To arrange and control labor, estimated fetal weight (EFW) provides useful information. By using various formulas, the majority of which were developed in the 1980s, this estimation is made. These equations combine several standardized measurements of a fetus, including head circumference (HC), biparietal diameter (BPD), abdominal circumference (AC), and femur length (FL). Although it is AC a great variable, it is one of these markers that are quite frequently used to estimate fetal weight. However, because these criteria do not take consider the bulk of soft tissues, the fetal weight is underestimated. In addition, these formulas are found to be less accurate for extreme weights [1].

It is possible to anticipate macrosomia by using measurements of soft tissues. Because subcutaneous tissue contains 75% of the body's fat. Predicting macrosomia can be done by using various ultrasonographic parameters including mid-thigh soft tissue thickness (STT), fetal abdominal subcutaneous tissue thickness (FASTT), and subscapular soft tissue thickness [2]. The major goal of this study was for comparing

Hadlock's technique and MTSTT estimates of fetal weight with those of actual birth weight [18].

Methods of Fetal-weight assessment

Multiple methods for estimating birth weight either clinically or by ultrasound:

The Symphysis fundal height is further called (fundal height)

Symphysis-fundal height (SFH) measurement is a screening technique frequently used to determine the fetal growth and also gestational age after twenty-four weeks of pregnancy. A piece of tape is placed over the abdomen to measure the SFH (Figure 1). The measurement should be performed with the mother's bladder empty. The symphysis pubis of the pubic bone and the top of a pregnant woman's uterus, known as the fundus, are separated by a centimeter (cm). The gestational age in weeks should be equal to the SFH in centimeters [3,9]. In one investigation, the SFH measurement sensitivity to identify aberrant intra-uterine growth was less than 35% [4]. Roex A. *et al.* discovered that the SFH repetitive plotting on specialized charts could increase the SFH sensitivity measurement to diagnose prenatal growth problems [5].

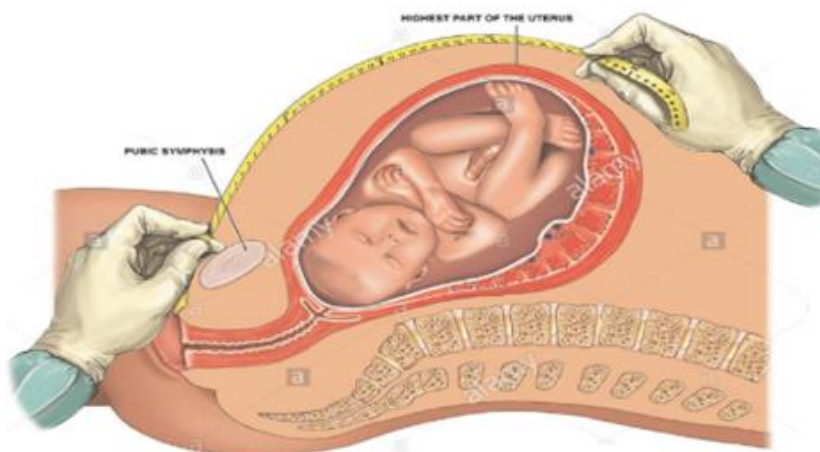


Figure 1: (measurement of SFH)

Following a Cochrane study, "The effectiveness of SFH measurement in detecting IUGR" cannot be determined based on the available data. As a result, we are unable to suggest changing the way things are done. More tests are required [6].

Two-dimensional ultrasound estimation of fetal weight

The Shepard and Hadlock formulas are reportedly the most widely used algorithms for estimating fetal weight (EFW) [7,10,11].

$$\begin{aligned}\text{Shepard: Log 10 (weight)} &= -1.7492 + 0.166 \cdot \text{BPD} + 0.046 \cdot \text{AC} - 2.646 \cdot (\text{AC} \cdot \text{BPD}) / 1,000 \\ \text{Hadlock 1: Log 10 (weight)} &= 1.304 + 0.05281 \cdot \text{Ac} + 0.1938 \cdot \text{FL} - 0.004 \cdot \text{AC} \cdot \text{FL} \\ \text{Hadlock 2: Log 10 (weight)} &= 1.335 - 0.0034 \cdot \text{AC} \cdot \text{FL} + 0.0316 \cdot \text{BPD} + 0.0457 \cdot \text{AC} + 0.1623 \cdot \text{FL} \\ \text{Hadlock 3: Log 10 (weight)} &= 1.326 - 0.00326 \cdot \text{AC} \cdot \text{FL} + 0.0107 \cdot \text{HC} + 0.0438 \cdot \text{AC} + 0.158 \cdot \text{FL} \\ \text{Hadlock 4: Log 10 (weight)} &= 1.3596 - 0.00386 \cdot \text{AC} \cdot \text{FL} + 0.0064 \cdot \text{HC} + 0.00061 \cdot \text{BPD} \cdot \text{AC} + \\ &0.0424 \cdot \text{AC} + 0.174 \cdot \text{FL}\end{aligned}$$

Biological variation and inadequate imaging have an impact on the sonographic estimation accuracy of the EFW, regardless of the applied formula. In addition, the accuracy of the sonographic estimation declines with birth weight [13,14] and is frequently overestimated in pregnancies thought to be large for gestational age (LGA) and undervalued in pregnancies thought to have fetal growth restriction (FGR) [12].

Hadlock Formula

$\log_{10} \text{ BW} = 1.335 - 0.0034(\text{abdominal circumference [AC]}) (\text{femur length [FL]}) + 0.0316(\text{biparietal diameter}) + 0.0457(\text{AC}) + 0.1623(\text{FL})$; [17].

Prediction of birth weight depended on anatomical measures of the fetus's, limbs, head, and abdomen. Using functions involving the circumference of the fetal head, AC, and FL, Hadlock *et al.* reported the prediction accuracy within fifteen percent (2 SD) of actual birth weight (BW). However, weight estimation formulas now only take into account the relevance of 2D ultrasound measures to birth weight [15]. Most ultrasound equipment employs traditional pre-programmed formulas. Biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL) are two-dimensional (2D) measurements that are

frequently vulnerable to errors as significant as fifteen percent from actual birth weight (BW). When choosing the birth mode in obstetric practice, the majority of equations tend to underestimate larger pregnancies and overestimate smaller fetuses [16].

Abdominal circumference

A growing percentile of the abdominal circumference (AC) relative to the biparietal diameter or head circumference on successive ultrasound examinations is evidence of accelerated fetal growth brought on by fetal hyperinsulinemia. Excess fetal insulin directly causes excessive abdominal fat accumulation, liver, and heart hypertrophy [19].

Mid-limb soft-tissue thickness by 3-dimensional ultrasound

Depending on a linear measurement in a conventional and longitudinal section for the FL from the outer edge of the skin to the outer margin of the femur shaft with the femur lying parallel (Figure 1) to the transducer, the estimated birth weight was calculated as follows: $1687.47 + (54.19 \text{ FL}) + (76.689 \text{ STT})$. According to Scioscia *et al.* [20], just women who gave birth within 48 hours following the ultrasound were considered for the analysis.



Figure 2: Measurement of midthigh soft tissue thickness (MTSTT)

Fractional volumes by 3-dimensional ultrasound

Many researchers now employ fetal volumes, such as the upper arm volume and the volume of the

thigh, to improve the birth weight prediction formula since the invention of three-dimensional ultrasound (3-D US). [7-10].

Fractional limb volume is a brand-new measure that enables fetal 3D ultrasound for soft tissue characterization. It can be utilized to assess fetal weight in the late 3rd trimester with reliability [22].

It involves the assessment of the volume of the fetal fractional limb, along with the whole thigh, as well as the amount of fat, muscle, and bone that can be used to assess the nutritional health of the fetus.

Three-dimensional ultrasound capabilities have been expanded by current computer software developments to produce more suitable images. As far as the knowledge of the authors goes on, this is the first study through software-generated time-fractional thigh volume (ThiV) to assess how well Thai population predictions of fetus birth weight have improved.

Aim of Study

To assess the precision of third-trimester ultrasound by using the cross-section area of fetal limbs by 3D ultrasound to anticipate birth weight versus sonographic parameters for estimated fetal weight by two-dimensional ultrasound.

Subjects and method

This prospective-observational study was conducted in the obstetrics and gynecology department, at Al-Yarmouk Teaching Hospital. This study was held for a duration of 8 months, from April 2021 to the end of January 2022. 100 participants as a sample size were conducted by using the equation $4pq/d^2$. All the pregnant women, seen in the outpatient clinic at Al-Yarmouk Teaching Hospital, were examined in

their late third trimester (37 weeks – 41 weeks). The gestational age was calculated according to sure LMP and first-trimester ultrasound, and then was seen again at the time of delivery (to measure the newborn weight, which is considered the actual fetal weight). Delivery was either spontaneous or induced vaginal delivery or cesarean section.

Exclusion Criteria: Women in labor, women who refused participation, women with renal disease, hypertension, intrauterine growth restriction, and ultrasonographic evidence of congenital morphological anomalies were considered as the exclusion criteria of the study.

The maternal age and maternal BMI were collected in a pre-designed questionnaire when they were initially seen, and gestational age (calculated based on accurate last menstrual period date [LMP] or early ultrasound in the first trimester)

All women underwent abdominal ultrasound in the late third trimester between 37 weeks till 41 weeks with ultrasound equipment (Philips HD11XE) by using a transabdominal probe by the same sonographer in Radiology Center. Using two-dimensional ultrasonography, the sonographic biometric parameters measured head and abdomen circumference as well as femur and humerus length. The Hadlock model which includes head circumference, biparietal diameter (BPD), femoral diaphysis length, and abdominal circumference (AC) was used to calculate the estimated fetal weight (EFW) (FL). The Modified Hadlock Model 2 was employed, as provided by Lee *et al.* [15].

$$\text{Log}_{10}^{BW} = 1.4035 + 0.0441 AC + 0.177 FL - 0.0037 (AC \times FL) + 0.0027 BPD^2$$

AC: abdominal circumference, FL: femoral length, BPD: biparietal diameter

The result represents the estimated fetal body weight by the 2D ultrasound.

In the typical longitudinal segment that was utilized for FL measurement, the midthigh soft tissue thickness (MTSTT) was measured linearly by using three-dimensional ultrasonography, in the middle part of the fetal thigh, with the femur

resting parallel to the transducer. MTSTT was calculated as the distance between the outer edge of the skin and the outer edge of the femur shaft. As long as the larger and smaller trochanters were oriented upward, the measurement was obtained. The lateral aspect of the femur was correctly visible in this section (Image 1). MTSTT was measured by using the following formula [23]:

$$-1687.47 + (54.1 \times FL) + (76.68 \times STT), [1]$$

The labor room at the obstetrics and gynecology department of the hospital recorded the birth weights of all the infants delivered in Al-Yarmouk Teaching Hospital and was used to determine the baby's real weight.

Results

The study enrolled 100 pregnant women, the mean age was (32.6 years old), mean BMI was (25.6 kg/m²), and most of them had a cephalic presentation (92%), as illustrated in Table 1.

Table 1: Demographic and maternal characteristics

Variables	Value
Number of subjects	100
Age (years), mean \pm SD	32.6 \pm 6.5
BMI (kg/m ²), mean \pm SD	25.6 \pm 4.1
Gestational age (USG), median (IQR)	37 (35-39) weeks
Gestational age (LMP), median (IQR)	38 (36-40) weeks
Fetal presentation, n (%)	
Cephalic	92 (92%)
Breech or transverse	8 (8%)

[BMI: body mass index, USG: ultrasound gestation, LMP: last menstrual period]

In the present study, MH overestimates the fetal weight (159.9 gm), while MTSTT underestimates the fetal weight (-67.3 gm), as illustrated in Table 2.

Table 2: The differences between estimated and actual fetal weight using different methods

Fetal weight	Mean \pm SD	Differences from AFW
Mid-thigh soft tissue thickness MTSTT(g)	3,257.8 \pm 773.7	-67.3 \pm 335.0
Modified Hadlock MH (g)	3,417.6 \pm 697.6	159.9 \pm 269.8
Actual fetal weight (g)	3,438.0 \pm 693.0	-

AFW: actual fetal weight, SD: standard deviation

There was a significant and direct correlation between all methods of estimated fetal weight with an actual fetal weight with a p-value < 0.001, as illustrated in Table 3 and Figures 3 and 4.

Table 3: The relationship between actual and estimated fetal weight

Fetal weight	R	P-value
Mid-thigh soft tissue thickness MTSTT (g)	0.780	<0.001
Modified Hadlock MH (g)	0.829	<0.001

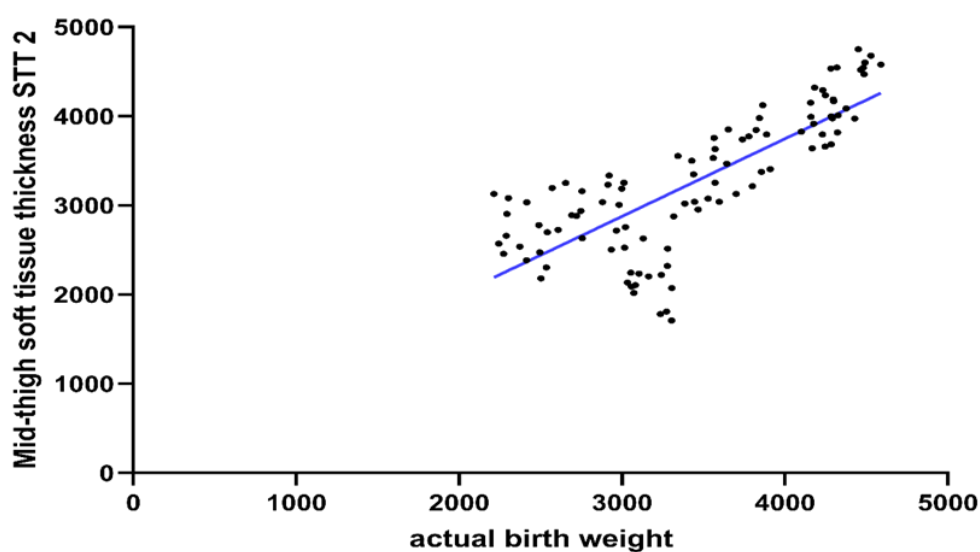


Figure 3: Scatterplot between actual body weight and MTSTT

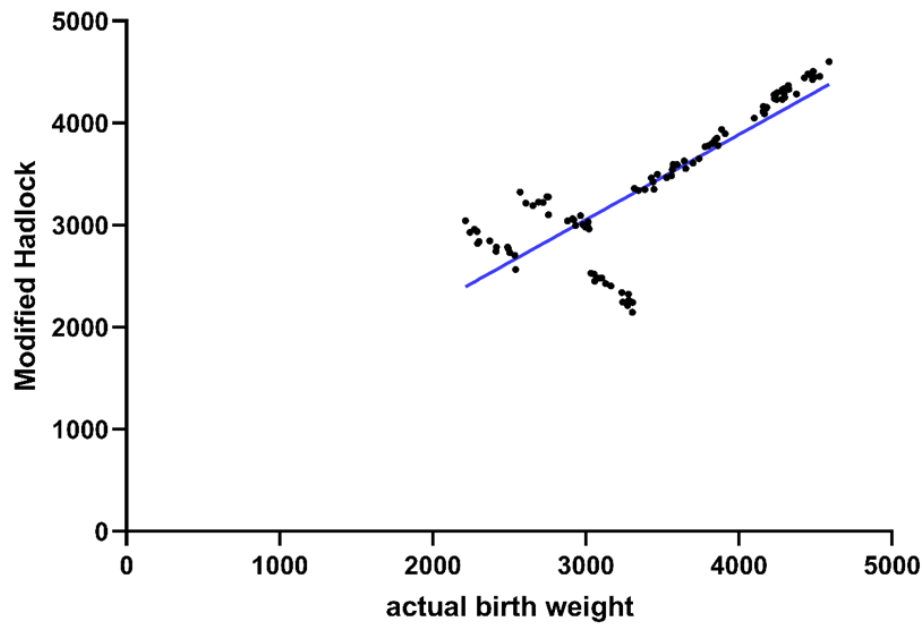


Figure 4: Scatterplot between actual body weight and MH

All types of errors are presented in Table 4. In terms of systematic errors, MH was not significantly different from zero, while the MTSTT model was significantly different from zero (one-sample t-test). In terms of random error, MTSTT was significantly different from MH and in terms of absolute error; the 3D model was significantly different from MH, as illustrated in Table 4.

Table 4: Assessment of systematic, random, and absolute errors

Fetal weight	Systemic error	P-value	Random error	Absolute error percentage
Mid-thigh soft tissue thickness MTSTT	-4.6%	0.006	8.3%	12.3%
Modified Hadlock MH	0.4%	0.775	6.5%	8.8%

Table 5: Assessment of systemic error according to macrosomia status

	Normal	Macrosomia	P-value
Mid-thigh soft tissue thickness MTSTT(g)	-5.1	-3.3	0.945
Modified Hadlock MH(g)	0.7	-0.3	0.445

MTSTT and MH modules were significantly different in terms of random errors, between normal weighted and macrocosmic infants, as illustrated in Table 6.

Table 6: Assessment of random error according to macrosomia status

	Normal	Macrosomia	P-value
Mid-thigh soft tissue thickness MTSTT (g)	9.2	6.1	0.034 [S]
Modified Hadlock MH (g)	7.5	4.2	0.028 [S]

[S/ Significant]

All modules were significantly different in terms of absolute errors, between normal weighted and macrocosmic infants, as illustrated in Table 7.

Table 7: Assessment of absolute error according to macrosomia status

	Normal	Macrosomia	P-value
Mid-thigh soft tissue thickness MTSTT (g)	14.9	5.6	<0.001 [S]
Modified Hadlock MH (g)	11.9	0.9	<0.001 [S]

[S/ Significant]

Discussion

Obstetric ultrasonography examinations include the prediction of fetal weight as a vital part of the procedure. To determine EFW, some institutions still use fetal biometry, while the other mathematical formulas are used too. The MH formula is the most well-known and popular formula [15].

The AC, BPD, and FL are combined logarithmically. This formula could still be wrong. The precision of Hadlock formula varies depending on the researcher. The random error ranged from 7% - 11.9 %, while the mean percentage error ranged from -9.1 to -14.2 %. The systematic error for MH was 0.4 percent and the random error was 6.5 percent in the current study [28,29].

In the present study, our aim is to measure the accuracy of midthigh soft tissue thickness by using 3-dimensional ultrasound in the calculation of fetal weight and compare them with the conventional MH formula that is regularly used for obstetric ultrasound examinations in our institution. In the final trimester of pregnancy, just before delivery, we assessed pregnant mothers.

In our study, there was a significant direct correlation between all methods of estimated fetal weight with an actual fetal weight with a p-value <0. 001. In terms of systematic errors, MH was not significantly different from zero, while the MTSTT model was significantly different from zero (one-sample t-test) with a p-value of 0.006. In terms of random error, MTSTT was significantly different from MH (8.3% and 6.5%, respectively), and in terms of absolute error, the 3D model was significantly different from MH (12.3% and 8.8%, respectively). It has been concluded in the current study a significant and specific correlation between MTSTT and estimation of fetal weight.

Kalantari *et al.* [25] agreed with our results; they found that the STT addition to the other variables in predicting models of fetal weight would give a good estimation. Similarly, Grace and Josefina [26] revealed that the MTSTT could be helpful in assessing the risk for malnutrition, intrauterine growth restriction, or macrosomia in fetuses. Results revealed a substantial association between ABW, EFW, and subcutaneous tissue thickness.

Our results were also similar to those obtained by Warska *et al.* [27] who studied the use of ultrasound measurement of fetal soft tissue for evaluating fetal weight. Results showed that ultrasound measurement in different parts of the body including STT may prove to be a strong predictor of fetal weight essential for sonographic assessment of pregnancy. Another study by Hebbar *et al.* [24] also agreed with our study. It studied the value of integration of mid-thigh STT in ultrasound birth weight estimation formula and found that the addition of mid-thigh STT to other biometric variables in model of fetal weight estimation improves neonatal outcome.

In the current study, there was a non-significant difference in the systematic error between normal and macrocosmic babies (p-value = 0.945, 0.445), while there was a significant difference between normal and macrocosmic babies in their random error (p-value = 0.034, 0.028), for the MTSTT and MH equation, respectively. The difference in random error could be attributed to the fact that the authors are applying MH equation to a wide range of infant weight which leads to a various range of errors.

Scioscia *et al.* [20] studied the correlation between MTSTT and detecting macrosomia. MTSTT was found to be useful for EFW and detecting macrosomia. The former measured FTSTT in 62 full-term pregnant women 48 hours before delivery and correlated MTSTT to the fetal birth weight and found a significant positive correlation between MTSTT and birth weight including macrosomia.

Earlier studies demonstrated that these variations are greater for macrosomic fetuses because of a propensity to underestimate birth weights [28,29]. According to the other investigators, Hadlock formulas were the most reliable among all categories of birth weight [30].

Conclusion

This study found that compared with using the traditional Hadlock's formula, the fetal thigh soft tissue thickness measured by the novel method of three-dimensional ultrasonography is more precisely and specifically related to the antenatal anticipated birth weight.

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Authors' contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

Conflict of Interest

There are no conflicts of interest in this study.

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