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Comparison between Different Ultrasound Formulae for Accurate Estimation of Fetal Weight

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Abstract

Background: Ultrasound estimation of fetal weight is a highly influential factor in antenatal management, guiding both the timing and mode of delivery of a pregnancy. The primary goal of this research was to compare the accuracy of 7 different sonographic formulae in estimation of fetal weight at term to show the most accurate formula and obtain the most effective fetal parameter. **Methods:** This comparative cross-sectional study was conducted at Benha University Hospital and included 120 pregnant women aged between (20 - 40 years) without any chronic diseases at term pregnancy (37- 40) weeks within one day prior to delivery, the ultrasonic study was done to estimate of Fetal weight. **Results:** Actual birth weight mean value at time of delivery was 3.16 kg. Mean levels of predicted weights using Formulae was 3.46 kg for warsof, 3.01 kg for vintzileos, 2.85 kg for hadlock I, 2.81 for hadlock II, 2.83 kg for hadlock III, 2.96 kg for hadlock IV and 2.83 kg for shepard formula. Spearman correlation was carried out to predict Formulae in significant correlation with log 10 actual birth weight. Actual birth weight has a significant positive correlation with vintzileos and hadlock IV Formulae. Linear regression analysis was conducted between actual body weight and Formulae results for prediction of accurate birth weight. Vitzileos and hadlock IV results were significantly associated with accurate birth weight. **Conclusions:** Vintzileos and Hadlock IV formulae were found to be significantly associated with accurate birth weight, while Warsof formula showed overestimation.

Keywords: Ultrasound, Formulae, Accurate Estimation, Fetal Weight.

1. Introduction

The assessment of fetal weight is essential for obstetric treatment, as it provides vital information for evaluating fetal development and directing clinical decision-making. Due to its non-invasive nature and availability in clinical settings, ultrasound-based fetal weight assessment has become a popular technique. Sonographic formulas derived from biometric measures gathered during ultrasound exams are often used to estimate fetal weight [1]. However, the accuracy of various formulas might vary, emphasizing the necessity to compare and choose the most accurate model for estimating the fetal weight at term [2].

The assessment of fetal weight is clinically essential because it permits the diagnosis of aberrant fetal development patterns, such as intrauterine growth restriction (IUGR) or macrosomia, which might have consequences for postnatal outcomes [3]. In addition, accurate fetal weight assessment is vital for directing obstetric procedures, such as establishing the ideal delivery time and method and predicting newborn outcomes. Consequently, it is crucial to assure the precision and dependability of fetal weight estimate techniques [4].

Numerous sonographic formulas for determining fetal weight have been developed; however, the accuracy of these formulas varies among research. These disparities may be attributable to variables like differences in research populations, variations in biometric measures used, and inconsistencies in formula creation processes [5, 6]. Therefore, a complete analysis of multiple formulas is required to discover the formula that consistently yields the best accurate fetal weight estimations.

This study aimed to compare the accuracy of 7 different sonographic formulae in estimation of fetal weight at term to show the most accurate formula and obtain the most effective fetal parameter.

2. Methods

This comparative cross-sectional study included 120 pregnant women without chronic diseases who were at term pregnancy (37-40 weeks) and within one day prior to delivery. The study took place at Benha University Hospital between July 2022 and November 2022, following approval from the institutional ethical committee. Written informed consent was obtained from all participants after explaining the study and its potential consequences in a comprehensible manner.

The inclusion criteria for this study were as follows: the presence of a single viable fetus, gestational age between 37 and 40 weeks, elective caesarean section delivery, and maternal age between 20 and 40 years. Exclusion criteria encompassed multiple pregnancies, stillbirth and intrauterine fetal death (IUFD), preterm labor, intrauterine growth restriction (IUGR), hydrops fetalis, and congenital malformations.

All patients underwent caesarean section delivery, and the gestational age was determined based on the last regular menstrual period (LRMP), confirmed by an early dating scan if available. The following assessments were performed on both patients and a control group: **Full history taking (**Personal history, including maternal age. Obstetric history, including gravidity and parity, Pregnancy-induced hypertension, Previous operative delivery, Any associated complaints during the current pregnancy. Menstrual history, including the last menstrual period. Maternal medical history, including hypertension and coagulopathies). **Examination**: General examination, including vital signs such as blood pressure, pulse, and temperature. Chest and heart examination. Abdominal examination to assess gestational age, fetal weight, amount of amniotic fluid, and detect fetal lie, presentation, fetal heart sounds, uterine contractions, and previous surgical scars. **Laboratory investigations:** Routine laboratory investigations, including CBC, liver functions, kidney functions, and prothrombin time (PT) and prothrombin concentration (PC). **Ultrasonic study:** Fetal weight estimation using various formulae, including Warsof (AC), Hadlock I (AC, FL), Hadlock II (AC, HC, FL), Hadlock III (AC, BPD, FL), Hadlock IV (AC, BPD, HC, FL), Shepard (AC, BPD), and Vintzileos (BPD, HC, AC, FL, TC) [7, 8].

Fetuses with congenital anomalies, multiple pregnancies, stillbirth, IUGR, IUFD, hydrops fetalis, and those with inadequate ultrasound images were excluded from the study. The biometric measurements, including BPD, HC, AC, FL, and TC, were performed by a highly trained obstetric specialist. The actual birth weights were recorded after delivery, and a comparison was made with the estimated fetal weights obtained from the sonographic formulae.

All examinations were performed using the same ultrasound machine (Mindray DP-2200) and a 3.5 MHz abdominal probe. The measurements of BPD, HC, AC, FL, and TC were recorded in centimeters, and the fetal weight was recorded in grams. The accuracy of the formulae was assessed by comparing the estimated fetal weights with the actual birth weights.

Sample size:

The sample size was determined using the Computer Program for Epidemiologist (PEPI), version 3.01, employing the formula: Sample size (n) = $(P(1-P)Z^2)/d$, Two-tailed level of significance = 0.055, Power chosen = 80, Difference between means = 0.1 kg, Standard deviation in population A = 0.361, Standard deviation in population B = 0.058, Common correlation coefficient value = 0.817. The sample size obtained was 106. However, 120 consecutive patients were considered for increasing the power of the study.

Statistical analysis:

The collected data was analyzed using the Statistical Package for Social Science (IBM Corp., Version 25.0). Descriptive statistics, such as mean and standard deviation for normally distributed numerical data, and median and range for non-normally distributed numerical data, were calculated. Frequency and percentage were used for non-numerical data. The normality of data distribution was assessed using the Shapiro-Wilk test. Analytical statistics included the one-way ANOVA test to assess differences between group means, the Kruskal-Wallis test for non-parametric variables, and the chi-square test to examine relationships between qualitative variables. Correlation analysis was conducted to assess the strength of association between quantitative variables. The receiver operating characteristic (ROC) curve was used to evaluate the sensitivity and specificity of diagnostic measures, with the optimum cut-off point determined by maximizing the area under the curve (AUC). Logistic regression analysis was employed for predicting risk factors, with odds ratios (OR) used to measure the association between exposure and outcome. Statistical significance was considered at a p-value < 0.05 with a 95% confidence interval.

3. Results

This study was carried out on 120 at term pregnant women. Their mean age was 30.16 years. According to parity, 26.6% of subjects were primigravida while 73.4% were multi gravida. Mean maternal BMI was 28.58 kg/m^2. Mean gestational age ranged from 37 to 40 weeks. Fetal gender was 60.8% males and 39.2% females. **Table 1**

Table (1) Demographic criteria and obstetric history of the studied subjects

	Total subjects n=120
Maternal age, years	
M±SD	30.16±6.37
Range	20-40
Parity, n (%)	
Primigravida	32(26.6%)
Multi gravida	88(73.4%)
Maternal BMI, kg/m^2	
M±SD	28.58±4.03
Range	23-37.64
Gestational age	
M±SD	37.5±0.83
Range	37-40
Fetal gender, n (%)	
Male	73(60.8%)
Female	47(39.2%)

A number of sonographic parameters were obtained to predict actual fetal weight. Mean BPD was 9.01 cm, FL 7.08 cm, HC 32.27cm, AC 31.85 and TC 15.98 cm. **Figure 1**

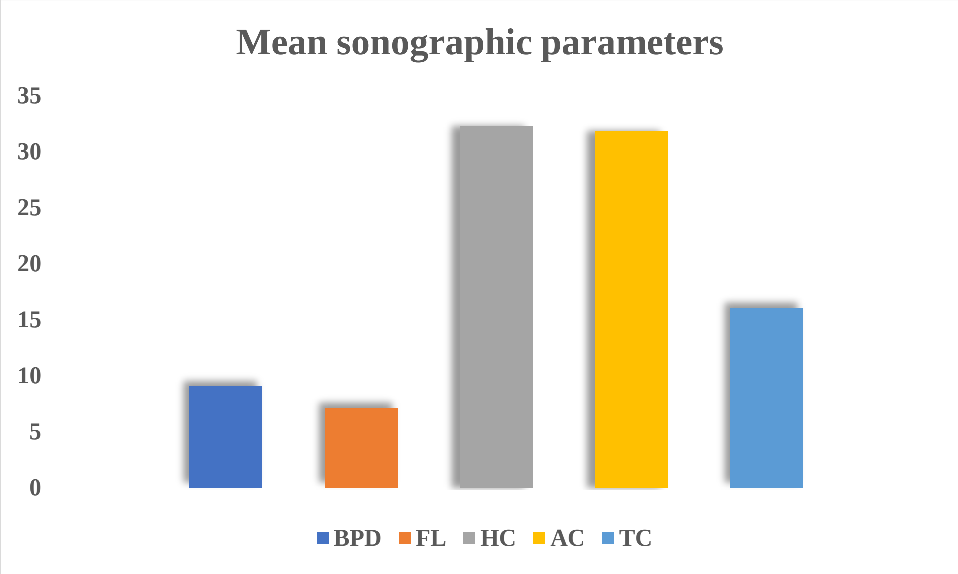

Fig.(1) Mean sonographic parameters to predict actual fetus weight.

Actual birth weight mean value at time of delivery was 3.16 kg. Mean levels of predicted weights using Formulae was 3.46 kg for warsof, 3.01 kg for vintzileos, 2.85 kg for hadlock I, 2.81 for hadlock II, 2.83 kg for hadlock III, 2.96 kg for hadlock IV and 2.83 kg for shepard formula. **Figure2**

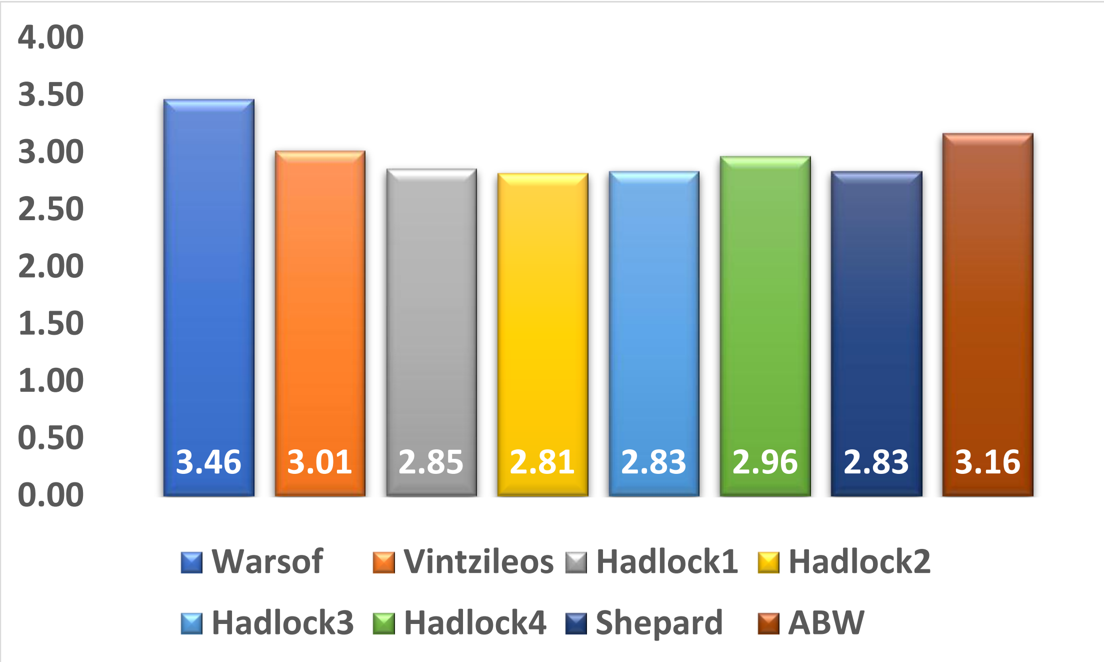

Fig.(2) Box plot of mean predicted weights calculated using given Formulae compared to ABW

Mean differences and mean percentage between actual birth weight and Formulae predicted weight were calculated to determine the amount of error, Formulae with overestimation and under estimation. Warsof formula showed over estimation by 4.86%. The rest of Formulae showed underestimation. **Table 2**

Table (2) Mean differences between actual birth weight and Formulae predicted weight

	Total subjects n=120	
	Mean difference, kg ±SD	**Mean percentage error, % ±SD**
Warsof (AC)	0.3±0.28	-0.02±0.02
Vintzileos (BPD,HC,AC,FL,TC)	0.15±0.25	-0.002±0.02
Hadlock I (AC, FL)	0.31±0.26	-0.03±0.02
Hadlock II (AC, HC, FL)	0.35±0.16	-0.04±0.01
Hadlock III (AC, BPD, and FL)	0.33±0.04	-0.02±0.004
Hadlock IV (AC, BPD, HC and FL)	0.2±0.36	-0.05±0.03
Shepard (AC, BPD)	0.33±0.26	-0.01±0.02

Spearman correlation was carried out to predict Formulae in significant correlation with log 10 actual birth weight. Actual birth weight has a significant positive correlation with vintzileos and hadlock IV Formulae. **Table 3**

Table (3) Correlation analysis between Formulae and log10 of actual birth weight

	r	p
Warsof	0.636	0.993
Vintzileos	0.289**	<0.001*
Hadlock II	0.128	0.164
Hadlock IV	0.229*	0.012*
Hadlock I	0.212	0.254
Shepard	0.122	0.185
Hadlock III	0.154	0.093

Linear regression analysis was conducted between actual body weight and Formulae results for prediction of accurate birth weight. Vitzileos and hadlock IV results were significantly associated with accurate birth weight. **Table**

Table (4) Regression analysis between log 10 ABW and Formulae

	OR	SE	t	p	95% CI for B
Warsof	0.138	0.231	0.598	0.551	-0.318-0.594
Vintzileos	0.376	0.130	2.901	0.004*	0.119-0.633
HadlockII	0.300	0.235	1.278	0.204	-0.164-0.764
Hadlock4	0.502	0.222	2.258	0.026*	0.061-0.942
Hadlock1	0.496	0.237	2.091	0.245	0.526-0.964
Shepard	0.280	0.206	1.356	0.178	-0.128-0.688
hadlock3	0.373	0.242	1.540	0.126	-0.106-0.852

4. Discussion

In this study, the demographic and obstetric history of the studied subjects were investigated to evaluate the accuracy of different sonographic formulae for estimating fetal weight at term. The mean age of the participants was 30.16 years, which is consistent with the mean maternal age reported in other studies [2, 9]. The majority of the participants were multigravida, which is in agreement with the fact that the risk of fetal macrosomia increases with maternal age and previous pregnancies [10].

The mean maternal BMI in this study was 28.58 kg/m2, which is in the overweight range. Maternal obesity is a known risk factor for fetal macrosomia and can also affect the accuracy of fetal weight estimation by ultrasound [11, 12]. Therefore, it is important to consider maternal BMI when interpreting the results of fetal weight estimation.

The mean gestational age in this study ranged from 37 to 40 weeks. Fetal weight estimation becomes more accurate as gestational age advances, especially after 28 weeks of gestation [2]. Therefore, the wide range of gestational age in this study may have affected the accuracy of fetal weight estimation.

In terms of fetal gender, the majority of fetuses were male (60.8%). Some studies have reported that male fetuses are more likely to be larger than female fetuses [13, 14]. Therefore, fetal gender may also influence the accuracy of fetal weight estimation.

The mean BPD in this study was 9.01 cm, which is within the normal range for gestational age [15]. The FL and HC measures were likewise within the normal range, however the AC and TC measurements were slightly over the gestational age-predicted values. These data may indicate fetal macrosomia, a recognized risk factor for severe newborn outcomes [16].

Numerous research have investigated the correlation between demographic and obstetric variables and fetal biometric measures. **Rubini et al. (2022)** discovered that maternal age, parity, and BMI were substantially related to fetal biometry parameters including BPD, HC, AC, and FL. According to the research, older age, more parity, and greater BMI were related with bigger fetal biometric measures [17].

Another research conducted by **Poprzeczny et al. (2018)** with 912 pregnant women revealed similar results. According to the research, maternal age, parity, and BMI were significant predictors of fetal biometry parameters such as BPD, HC, AC, and FL. The research also discovered a significant correlation between gestational age and fetal biometry measures, with bigger readings recorded in later stages of pregnancy [18].

Regarding the demographic characteristics and obstetric history of pregnant women, a number of research have shown comparable results. For example, a study conducted in Turkey by **Guven et al. (2018)** on 1000 pregnant women reported that the mean age of the participants was 29.8 years, while the mean gestational age was 28.3 weeks. The study also found that the majority of the participants were multiparous (70.6%) and that the mean BMI was 24.8 kg/m2 ***(Guven et al., 2018)***.

Regarding fetal biometry parameters, the current study found that the mean BPD, FL, HC, AC, and TC were within the range reported in other studies. A study conducted in India by **Sharma et al. (2018)** on 400 pregnant women reported a mean BPD of 9.08 cm, FL of 6.96 cm, HC of 32.31 cm, AC of 30.9 cm, and TC of 15.57 cm ***(Sharma et al., 2018)***.

Another study by **Al-Jabri et al. (2018)** on 202 pregnant women in Oman reported a mean BPD of 9.23 cm, FL of 7.09 cm, HC of 32.2 cm, AC of 32.2 cm, and TC of 16.09 cm ***(Al-Jabri et al., 2018)***.

In the current work, actual birth weight mean value at time of delivery was 3.16 kg. Mean levels of predicted weights using Formulae was 3.46 kg for warsof, 3.01 kg for vintzileos, 2.85 kg for hadlock I, 2.81 for hadlock II, 2.83 kg for hadlock III, 2.96 kg for hadlock IV and 2.83 kg for shepard formula.

In the present study the mean differences and mean percentage between actual birth weight and Formulae predicted weight were calculated to determine the amount of error, Formulae with overestimation and under estimation. Warsof formula showed over estimation by 4.86%. The rest of Formulae showed underestimation.

Several studies have been conducted to compare different sonographic formulae for accurate estimation of fetal weight. A study by **Mohamed et al. (2021)** compared five commonly used formulae and found that the Hadlock III formula had the highest accuracy in predicting birth weight [19].

Another study by **Warshafsky et al. (2021)** compared six formulae and found that the Hadlock III formula was the most accurate, followed by the Hadlock II and III formulas [20]. In a study by **Konwar et al. (2021)**, five formulae were compared, and it was found that the Hadlock III formula had the highest accuracy and the least error [6].

In a study by **Eze et al. (2015)**, eight different formulae were compared, and it was found that the Warsof formula had the highest accuracy, followed by the Hadlock III formula [8]. However, in the present study, the Warsof formula showed overestimation, which is not consistent with the results of **Eze et al. (2015)**. It is worth noting that the present study included a smaller sample size and only included women at term pregnancy, which may have contributed to the different results.

The use of different formulae for fetal weight estimation can have clinical implications, especially in cases where accurate estimation is crucial, such as in cases of fetal macrosomia or growth restriction. **Milner and Arezina et al. (2018)** determined in a systematic study that the Hadlock III formula is the most accurate and consistent method for calculating fetal weight [5]. In contrast, **Sereke et al. (2021)** discovered that the Warsof formula had the best accuracy in predicting birth weight, with a 5.1% margin of error [21].

Konwar et al. (2021) examined four different sonographic formulas for fetal weight estimates in the Indian population. The study included 100 pregnant women between 28 and 42 weeks of gestation. The authors reported that the Hadlock I formula was the most accurate with a mean percentage error of 5.57%. The authors concluded that there is a need for developing population-specific formulae for accurate estimation of fetal weight [6].

Another study by **Lee et al.** compared six different sonographic formulae for the estimation of fetal weight. The authors reported that the Hadlock I formula was the most accurate with a mean percentage error of 5.8%. The authors also reported that the Warsof formula showed the highest overestimation of fetal weight [22].

Spearman correlation was carried out to predict Formulae in significant correlation with log 10 actual birth weight. Actual birth weight has a significant positive correlation with vintzileos and hadlock IV Formulae.

Linear regression analysis was conducted between actual body weight and Formulae results for prediction of accurate birth weight. Vitzileos and hadlock IV results were significantly associated with accurate birth weight.

The finding of a significant positive correlation between actual birth weight and Vintzileos and Hadlock IV Formulae in the present study is consistent with the results of several previous studies. A study conducted by **Nyberg et al. (1987)** reported that the Hadlock IV formula was the most accurate formula for predicting fetal weight, with a correlation coefficient of 0.83 [23]. Similarly, a study by **Parvathavarthini et al. (2018)**

found that the Hadlock IV formula had the highest correlation coefficient with actual birth weight compared to other formulas [24]. Another study by **Malin et al. (2016)** reported that the Hadlock IV formula had the highest sensitivity and specificity for predicting macrosomia [25].

The use of linear regression analysis to determine the accuracy of fetal weight estimation using different formulae has also been investigated in previous studies. In a study by **Savitz et al. (2003)**, the authors reported that the Hadlock formula had the highest correlation coefficient with actual birth weight and was the most accurate formula for predicting fetal weight [26]. In addition, **Kang et al. (2021)** determined that the Vintzileos formula was the most precise formula for forecasting fetal weight in late pregnancy using linear regression analysis [27].

5. Conclusion

Based on our findings, Vintzileos and Hadlock IV formulae were found to be significantly associated with accurate birth weight, while Warsof formula showed overestimation. These findings suggest that Vintzileos and Hadlock IV formulae may be more reliable for estimating fetal weight at term, and their use may improve obstetric outcomes.

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