THE SIGNIFICANCE OF THREE-DIMENSIONAL SOFT TISSUE MARKERS IN ESTIMATING FETAL WEIGHT AMONG IRAQI WOMEN: A CROSS-SECTIONAL STUDY

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ABSTRACT

BACKGROUND: Estimating fetal weight (EFW) is essential for safeguarding laboring mothers and newborns. Higher birth weight is associated with poor delivery outcomes; earlier detection is crucial to improve the outcome. Current use of a two-dimensional ultrasonic shows limitations, especially among higher birth weight and those in the late third trimester. We aimed to examine whether the fractional thigh volume (FTV), a three-dimensional ultrasonic parameter, can predict fetal birth weight at 38-42 weeks.

METHOD: A cross-sectional study recruited 80 pregnant women who fulfilled the criteria; at University Hospital from June 2018 for 14 months. Patients were referred cases for labor induction. Women were assessed by clinical and obstetrical examination. A three-dimensional ultrasound evaluated FTV at the labor ward; 24-48 hours before delivery. Maternal demographics, an indication of admission, and outcomes were recorded. After delivery, the infants' actual birth weight was recorded.

RESULTS: The actual birth weight versus EFW by FTV was 3438.01 ±693.04 vs. 3548.47±706.71 grams. A third-degree polynomial equation highlighted the correlation between the EFW by FTV versus actual birth weight. ANOVA tested the equation accuracy, as F-ratio was 299.58, P value< 0.0001. The concordance correlation coefficient was 0.95.

CONCLUSION: The strong correlations of FTV in predicting fetal weight with a substantial concordance agreement, besides its simplicity and rapid examination time, especially when incorporated into commercial software, makes FTV a recommended marker for predicting EFW.

KEYWORDS: Prediction, fractional thigh volume, birth weight, estimated fetal weight, three-dimensional US.

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INTRODUCTION

Accurate estimation of fetal weight is challenging and represents an essential aspect of obstetric practice, especially when growth problems are suspected; larger-weight infants were linked to many bad labor outcomes[1]. Shoulder dystocia and neonatal respiratory distress showed increased incidents among those infants. Mothers show a higher risk of operative delivery, vaginal tears, and postpartum bleeding complicating many deliveries[2]. Estimating fetal weight (EFW) based on previous obstetrical history and fundal height estimation showed poor performance[3].

The giant leap presented by 2-Dimensional Ultrasonic (2D) estimation has improved our prediction. Hadlock formula is currently used in practice to determine EFW with a sensitivity of 62 percent and a specificity of 93 percent[4]. However, a 2D assessment was further subjected to analysis. It shows some drawbacks, particularly for fetuses less than 34 weeks and those with higher birth weight[5,6]. Because 2D assessments rely on bone measurements, they underestimated soft tissue mass and fetal visceral fat; visceral fat is a good indicator of the true nutritional state of the growing fetus[7]. Since fetal fat is accredited for 45% of birth weight variance thus, EFW accuracy by 2D is only 62%[8]. Earlier studies discussed the role of thigh circumference and mid-thigh soft tissue thickness in improving the accuracy of predicted fetal weight. This ultrasonic parameter has the advantage of simplicity, practicality, and feasibility to be used in practice[9].

However, these proposed fetal diameters were difficult to assess through 2D studies due to the irregular thigh morphology. From that came the necessity to apply 3D studies, which provided an accurate estimation of the thigh volume, thus enhancing EFW[10]. Using 3D measurements for EFW showed to be more precise; fractional thigh volume FTV is a 3D sub-volume assessing soft-tissue growth as a surrogate for fetal nutritional condition. Earlier reports proposed using the thigh; or the arm volume; others used both[11]. They recommended their use owing to the lower absolute errors and better accuracy compared to the current 2D formulae.

Combining 3D measurements with additional fetal biometric data such as femur length (FL), head circumference (HC), and bi-parietal diameter (BPD) allowed for a more reliable assessment of fetal weight in the extremities of fetal weight[12]. Still, this alternative approach was more time-consuming. Each limb measurement lasted 10 to 15 minutes[13]. To reduce the time needed to complete the measurements, researchers used a commercial software program[14] to reduce the examination time to 10 seconds. Moreover, other studies confirmed the value of FTV in improving the accuracy for gestational age in 34 – 36 weeks and not only the EFW[15].

3D ultrasound can provide important details about the soft tissue development of growing fetuses. However, it is unclear how accurate FTV can be in predicting fetal birth weight versus actual birth weight. Little evidence exists regarding its use among the Iraqi population. This study aimed to verify the significance of FTV, a three-dimensional ultrasonic parameter, in evaluating EFW among term pregnant women.

METHOD AND MATERIALS

A cross-sectional study recruited 80 pregnant women from The University Hospital. The study lasted 14 months, from June 2019-August 2020. The study was approved by the Institutional Review Board of Mustansiriyah University/Faculty of Medicine, Department of obstetrics and gynecology (IRB 158 dated March 2019). Informed written and verbal consent was taken from all participants.

The study participants were referred cases for labor induction in the labor ward of our maternity center, all were briefed about the study's aim, and they gave their consent to participate. We included cases with confirmed dates; between 38 - 42 weeks of singleton pregnancy calculated on a regular LMP and early pregnancy dating ultrasound. The participant should have a viable normal-cephalic presented fetus.

Cases with twin pregnancies, non-viable or malformed fetuses, and mal-positioned or mispresented fetuses were all an exclusion. Patients with hypertensive disorders or chronic renal diseases and those with suspected fetal growth restriction were excluded. As for diabetic cases, we included Gestational DM cases discovered late in pregnancy and not started treatment; we aimed to see the performance of FTV among higher-weight infants.

A detailed history was taken, and general and obstetrical examinations were performed. In the labor ward, a trained sonographer conducted 3DU exanimation for the participant by ultrasound equipment (Philips HD11XE) via a transabdominal probe 24-48 hours before labor. Estimation was made for the fetal weight by FTV; all Digital data images were saved to digital media for further examination offline.

The total fractional thigh volume was determined in the same way as the fetal limb lean volume and was calculated by commercially available Virtual dub v1.10.4 software formulae:

Volume (mL) = Avg (A1 + A2 + A3 + A4 + A5) × FL/2

(A = Area, Avg = Average of all areas calculated on five slices) described by Lee et al.

After the delivery, anthropomorphic measurements for newly born in addition to birth weight were taken by an electronic scale as the actual birth weight[16].

Method for Three-Dimensional FTV:

The entire length of the thigh was primarily scanned in the sagittal plane, then measured with a transabdominal probe, which was rotated 90 degrees and linear sweeps from the beginning of thigh diaphysis till its end. The volume of interest should occupy at least 2/3 of the digital video display; we tuned the image's depth and magnifications. Near the thigh diaphysis, the acoustic focus zone was positioned. During the maternal breath-hold, soft tissues were included in the volume assessment. The midpoint of the femur was determined using 3 -dimensional multiplanar imaging. The fractional limb volume was calculated using five evenly spaced sections around the femur's midpoint, shown in Figure 1. The skin, fat, muscle, and bone of the fetus were all included in each section. The lean and fat regions of the fetal thighs were differentiated in cross-section by their differing echogenicity. We assessed the inner lean limb mass after identifying the outside more echogenic fat part and the inner less echogenic lean section of the thigh.

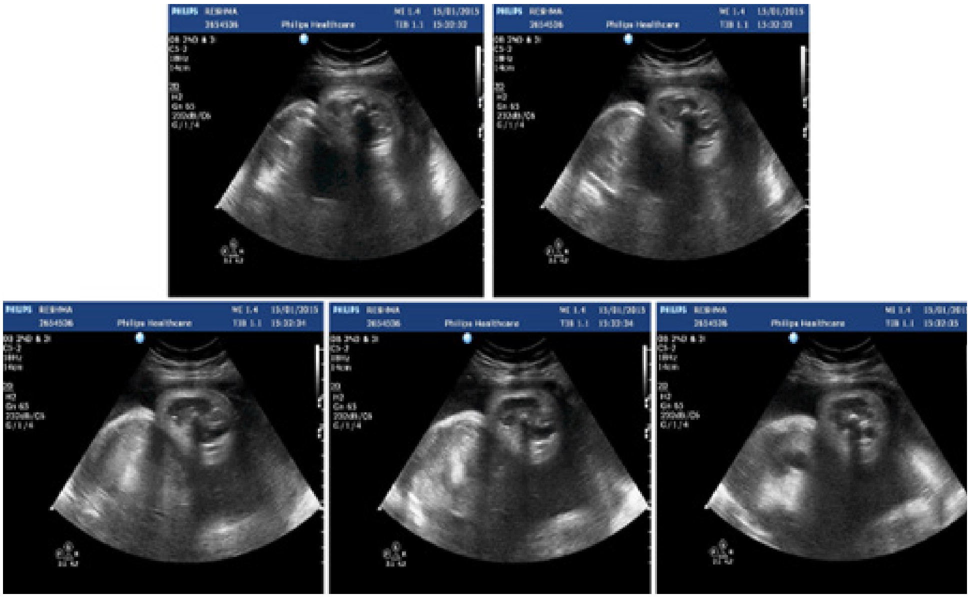

Figure 1. The technique of fractional thigh volume measurements; it's calculated using five evenly spaced sections around the femur's midpoint

Sample size calculation

According to the equation; sample size =(Z1-/2) 2 SD2 /d2 [17]

Where: Z1-/2 equals to 1.96; represent the usual normal variate

SD: stands for standard deviation that might have different values extracted from a previously completed study

d: denotes the researcher's absolute precision.

(1.96)2 sample size

(0.4)2 / (0.1) (0.1)2 = sixty patients is needed; we recruited eighty cases.

Statistical analysis

Continuous data were expressed as Mean ± standard deviations (SD) with respective SE of the Mean. Schapiro Wilkinson's test tested the data normality. A third-degree polynomial equation was used to link the Fractional thigh volume FTV as an independent variable versus actual fetal weight as a dependent variable. The equation accuracy was tested by the ANOVA test and its respective F ratio. A linear equation was constructed to highlight the correlation between EFW measured by Fractional thigh volume and actual birth weight. Concordance correlation coefficient(pc) was used to assess the inter-rater observational agreement between the EFW measured by fractional thigh volume FTV versus the actual birth weight. Significance was set at <0.05 for all tests; analysis was done by MedCalc - version 20.

RESULTS

In this cross-sectional study, 80 pregnant women we recruited. A comparison was made to EFW calculated by FTV versus actual birth weight measured post-delivery. The essential demographic criteria of participants were illustrated in Table. 1 as Means, SD, and SE of the mean. The actual birth weight versus the EFW by the FTV was 3438.01 ±693.04 vs. 3548.47±706.71 grams, respectively. Among the causes of inducing labor, ruptured membrane in 35 cases (43%), diabetic cases in 20 (25%), non-reassuring biophysical profile in 15 cases (18 %), and postdate10 cases (14 %) summarized in Table 2. Figure 2. demonstrated a third-degree polynomial equation that showed the correlation between the EFW by FTV versus the actual birth weight. ANOVA confirmed the accuracy of the equation, as F-ratio was: 299.58, P value< 0.0001. Figure 3. showed a linear regression for EFW by FTV and actual birth weight; it proved a strong positive correlation as (r)=0.82, P<0.001. Table 3 illustrated that the concordance correlation coefficient (pc) estimated value as: 0.95, which was interpreted as a substantial strength of agreement for the weight estimated by FTV and actual birth weight.

Table1. The basic demographic criteria of the study participants

Parameters, N= 80 women	Mean ±SD	SE of Mean
Maternal Age (years)	31.58 ± 6.49	0.64
BMI (kg/m2)	25.43 ± 4.06	0.04
Gestational age by LMP dating (weeks)	38.59±2.31	0.23
EFW by Fractional Thigh Volume FTV (grams)	3548.47±706.71	70.67
Actual birth weight post-delivery (grams)	3438.01±693.04	69.30

Table 2. The causes for induction among the study participants

The cause of induction	No.of cases	Percentage
Rupture of membrane	35	43%
Diabetic related indication	20	25%
Non-reassuring biophysical profile	15	18%
Postdate	10	14%
Total	80	100%

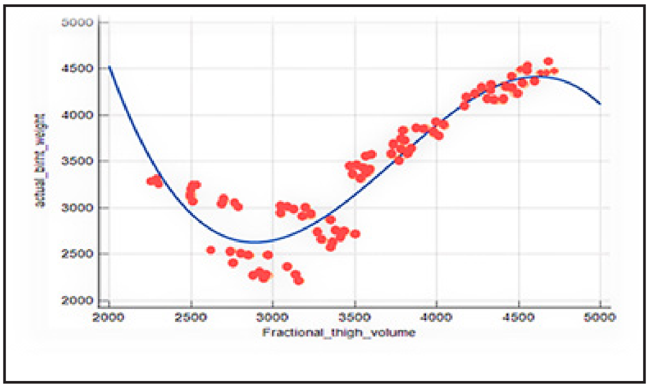

Figure 2. Non-linear regression,where X = fractional thigh volume , and Y= actual birth weight ;

F ratio=299.58, P<0.0001
Regression Equation
a+b*x+c*x^2+d*x^3
Parameter Coefficient
a =34283.05
b =-27.69
c =0.008
d= -0.00000069

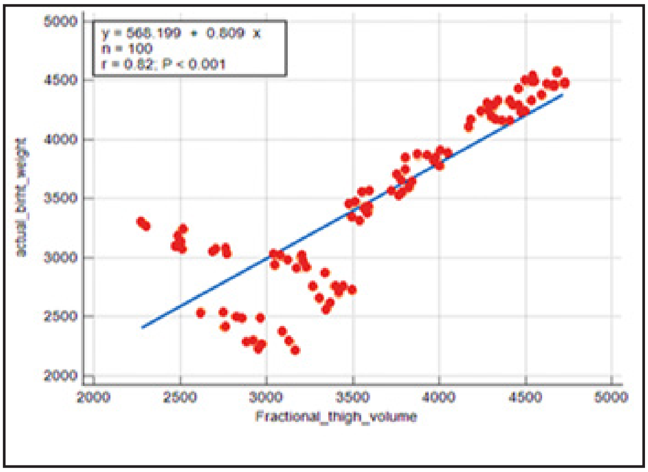

Figure 3. The linear correlation between the actual birth weight as an independent variable versus fractional thigh volume as a dependent variable, there was a strong positive correlation as r =0.82, P<0.001

Table 3. Concordance correlation coefficient (Pc)

Parameters	**Value**
Sample size	80 participants
Concordance correlation coefficient	0.95
95% Confidence interval	0.93-0.96%

Strength of agreement can be interprtated based on Pc value as : < 0.90 = poor , 0.90-0.95 = moderate , 0.95 - 0.99 = substantial , and > 0.99 = almost perfect .

DISCUSSION

Fetal weight is an essential prerequisite to ensure feto-maternal outcomes during labor. This study tested a model for estimating fetal weight using a three-dimensional limb volume ultrasonography; FTV showed a correlation to the actual birth weight, and ANOVA proved its accuracy; as F- ratio was 299.6, P-value <0.05. Furthermore, we confirmed a strong positive correlation between FTV and actual birth weight r = 0.82, P<0.001. The concordance correlation coefficient highlighted a substantial strength of agreement for the weight estimated by FTV and actual birth weight. The conventional 2D has 20 % errors in EFW, besides difficulties in visualizing fetuses attributed to maternal obesity, anteriorly located placenta, and oligohydramnios [18]. As a result, scientists seek other sonographic markers that correlate with a fetal weight with a greater predictive value[19].

Lee et al.in 2001 assessed the performance of multiple 3-Dimensional Ultrasonic parameters versus 2D in evaluating the EFW for an unselected population in the late 3rd trimester. He declared that abdominal circumference and FTV gave the best prediction with a difference from actual birth weight by -0.026% ±7.8% compared to the use of conventional Hadlock formulae. The newly tested prediction model accuracy was 2.32% ± 6.61%[14].

Li Kang et al. conducted a study on predicting fetal weight in 28–34-week pregnant women by semi-automatic 3D limb volume. The researchers calculated FTV and FAV combined with abdominal circumference; their prediction model showed high accuracy. The sensitivity and the specificity were 87.2% and 91.2%, respectively, and they declared higher predictive efficiency than Hadlock formulae, especially for the diagnosis of macrosomia[20].

Khoury et al. declared that 3D volume-based fetal weight scored higher accuracy for both underdeveloped fetuses and the low-risk general population. By including soft tissue assessment in the birth weight prediction process[21]. Pagani et al. tested the value of FTV in pregnant women with gestational diabetes mellitus at 34 + 0 to 36 + 6 weeks gestation, highlighting its precision in predicting EFW compared to the traditional Hadlock's formula. Furthermore, FTV predicted neonatal macrosomia with a similar sensitivity but higher specificity than the Hadlock method[22]. O'Connor investigated the value of FTV throughout gestation and tested its correlation with EFW and neonatal body composition. At 33-38 weeks of gestation, the author recommended FTV as a screening for cases at increased risk of macrosomia and FGR. The study correlated FTV to EFW and lean body mass among newborns as P =0.03[23].

Xining Wu et al. compared EFW in term pregnancies 7 days before the delivery; by an automated three-dimensional fractional limb volume model versus a traditional 2D. They concluded that automated fractional limb volume has better performance [particularly for fetuses < 3500 g] than that of the traditional 2D model. The inter-observer reliability of measuring fetal Fractional arm volume and FTV were high, with the interclass correlation coefficient of 0.92 and 0.96, respectively[24].

Cinar et al. investigated the associations between prenatal FTV and FAV versus neonatal anthropometric indicators within 24 h of scheduled caesarian deliveries. FAV showed moderate correlations to most neonatal parameters. In contrast to the weak correlation of FTV to some neonatal parameters. After controlling other variables, FTV showed no correlation; only FAV was independently correlated to neonatal anthropometric parameters irrespective of maternal criteria. The authors acknowledge that most of their participants were Caucasian women having higher BMI, which hinders their results[25].

Gembicki et al. examined the performance of modified FTV and arm volume in unselected pregnant women during the third trimester. Their result showed less accuracy for modified FTV than Hadlock's but presented a more precise result. The authors recommended modified FTV as a predictor for birth weight within (±10%) of actual weight in comparison to Hadlock's model[26].

Mlodawski et al. investigated the value of adding FTV to the Lee formulae and compared their performance to the Hadlock formulas in predicting fetal weight for term pregnant mothers. Their proposed method did not score significant differences compared to the Hadlock I formula in terms of accuracy or timeframe for conducting the examination. The authors rerecommended Lee formula in women with deep engaged fetal heads where it becomes challenging to estimate abdominal circumference and biparietal diameters[27].

Although over 30 equations are available for predicting EFW[28], we used a simple, rapid, yet applicable clinical model with high accuracy and substantial strength of agreement with the actual birth weight. Using commercial software could reduce examination time, a major limiting step for FTV use. Fractional thigh volume is already a validated marker for fetal growth disorders. It is used for estimating fetal weight, screening for macrocosmic fetuses, and in growth-restricted fetuses, so we needed no validation for its use[14,29].

Limitations; FTV showed technical difficulties; experienced sonographers can enhance its performance. Our study was a single-center study with a relatively small sampling size. In addition, some of the confounding factors that affect fetal fat that was not addressed; as race, maternal body mass index, weight gain during pregnancy, and fetal sex.

Birth weight is an important predictor of maternal and perinatal wellbeing[30]. An accurate assessment of fetal weight is crucial as it can guide the obstetrician's decision regarding the time and mode of delivery. In addition to considering the triangular trade-off between low - and adequate fetal weight-related complications and maternal indications for induction[31,32]. Randomized control studies are needed to appreciate FTV performance among high-risk Iraqi populations and at a wider gestational range.

CONCLUSION

Fractional thigh volume, a three-dimensional ultrasonic parameter, showed high accuracy in estimating actual birth weight. Using commercial software overcomes technical limitations that preclude three-dimensional ultrasound application in practice. Its strong correlation and inter-observer reliability make it an interesting option for improving fetal weight estimation.

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Conflict of interest: The corresponding author states no conflict of interest on behalf of all authors.

List of abbreviation

EFW estimated fetal weight
FTV fractional thigh volume
2D two dimensional ultrasound
3D three dimensional ultrasound
FAV Fractional arm volume

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