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ACCURACY OF SONOGRAPHIC FETAL WEIGHT ESTIMATION USING THE HADLOCK III FORMULA AT THE NATIONAL HOSPITAL OF OBSTETRICS AND GYNECOLOGY

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ABSTRACT

Objective: This study aimed to evaluate the accuracy of the Hadlock III formula in estimating fetal weight at the National Hospital of Obstetrics and Gynecology, Hanoi, Vietnam.

Methods: A cross-sectional study was conducted on 268 singleton term pregnancies (37–41 weeks) at the National Hospital of Obstetrics and Gynecology. Estimated fetal weight (EFW) was calculated using the Hadlock III formula based on biparietal diameter, head circumference, and femur length. Actual birth weight was measured immediately after delivery. Accuracy was assessed using mean percentage error (MPE), absolute percentage error (APE), and the prediction accuracy rate (APE ≤10%). Agreement was evaluated using Bland-Altman plots and Spearman correlation.

Results: The mean percentage error was –0.47%, and the prediction accuracy rate was 82.4%. Bland-Altman analysis showed a mean bias of 50.96g with 95% limits of agreement from –460.99g to 562.91g. Accuracy was reduced in birth weight extremes (<2500g and >4000g). No significant associations were found with maternal age, parity, gestational age, or fetal sex. A significant negative correlation was observed between birth weight and MPE ($\rho = -0.351$, $p < 0.001$).

Conclusion: The Hadlock III formula demonstrated high accuracy in fetal weight estimation among term pregnancies in a Vietnamese population and is a reliable tool in routine obstetric practice, particularly in settings where abdominal circumference measurement is limited.

Keywords: Fetal weight estimation, Hadlock III, ultrasound, accuracy, birth weight.

1. INTRODUCTION

Accurate estimation of fetal weight (EFW) is a critical component of antenatal and intrapartum care. It assists clinicians in identifying fetuses at risk of growth abnormalities and supports decision-making regarding the timing and mode of delivery. Particularly in late-term pregnancies, fetal weight estimation helps guide interventions to reduce the risks of complications associated with macrosomia, intrauterine growth restriction (IUGR), and shoulder dystocia. Errors in EFW may lead to unnecessary inductions, cesarean deliveries, or missed opportunities to intervene in high-risk pregnancies[1].

Ultrasonography remains the most widely used and validated method for fetal weight estimation. Among various sonographic models, the Hadlock formulas are the most commonly applied in clinical settings, incorporating biometric parameters such as biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL). These formulas were developed using regression models in mixed fetal populations and are generally recognized for their robust performance. However, differences in accuracy

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have been observed across versions of the Hadlock formula and among different populations[2].

The Hadlock III formula, which uses BPD, HC, and FL but excludes AC, has been recommended in specific contexts where AC measurement may be unreliable—for example, in cases of fetal positioning or maternal obesity.[3] Although this formula offers practical advantages, its accuracy in estimating birth weight, particularly in standard term pregnancies, remains underexplored. Existing literature has primarily focused on Hadlock I and IV, which include AC, with limited direct assessment of Hadlock III's performance as a standalone model[4].

Previous studies suggest that the accuracy of fetal weight estimation is influenced by gestational age, birth weight, fetal sex, and maternal characteristics. Lindström et al. (2023) reported that while Hadlock II and Shepard's formulas demonstrated reasonable performance in the Swedish population, systematic bias was present in extreme weight ranges.[5] Ezeugo et al. (2021) confirmed the high accuracy of Hadlock IV in Nigerian women but emphasized the need for local validation of formulas, especially in non-Caucasian cohorts.[6] Given these concerns, there is a need to evaluate the Hadlock III formula in a well-defined term population. This study aims to assess the accuracy of fetal weight estimation using the Hadlock III formula in Vietnamese women undergoing term cesarean delivery at the National Hospital of Obstetrics and Gynecology.

2. MATERIALS AND METHODS

2.1. Study Participants

This cross-sectional descriptive study was conducted at the National Hospital of Obstetrics and Gynecology from June to December 2024. The study population included pregnant women at term (from 37 to 41 completed weeks of gestation) who were scheduled for cesarean delivery. Eligible participants were those with singleton pregnancies in cephalic presentation and no signs of labor or in early labor (stage IA), who had a medical indication for cesarean section. Inclusion criteria also required participants to have a normally developed fetus, no chronic maternal illness, and an anatomically normal pelvis. Women were excluded if they had ruptured membranes, congenital anomalies of the uterus or genital tract (such as uterine malformation or fibroids), or a history of surgery involving uterine anomalies. Informed consent was obtained from all participants prior to enrollment.

2.2. Study Design: The study was designed as a cross-sectional study.

2.3. Sampling and sample size

A convenience sampling method was used to recruit participants who met the inclusion and exclusion criteria.

The required sample size was calculated based on a single proportion, using a 95% confidence level (Z = 1.96), an anticipated accuracy rate of 82.3% for ultrasound-based fetal weight estimation as reported by Ezeugo et al. (2021), and a margin of error of 5%. This yielded an estimated sample size of approximately 223 participants.[6] To enhance statistical reliability and compensate for potential data loss, the final sample included 268 participants.

2.4. Data Collection Procedures

Data collection involved a standardized process beginning with participant interviews to gather demographic and obstetric history. A general physical examination was then conducted to record vital signs and anthropometric measurements, including maternal height and weight. Obstetric evaluation involved measuring symphysis-fundal height and abdominal circumference. All measurements were taken while participants were lying in the supine position using a standardized measuring tape.

Fetal biometric parameters were obtained via ultrasound by a single experienced obstetrician with over 20 years of expertise in obstetric sonography. All measurements were performed using the same ultrasound machine. The parameters recorded included biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL). These measurements were then used to estimate fetal weight using the Hadlock III formula:

$$\mathrm{Log10}\,(EFW) = 1.326 - 0.00326 * AC * FL + 0.0107 * HC + 0.0438 * AC + 0.158 * FL$$

2.5. Study variables

The outcome variables in this study were three measures of fetal weight estimation accuracy. These included:

(1) Mean Percentage Error (MPE), which reflects the systematic error by calculating the mean of the percentage differences between estimated fetal weight (EFW) and actual birth weight;

(2) Absolute Percentage Error (APE), calculated as the absolute value of the difference between EFW and actual birth weight, divided by actual birth weight and multiplied by 100; and

(3) Accuracy rate, defined as the proportion of cases with APE ≤10%, indicating clinically acceptable estimation accuracy.

The independent variables included a range of maternal and fetal characteristics. Maternal factors were maternal age (<35 or ≥35 years), area of residence (urban or rural), and parity (categorized as 0, 1, 2, 3, or ≥4). Fetal and neonatal variables included gestational age at delivery (36–41 completed weeks), infant sex (male or female), and actual birth weight (<2500 g, 2500–<3500 g, 3500–<4000 g, or ≥4000 g).

2.6. Statistical Analysis

Data were initially entered and validated using Epidata software, and all statistical analyses were performed using Stata version 18. Descriptive statistics were used to summarize participant characteristics and fetal outcomes. For group comparisons, t-tests or ANOVA were used for normally distributed variables, and Mann–Whitney or Kruskal–Wallis tests for non-normal data. Depending on the distribution of data, Pearson or Spearman correlation coefficients were used to evaluate associations between quantitative variables. Scatter plots were generated to visualize relationships between actual birth weight and estimated fetal weight, gestational age, and absolute error, as well as birth weight and absolute error. Bland-Altman plots were constructed to evaluate the agreement between estimated fetal weight (EFW) and actual birth weight. These plots visualized the mean difference (bias) and the 95% limits of agreement between the two methods.

2.7. Ethical Considerations

The study was approved by the Institutional Review Board of Hanoi Medical University prior to implementation. All participants were fully informed about the study objectives, procedures, potential risks and benefits, and their rights as research subjects. Participation was entirely voluntary, and participants had the right to withdraw from the study at any point without affecting their medical care. Confidentiality of all personal and medical information was strictly maintained.

3. RESULTS

Table 1. Characteristics of the study participants

Characteristics		N	Percent %
Maternal age	<35	197	73,51
	to5≥35	71	26,49
	Mean ± SD	32,0 ± 5,2	
Area	Rural	145	54,72
	Urban	120	45,28
Parity	0	7	2,66
	1	40	15,21
	2	68	25,86
	3	63	23,95
	>= 4	85	32,3
Gestational Age (weeks)	36	1	0,38
	37	15	5,66
	38	129	48,68
	39	105	39,62
	40	14	5,28
	41	1	0,38
Infant Sex	Male	164	61,19
	Female	104	38,81
Birth Weight	<2500g	3	1,12
	2500 - <3500	205	76,49
	3500 - <4000	53	19,78
	> 4000	7	2,61
	Mean ± SD	3193,5 ± 354,9	
History of gestational diabetes mellitus		41	15,30
Cesarean section		175	65,30
Total		268	100,0

The majority of participants were under the age of 35 (73.51%), with a mean maternal age of 32.0 years (SD = 5.2). The study sample was almost evenly split between rural (54.72%) and urban (45.28%) areas. Most participants had given birth two or more times, with a notable proportion (32.3%) having parity ≥4. Gestational age at birth was concentrated around 38 to 39 weeks (88.3%). Infant sex distribution was skewed toward males (61.19%). Birth weight data showed that 76.49% of neonates weighed between 2500–3500g, with a mean birth weight of 3193.5g (SD = 354.9). A minority of participants had a history of gestational diabetes (15.30%), and a cesarean section rate of 65.30% was observed.

Table 2. Accuracy of Fetal Weight Estimation by Characteristics

Characteristics	N	Mean percentage error ± SD, %	Accuracy rate n (%)	p value
Maternal age				
<35 years old	197	-0,73 ± 8,3	163 (82,7%)	0,842
≥35 years old	71	0,25 ± 7,74	58 (81,7%)	
Parity				
0	7	4,91 ± 6,5	6 (85,7%)	0,842
1	40	-0,01 ± 6,23	36 (90,0%)	
2	68	-1,65 ± 8,38	54 (79,4%)	
3	63	-0,71 ± 7,13	54 (85,7%)	
>= 4	85	-0,14 ± 9,72	66 (77,6%)	
Gestational Age (weeks)				
36	1	-4,94	1 (100,0%)	0,831
37	15	-1,02 ± 8,62	12 (80,0%)	
38	129	-0,12 ± 8,94	108 (83,7%)	
39	105	-0,87 ± 7,58	84 (80,0%)	
40	14	1,23 ± 6,17	13 (92,9%)	
41	1	1,16	1 (100,0%)	
Infant Sex				
Male	164	-1,02 ± 7,64	131 (79,9%)	0,162
Female	104	0,38 ± 9,01	90 (86,5%)	
Birth Weight				
<2500g	3	33,0 ± 19,4	0 (0,0%)	0,001
2500 - <3500	205	-0,04 ± 6,99	174 (84,9%)	
3500 - <4000	53	-3,25 ± 7,69	42 (79,2%)	
> 4000	7	-6,47 ± 4,23	5 (71,4%)	
Total				
	268	-0,47 ± 8,21	221 (82,4%)	

Table 2 compares the accuracy of fetal weight estimation across various maternal and neonatal characteristics using mean percentage error and accuracy rate. No statistically significant differences in estimation accuracy were observed across maternal age, parity, gestational age, or infant sex (all p > 0.05). However, birth weight groups demonstrated a significant difference (p = 0.001), with higher mean percentage error and lower accuracy in the <2500g and >4000g categories. Overall, the estimation was relatively accurate, with a total mean percentage error of -0.47% (SD = 8.21) and an overall accuracy rate of 82.4%.

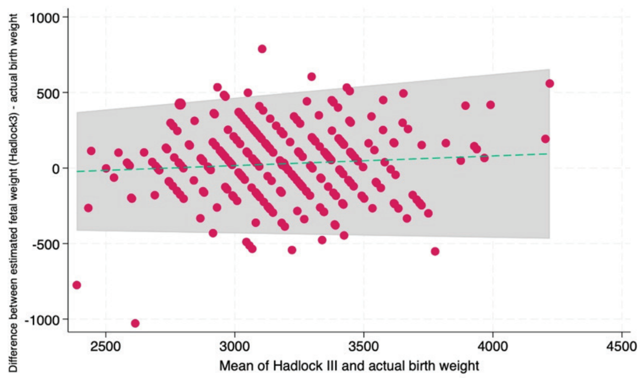

Figure 1. Bland-Altman plot showing the difference between Hadlock I and actual birth weight

The Bland-Altman plot illustrates the agreement between the Hadlock I estimated fetal weight and actual birth weight. The majority of points lie within the 95% limits of agreement, indicating acceptable concordance between the two measures. A mean difference of 50.96 grams was observed, with 95% limits of agreement ranging from -460.99 g to 562.91 g.

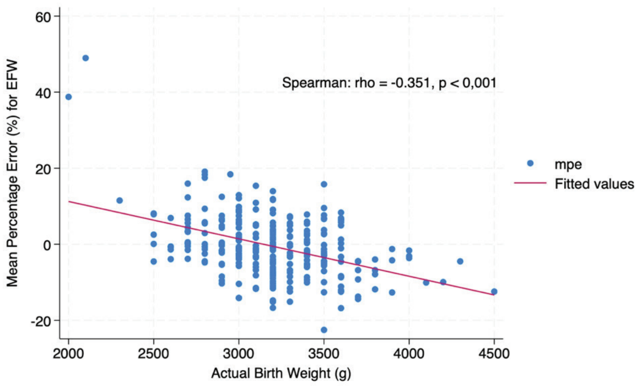

Figure 2. Correlation between Actual Birth Weight and Mean Percentage Error of Estimated Fetal Weight (EFW)

This scatter plot illustrates the relationship between actual birth weight and the mean percentage error (MPE) in estimated fetal weight. Each dot represents an individual case, while the red line indicates the fitted regression line. A moderate negative correlation was observed between actual birth weight and MPE, with a Spearman's rho of -0.351 and a p-value < 0.001. This statistically significant result indicates that as actual birth weight increases, the mean percentage error in EFW tends to decrease. The distribution shows greater overestimation at lower birth weights and relatively better accuracy as birth weight increases, suggesting that EFW is less reliable in cases of low birth weight.

4. DISCUSSION

This study aimed to evaluate the accuracy of fetal weight estimation at term using ultrasound-based Hadlock formulas in a Vietnamese population. With a sample of 268 women undergoing cesarean section between 37 and 41 weeks of gestation, the study demonstrated a high degree of agreement between estimated fetal weight (EFW) and actual birth weight (BW), confirming the reliability of sonographic estimation in this context. The overall mean percentage error (MPE) was -0.47%, indicating only a minimal systematic bias, and 82.4% of the estimations fell within the clinically acceptable range of absolute percentage error (APE) ≤10%. These findings are consistent with the performance of the Hadlock formula in other international studies and add evidence supporting its validity in Southeast Asian populations.

The accuracy rate observed in this study aligns closely with results reported by Ezeugo et al. (2021), who found an 82.3% accuracy rate for the Hadlock IV formula in a Nigerian cohort, using the same APE threshold for classification. Similarly, Lindström et al. (2023) in a Swedish study reported an accuracy rate of 69.4% using Hadlock-based formulas in routine obstetric care. Although slightly lower than our results, their study excluded head circumference (HC) in formula application and included broader gestational ages, which may explain the difference [5, 6].

Our analysis further revealed that estimation errors were more prominent at the extremes of birth weight. Specifically, neonates weighing less than 2500g or greater than 4000g had significantly higher mean percentage errors, a pattern consistent with the U-shaped distribution described in multiple studies. In our cohort, the mean percentage error in the <2500g group was 33.0%, indicating consistent overestimation, whereas it was -6.47% in the >4000g group, reflecting a trend toward underestimation. These results are in agreement with studies by Taiwo et al. (2018), both of which identified reduced accuracy in low and high birth weight categories and attributed these errors to limitations in ultrasound resolution and anatomical variability in extreme fetal sizes [7].

The Bland-Altman plots in our study confirmed acceptable agreement between estimated and actual weights using both Hadlock I and Hadlock II formulas. The mean bias for Hadlock III was 50.96g, with 95% limits of agreement ranging from –460.99g to 562.91g. These findings support the robustness of the Hadlock models in accurately estimating fetal weight across diverse settings. Similar trends were reported by Blumenfeld et al. (2010), who emphasized that while Hadlock models maintain reasonable accuracy across average weight ranges, clinical caution is advised when interpreting results at the tails of the weight spectrum [8].

Interestingly, no statistically significant differences in estimation accuracy were observed when stratifying by maternal age, parity, gestational age, or fetal sex. This lack of association has been previously observed in other cohorts as well. For instance, Lindström et al. (2023) found that maternal BMI and parity had limited influence on estimation error in their Swedish population. Similarly, a study by Dudley (2005) found that EFW performance was not substantially altered by maternal characteristics alone but was more affected by fetal presentation and operator technique [4, 5]. Spearman correlation analysis in our study revealed a moderate but statistically significant negative association between actual birth weight and MPE (rho = –0.351, p < 0.001), suggesting increased estimation error in smaller fetuses. This aligns with the notion that soft tissue compression and atypical fetal proportions in small-for-gestational-age (SGA) fetuses may compromise the accuracy of biometric formulas.

Several limitations must be acknowledged. First, the use of convenience sampling may introduce selection bias, limiting the generalizability of our findings to all term pregnancies, particularly those in labor or with fetal growth abnormalities. Second, although the use of a single ultrasound machine and operator enhances internal consistency, it may reduce the external validity of the results in settings with multiple sonographers and equipment variability. Third, our analysis did not evaluate the influence of maternal BMI or amniotic fluid volume, which have been shown to affect sonographic measurements. Lastly, our study focused exclusively on term pregnancies, and findings may not apply to preterm or post-term populations.

5. CONCLUSION

The Hadlock III formula demonstrated high accuracy in estimating fetal weight among term pregnancies at the National Hospital of Obstetrics and Gynecology, with minimal mean error and over 80% of estimates within ±10% of actual birth weight. These findings support the continued use of Hadlock III as a valid and clinically useful tool in routine obstetric practice, particularly in settings where measurement of abdominal circumference may be limited or unreliable. Further multicenter studies across different regions in Vietnam are recommended to confirm the generalizability of these results.

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