

# VALIDATION OF HADLOCK'S AND SHEPARD FORMULAE OF FETAL WEIGHT ESTIMATION IN EASTERN REGION OF NEPAL

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## ABSTRACT

### Introduction

Ultrasonography plays a pivotal role in present day obstetrics. It has been well recognized that the fetuses of extremes of the normal birth weight range are associated with increased perinatal morbidity, mortality and adverse development outcomes. Categorization of fetal weight into either the small or large for gestational age may lead to timed obstetric interventions that collectively represent significant departure from routine antenatal care.

### Objective

To compare the accuracy of Hadlock's 1, 2, 3, 4 and Shepard model in estimating expected fetal weight and its comparison with actual birth weight in our population at eastern region of Nepal.

### Methodology

A prospective observational study was performed in the Department of Radiodiagnosis, Nobel Medical college and teaching hospital, Biratnagar, over a period of 6 months dated Jan 2018 to June 2018 using systematic random sampling with sample size estimated as 160, with 5% level of significance, 80% power of test and a maximum of 200 grams differences by our predicting model from actual mean weight. Singleton, term pregnancy (37-42 weeks gestational age) verified with antenatal USG performed prior to 20 weeks' gestation. Pregnancies complicated by congenital anomalies and deliveries after 2 days of USG examination were excluded.

### Results

159 pregnant ladies were enrolled in our study with mean age of  $27.60 \pm 5.633$  years (range 18-43 years). The average (actual) birth weight recorded was  $3450.79 \pm 438.73$  gms. The different formulae for estimating birth weight gave us similar results. Estimation of fetal weight by Shepard gave us a mean of  $3340.80 \pm 463.72$ . Hadlock1, Hadlock2, Hadlock3 and Hadlock4 were  $3546.55 \pm 429.92$  grams,  $3491.18 \pm 439.49$  grams,  $3445.23 \pm 422.79$  grams, and  $3446.12 \pm 418.43$  grams respectively.

### Conclusion

All four Hadlock formulae gave comparable results for fetal weight estimation including the Shepard formula; however, Shepard formula tends to underestimate fetal weight as compared to rest of the formulae. Among the Hadlock's, Hadlock 2 seems to show better accuracy in fetal weight prediction in our population of study. The mean birth weight recorded using Hadlock 1 formula gave the best correlation with the actual birth weight though the difference between four Hadlock formulae was all insignificant.

## Citation

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## KEYWORDS

*birth weight, fetal weight, ultrasonography*



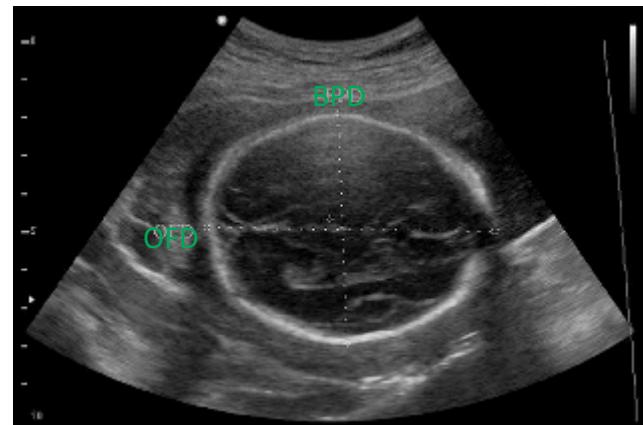
## INTRODUCTION

Accurate pre delivery assessment and estimation of fetal weight is important in many obstetrics situations.<sup>1</sup> Fetuses at extremes of normal birth weight range are associated with increased perinatal morbidity, mortality and adverse development outcomes.<sup>2</sup> Further, macrosomic infants have a six fold increased risk of birth trauma.<sup>3</sup> Categorization of fetal weight into either the small or large for gestational age helps in timely obstetric interventions.<sup>4</sup> Ultrasound models using combination of various fetal parameters like head measurements (biparietal diameter or head circumference), abdominal circumference (AC), femur length (FL) and trunk circumference yield more accuracy.<sup>5,6</sup> Different models have been formulated for fetal weight estimation using different combinations of fetal biometric parameters; but most of these models have been derived from western population data.<sup>7-9</sup> Fetuses tend to gain some weight in utero from the day of scan till date of delivery.<sup>10</sup> Various researches were done to find out the best time to document ultrasonically derived fetal weight and a recent study identified that the results were better for the calculated birth weight within 3 days of delivery<sup>11</sup> There is no general consensus as to which model gives a better validity in predicting birth weight in particular race or ethnicity. Birth weight estimation models derived from one ethnic population applied to another population might result in erroneous estimations, therefore, judicious selection of appropriate models for the local population is important to ensure precision in the assessment. The aim of our study was to compare the accuracy of Hadlock's 1, 2, 3, 4 and Shepard model in estimating expected fetal weight and its comparison with actual birth weight in our population at eastern region of Nepal.

## METHODOLOGY

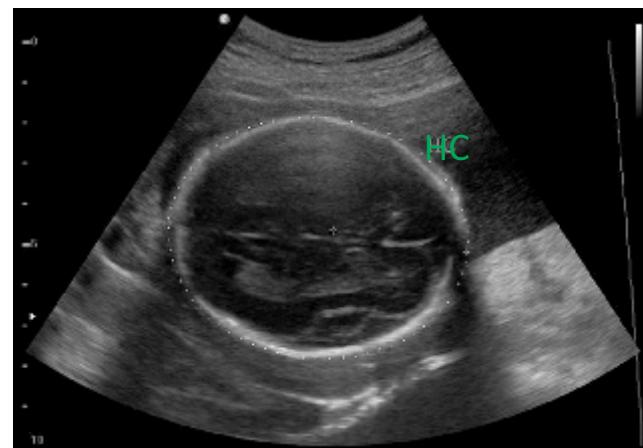
An analytical study was performed in the department of Radiology and department of Obstetrics Nobel Medical College and teaching hospital, Biratnagar, for a period of 6months dated Jan 2018 to June 2018 using Systematic random sampling with sample size estimated as 160, with 5% level of significance, 80% power of test and a maximum of 200 grams differences by our predicting model from actual mean weight. Ethical clearance was obtained and consent of the patients were taken before conducting the study. All Singleton term pregnancies (37- 42 weeks gestational age) were included and pregnancies complicated by congenital anomalies and deliveries after 3 days of USG examination were excluded from the study. The relevant fetal parameters viz. biparietal diameter, head circumference, femur length and abdominal circumference were recorded using Samsung ultrasound machine with a 3.5 MHz curvilinear probe and fetal weights entered for each formula.

**Biparietal diameter (BPD)** was measured on a real time ultrasound machine in a transverse plane over the frozen image from the outer edge of the proximal skull to the inner edge of the distal skull table, with electronic calipers placed on a line perpendicular to the mid line echo.



**Figure 1:** Measurement of biparietal diameter (BPD)

**Head circumference (HC)** was measured on a real time ultrasound machine at the same section as above using ellipse method by tracing the head circumference along the outer skull table.



**Figure 2:** Measurement of Head circumference (HC)

**Abdominal circumference (AC)** was measured on a real time ultrasound machine at the level of umbilical vein as it enters the left portal vein. Stomach bubble was also taken as landmark. It was measured using ellipse method.



**Figure 3:** Measurement of abdominal circumference (AC)

**Femur Length (FL)** was measured on a real time ultrasound machine from greater trochanter to external condyle, excluding femoral head.



**Figure 4:** Measurement of femur length (FL)

The estimated fetal weight was obtained using the following parameters viz BPD, HC, AC, FL, which were applied to the under mentioned formulae, and entered in Microsoft excel.

The formulae given for the models are:

#### HADLOCK1FORMULA:

$$\text{LogFW}(g) = 1.304 + (0.05281 \times \text{AC}) + (0.1938 \times \text{FL}) - (0.004 \times \text{AC} \times \text{FL})$$

$$\text{HADLOCK2FORMULA: } \text{LogFW}(g) = 1.335 - (0.0034 \times \text{AC} \times \text{FL}) + (0.0316 \times \text{BPD}) + (0.0457 \times \text{AC}) + (0.1623 \times \text{FL})$$

$$\text{HADLOCK3 FORMULA: } \text{LogFW}(g) = 1.326 - (0.00326 \times \text{AC} \times \text{FL}) + (0.0107 \times \text{HC}) + (0.0438 \times \text{AC}) + (0.158 \times \text{FL})$$

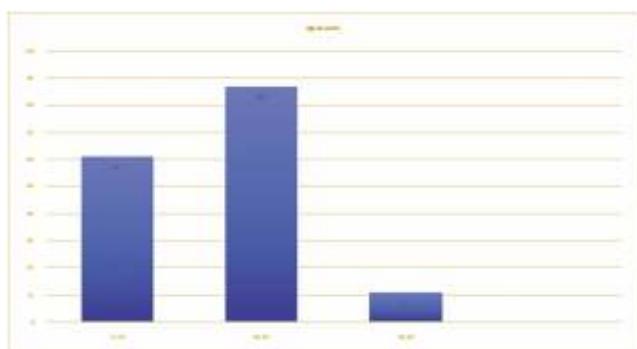
$$\text{HADLOCK4FORMULA: } \text{LogFW}(g) = 0.3596 + (0.00061 \times \text{BPD} \times \text{AC}) + (0.0424 \times \text{AC}) + (0.174 \times \text{FL}) + (0.0064 \times \text{HC}) - (0.00386 \times \text{AC} \times \text{FL})$$

$$\text{SHEPARD FORMULA: } \text{LogFW}(g) = -1.7492 + (0.166 \times \text{BPD}) + (0.046 \times \text{AC}) - (0.002646 \times \text{AC} \times \text{BPD}) \times 1000$$

Respective expected fetal weight was calculated and the actual birth weight of the baby was recorded within 15 minutes post-delivery on a baby scale. The actual weight of the neonate was then compared to ultrasound predicted birth weight. Collected data were entered and analyzed using SPSS 15.0. The comparison between different formulae for predicting birth weight by USG was performed. Pearson's correlation test was used to see the relation between predicted birth weight and the actual birth weight. A p-value less than 0.05 were considered significant.

## RESULTS

159 pregnant ladies were enrolled in our study with mean age of  $27.60 \pm 5.633$  years (range 18-43 years).



The average (actual) birth weight recorded was  $3450.79 \pm 438.73$  gms. The different formulae for estimating birth weight gave us similar results. The mean estimated fetal weight by Shepard model was  $3340.80 \pm 463.72$  and by Hadlock1, Hadlock2, Hadlock3, Hadlock4 were  $3546.55 \pm 429.92$ ,  $3491.18 \pm 439.49$ ,  $3445.23 \pm 422.79$ , and  $3446.12 \pm 418.43$  respectively.

**Table 1:** Minimum and maximum estimated fetal weight, mean and standard deviation of estimated fetal weight as calculated by different formulae

	Minimum Estimated fetal weight	Maximum Estimated fetal weight	Mean Estimated fetal weight	Std. Deviation of estimated fetal weight
Hadlock1	2546	4417	3549.55	429.924
Hadlock2	2447	4376	3491.18	439.485
Hadlock3	2490	4333	3445.23	422.787
Hadlock4	2455	4339	3446.12	418.425
Shepard	2179	4306	3340.80	463.724
AFW	2400	4750	3450.79	438.373

When weights estimated by various formulas were compared with the actual weight it was observed that the estimated weights varied between more than 900 grams of underestimation to more than 800 grams of over estimation in different cases. Further, it was seen that all Hadlock formulae had comparable results whereas Shepard formula tends to underestimate more than the rest, however overestimation was not of much concern with all of the studied formulae.

**Table 2 :** Distribution of cases by the difference between actual fetal weight and estimated weights by various formulae (Actual - Estimated)

Range of Difference (Actual - Estimated)	Formulas									
	Hadlock1	Hadlock2	Hadlock3	Hadlock4	Shepard					
≤ -900.00	1	0.6	1	0.6	1	0.6	0	0	0	0
-899.99 - -800	0	0	0	0	0	0	1	0.6	0	0
-799.99 - -700	1	0.6	0	0	0	0	0	0	0	0
-699.99 - -600	3	1.9	4	2.5	1	0.6	3	1.9	2	1.3
-599.99 - -500	2	1.3	0	0	3	1.9	1	0.6	3	1.9
-499.99 - -400	5	3.1	6	3.8	4	2.5	6	3.8	4	2.5
-399.99 - -300	10	6.3	5	3.1	3	1.9	4	2.5	4	2.5
-299.99 - -200	17	10.7	10	6.3	11	6.9	9	5.7	7	4.4
-199.99 - -100	33	20.8	22	13.8	13	8.2	14	8.8	11	6.9
-99.99 - 0	42	26.4	38	23.9	30	18.9	32	20.1	12	7.5
.01 - 100.00	30	18.9	38	23.9	44	27.7	36	22.6	30	18.9
100.01 - 200.00	9	5.7	22	13.8	26	16.4	29	18.2	25	15.7
200.01 - 300.00	3	1.9	9	5.7	17	10.7	16	10.1	23	14.5
300.01 - 400.00	1	0.6	0	0	2	1.3	4	2.5	20	12.6
400.01 - 500.00	1	0.6	2	1.3	2	1.3	2	1.3	10	6.3
500.01 - 600.00	0	0	1	0.6	1	0.6	1	0.6	4	2.5
600.01 - 700.00	0	0	0	0	0	0	0	0	1	0.6
700.01 - 800.00	0	0	0	0	0	0	0	0	3	1.9
800.01+	1	0.6	1	0.6	1	0.6	1	0.6	0	0

When observed for the range of  $\pm$  200 grams it was observed that the weights estimated by the Hadlock 1 formula gave 115(72.3%), Hadlock 2 gave 120(75.4%), Hadlock 3 gave 113(71%) and Shepard formula gave 78(49%) cases in this range.

**Table 3: Comparison of accuracy among different formulas within a range of 200 grams on each side.**

	Hadlock1	Hadlock2	Hadlock3	Hadlock4	Shepard
Accurate	115	120	113	111	78
Inaccurate	44	39	46	48	81
Total	159	159	159	159	159

Considering the cases estimated within range of 200 grams as accurate and other cases as inaccurate, there was no significant difference between different formulae, other than Shepard formula giving least accurate measure and Hadlock 2 giving the most accurate measure.

Pearson's correlation analysis was done to find the relationship between actual fetal weight and those measured by the different models. All of these formulae gave good correlation but the highest degree of correlation with p value of <0.001 was observed with Hadlock's 1.

**Table 3: Comparison of accuracy among different formulas within a range of 200 grams on each side.**

S.No.	Model	Test	Actual Fetal weight
1.	Hadlock 1	Pearson correlation p-value	0.876 <0.001
2	Hadlock 2	Pearson correlation p-value	0.870 <0.001
3	Hadlock 3	Pearson correlation p-value	0.871 <0.001
4	Hadlock 4	Pearson correlation p-value	0.859 <0.001
5	Shepard	Pearson correlation p-value	0.827 <0.001

## DISCUSSION

Estimation of fetal weight using Ultrasonography has a paramount role in the obstetrics practice. Identification of small and large fetus in-utero not only is helpful in determining the route of delivery but also helps in gearing up for better antepartum care. Software is installed in the ultrasound machines containing various formulae derived from one or combination of the multiple fetal biometric parameters and the formula to calculate fetal weight is solely dependent upon the sonographer's choice. Hadlock 1 formula uses femur length (FL) and abdominal circumference (AC). It was found to be a good predictor of birth weight compared to other methods as it makes use of femur length and abdominal measurements which are not altered at term. Hadlock 2 formula uses all the three parameters viz., Biparietal diameter (BPD), Femur length (FL) and Abdominal circumference (AC). Previous studies have shown that greatest accuracy is achieved with the combination of head, abdominal and femur measurements.<sup>5, 7</sup> Hadlock 3 formula uses abdominal circumference (AC), femur length (FL) and

head circumference (HC). In cases of preterm, oligohydramnios, premature rupture of membranes, and dolichocephaly, head circumference (HC) was found to be more reliable than biparietal diameter for estimation of fetal weight.<sup>27</sup> Shepard's formula uses biparietal diameter (BPD) and abdominal circumference (AC) only, so it reflects less upon the actual fetal weight estimation as observed in our study as well. Hadlock 4 formula uses all of the parameters viz. BPD, AC, FL and HC but this formula was also equally contributory as compared to Hadlock 2 or Hadlock 3 formulae.

A study done in 109 pregnant Caucasian patients showed that the best in utero weight estimates result from the use of models based on head size, abdominal size and femur length. Since the accuracy of these models (1SD= 7.5%) is significantly better than those based on head and body (BPD and AC), routine use of such models has been recommended<sup>6</sup>. Different formulae yield different expected birth weight therefore it is imperative that we choose the best fetal weight prediction model in order to ensure proper guide to the clinician to decide upon the proper care and intervention for better perinatal outcome. It has been noticed that the fetuses tend to gain weight in utero till the time of delivery, therefore various studies were conducted to find out the best time to document ultrasonically derived birth weight. In a recent study it was found that accurate estimation could be predicted if the fetal weight was calculated within 3 days of delivery.<sup>11</sup> Therefore, this factor has also been accounted in this study and only deliveries within 3 days of last pre-delivery Ultrasonography were included.

Various observations have been made to derive an ideal formula for the estimation of birth weight for different weight groups of infants.<sup>11-13</sup> Parameters like cheek-to-cheek diameter, shoulder skin fold thickness were incorporated in estimating birth weight in macrosomic fetus.<sup>14</sup> Soft tissue was included to aid in the prediction of birth weight and to correlate the fetal limb fat volume with neonatal parameters of fat. It was found that estimated fetal weight from 2D biometric measurements and the fractional thigh volume correlated with actual birth weight better than estimated fetal weight collected on the basis of traditional biometric measurements on 2D ultrasonography alone.<sup>15-17</sup> The advantage of volumetric ultrasonography over conventional two-dimensional ultrasound is that reproducible circumference and volumetric measurements ease simultaneous visualization of three orthogonal fetal limb sections. The disadvantage however is that 3-D sonography is a technically demanding and a time-consuming process requiring advanced and expensive equipment with special operator training and skills and moreover, it may also be more difficult to apply during labor. It seems therefore unreasonable to adopt 3D over 2D ultrasound imaging for fetal weight estimation. MRI has been found to be promising than ultrasonography in estimating birth weight.<sup>18</sup> Fetal weight was estimated in utero in eleven singleton pregnancies by measurement of fetal volume with echo-planar imaging (EPI), a form of magnetic resonance imaging, and by ultrasound measurements. EPI estimates of fetal volume were closely correlated with actual birth weight ( $R=0.97$ ). The median



between actual and EPI-estimated birth weight was 3·0% (range 0·6-9·9); this discrepancy was significantly smaller than that found for ultrasonographic estimates (6·5% [1·7-17·8]; p <0·01).<sup>24</sup> The ability to obtain multiplanar acquisitions and its theoretic improved resolution serves as the advantages of MRI compared with other imaging techniques.<sup>25</sup> The disadvantage however, in addition to the expense, is the impracticability in collecting measurements during labour.

Birth weight estimation models derived from one ethnic population applied to another population might result in erroneous estimations. Studies have therefore been done in different places like Ireland, Australia, Iran, and China, to find whether the international ultrasound reference standards were appropriate for their population groups.<sup>22</sup> A comparative study done between Iranian and Australian fetuses found that the use of European or Australian standards was causing overestimation of expected fetal weight in growth retarded fetuses in Iranian population.<sup>18</sup> A study done in Chinese population comparing use of Hadlock 1-4, Shepard, Wars of, Campbell and WOO 1 and 2 showed that Woo 2 model produced a better estimate of the actual birth weight with least difference in systematic bias and with acceptable limits of agreement<sup>19</sup>

It is observed in our study that there were no significant differences among all the formulae being studied; however, Hadlock2 which uses all the three parameters viz., Biparietal diameter (BPD), Femur length (FL) and Abdominal circumference (AC) showed better accuracy in fetal weight prediction than rest of the models in our population. This result favors similar results obtained by Hadlock using these parameters<sup>20,21</sup>

## LIMITATION OF THE STUDY

The limitations of this study are that the data collected was from a single center involving a small number of samples, which makes it difficult to generalize these results for the entire eastern region due to prevailing ethnicity difference. Very limited information is available in our country regarding the accuracy of various existing models. It is imperative therefore for further evaluation of existing ultrasonography-based fetal weight estimation models with well-designed prospective studies across the country and to derive a formula which will be better representative of the birth weight in our population

## CONCLUSION

The mean birth weight recorded using Hadlock 1 formula gave the better correlation with the actual birth weight though the difference between four Hadlock formulae was all insignificant. All four Hadlock formulae were accurate within 200gms range of weight, but the best accuracy rate was observed for Hadlock 2 though the individual formulae were not statistically compared. Also, our study suggests that having multiple parameters does not necessarily result in a better accuracy of estimation. Hadlock 1 formula therefore seems to be promising in fetal weight prediction in our population.

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## CONFLICT OF INTEREST

No conflict of interest to declare.

## FINANCIAL DISCLOSURE

None.

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