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RESEARCH ARTICLE

A comparative study of fetal weight estimation using Johnson's formula and ultrasound and their correlation with actual birth weight

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ABSTRACT

Objectives: This study was aimed to compare and correlate the accurate estimation of foetal weight (EFW) obtained by clinical method (cEFW) and ultrasonographically (uEFW) with actual birth weight (ABW). **Methods:** This hospital based prospective comparative study was done in a tertiary care teaching hospital situated in South India, from January 2017 to December 2019 on 200 antenatal pregnant women with singleton pregnancy. **Results:** The mean maternal age was 23.74±3.60 years. Most of the women (43%) belonged class 3 socio economic strata. The mean BMI was 23.34±3.29 Kg/m^2. LSCS was more common than (60.50%) vaginal delivery (37.50%). The mean cEFW was 2997.30±420.06 gm, uEFW was 2768.91±412.01 gm and ABW was 2765.05±412.89 gm ($p<0.001$). The kappa agreement between ABW and uEFW was 0.532 with SE of 0.048 and it was 0.022 with 5.688 for cEFW respectively. The mean percentage difference between cEFW and uEFW with ABW (9.43±14.26 and 0.45± 8.15; $p<0.001$) was statistically significant. There was significant strong positive correlation between ABW and uEFW ($\rho=0.836$; $R^2=0.728$; $p<0.001$) as well as cEFW ($\rho=0.641$; $R^2=0.4082$; $p<0.001$). **Conclusion:** Clinical estimation of birth weight being simple and cost effective definitely has a role in the management of labour and delivery but the ultrasound derived EFW seems to be more valid and accurate than clinical method as it is highly reproducible.

Keywords: Estimated fetal weight, Hadlock's formula, Johnson's formula, symphysio-fundal height.

Birth weight of an infant is an important determinant of the newborn health as well as survival.[1] Both low and excessive fetal weights at delivery are associated with an increased risk of newborn complications during labour and puerperium. It is recommended that newborn babies with birth weight less than 2500 grams may be considered to fall in low birth weight categories and are prone to develop recurrent infection, malnutrition, diabetes, hypertension and neuro developmental handicaps in their later life.[2] On the other hand, fetal macrosomia[3] is associated with more maternal and fetal complications at the time of birth.[4, 5] Hence accurate estimation of fetal weight is necessary before decision of delivery is made. Birth weight cannot be measured until delivery, therefore, accurate estimation of fetal weight (EFW) in utero is a vital and universal part of antenatal care (ANC) that provides an improved prospective management of high risk pregnancies thereby reducing perinatal morbidity and mortality.[1, 6]

Various methods for fetal weight estimation include clinical, radiological, ultrasonography (USG) and magnetic resonance imaging (MRI). Clinical methods of EFW include tactile assessment of fetal size by abdominal palpation, e.g. Leopold's manoeuvre, maternal self-estimation especially in the literate society and in multiparous women, prediction of birth weight equations by (i) Dare's formula (ii) Insler and Bernstein's formula (iii) Dawn's formula and (iv) Johnson's formula for estimation of fetal weight in vertex presentation.[7, 8] Imaging methods are USG,[9] radiography and

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MRI.[10] Sonographic examination done for determination of fetal parameters, fetal wellbeing and was also found useful for estimation of fetal weight and location of placenta .The fetal dimensions that have been studied are biparietal diameter (BPD), head circumference (HC) abdominal circumference (AC) and femur length (FL) and they are measured in centimetres on sonography machine to calculate fetal weight in grams.[11,12] Radiography is now abandoned because of its hazards to both fetus and the mother. Fetal weight estimation by MRI may be recommended for clinical situation where accurate estimation is essential but is limited by lack of availability and it is expensive.[13]

Thus, the two important methods for predicting birth weight in current day obstetric practice are clinical and ultrasonographic methods.[14] Ultrasound is preferred because of its ease of use, objectivity and precision, at the same time several technical limitations of the sonographic technique for estimating foetal weight are well known. Among these are maternal obesity, oligohydramnios, and anterior placentation. It also requires costly sonographic equipment and specially trained personnel. Although such expensive imaging equipment is widely available in developed countries, this is generally not the case in developing nations like ours where medical resources are scarce.[15]

Despite of various methods being available for the determination of EFW, all currently available techniques for estimating foetal weight have significant degree of inaccuracy. Further, potential complications associated with birth of both small and excessively large foetuses prompt to accurate estimation of EFW prior to delivery, [15] making it an important part of ANC in identifying the high risk population. The present study was planned to compare and correlate the EFW obtained by clinical method by Johnson's formula and ultrasonographically by Hadlock's formula with actual birth weight.

Methodology

This hospital based prospective comparative study was undertaken in the department of obstetrics and gynaecology of a tertiary care teaching hospital situated in South India, from January 2017 to December 2019. A total of 200 antenatal pregnant women with singleton vertex presentation, gestational age between 37 to 40 weeks and in early labour, from all socioeconomic classes, with medical disorders complicating pregnancy were enrolled. Pregnant women with history of irregular menstrual cycles and those who were not willing to participate in the study were excluded. The ethical clearance was obtained from the institutional ethics committee prior to the commencement.

The eligible pregnant women were briefed about the nature of the study and a written informed consent was obtained. An interviewer based, pilot tested questionnaire was administered to each patient which included information about age, socio-economic status according to Kuppuswamy index,[16] parity and body mass index (BMI). Detailed obstetric and menstrual history was taken. Significant antenatal history such as history of antepartum haemorrhage, hypertensive disorders, diabetes mellitus, cardiac disease, anaemia and tuberculosis were noted. The period of gestation was calculated according to Naegele's rules.[17] After general physical examination, careful obstetric examination was done in supine position after emptying of bladder and with hips semi flexed to determine the presentation and position of the foetus. Position of the fetal heart sound was noted. Vaginal examination was done to determine the dilatation and effacement of the cervix, presentation and position of the foetus and station. Symphysio-fundal height measurement was taken in supine position with knee and hip semi flexed along the longitudinal axis of uterus with a measuring tape from upper border of pubic symphysis along the curvature of gravid uterus up to the fundus where the height of the fundus is defined by the gentle pressure exerted by the ulnar border of the left hand in a plane right angle to the abdominal wall, dextrorotation if present was corrected beforehand. Measurements were taken during uterine relaxation, if patient was in labour ward. Clinical estimation of EFW was done by Johnson's formula.[18, 19]

Johnson's formula:

Foetal weight (in grams) = (SFH – n) X 155

SFH = Symphysio-fundal height in centimetres

n= 12 if vertex is above or at the level of ischial spines,

n= 11 if vertex is below the level of ischial spines.

All women were subjected to ultrasonography using real time ultrasound scanner linear probe 4MHz. The fetal dimensions studied were BPD, HC, AC and FL which were obtained in centimetres. Estimation of EFW based on USG was done by using Hadlock's formula which yields foetal weight in grams.[11, 20]

Hadlock's formula:

Log 10 EFW (grams) = 1.3596 – 0.00386(AC x FL) + 0.0064 (HC) + 0.00061(BPD x AC) + 0.0425 (AC) + 0.174 (FL).

After birth, the actual birth weight was measured using a standardized digital neonatal weighing machine approved by

ISI. The estimated fetal weight by Johnson's formula[18, 19] and USG were compared with the actual birth weight.

Statistical analysis: The data obtained was coded and entered into Microsoft excel worksheet. The data were analysed using statistical software SPSS version 20.0. Continuous variables were presented as mean ± standard deviation (SD) and analyzed for normality by the Shapiro-Wilk test. Categorical data was expressed in terms of numbers and percentages. The agreement between actual birth weight with EFW was done by kappa statistics. The comparison of actual birth weight (ABW), with EFW by clinical method (cEFW) and EFW by USG method (uEFW) was done by Friedman's two-way analysis of variance. The percentage difference for ABW, cEFW and uEFW were compared using paired sample t-test and Wilcoxon rank signed test. The correlation between ABW, cEFW and uEFW was determined by Spearman's correlation coefficient. All tests were two tailed and a p-value of less than 0.05 was considered significant.

Results

In the present study the age of the mothers ranged from 18 to 39 years. The mean and median maternal age was 23.74±3.60 and 23.00 (IQR 3.00) years. Out of 200 women, 55% of the women were aged between 21 to 25 years. Anaemia was the common association medical complication (49%). With regard to obstetric history, 37.50% of the women belonged to gravida 2. The BMI of the mothers ranged from 16.70 to 34.20 kg/m^2. The mean and median BMI was 23.34±3.29 and 23.90 (IQR 2.58) Kg/m^2, 74% of the women had BMI between 18.50 to 24.90 Kg/m^2. Previous LSCS was the common obstetric complication (57.85%). Out of 200, 121 women (60.50%) underwent LSCS and 75 (37.50%) had vaginal delivery. Of the 121 women who underwent LSCS, 83 (68.60%) had elective LSCS and 38 women (31.40%) had emergency LSCS. Among the 75 women who underwent vaginal delivery 49 (65.33%) had spontaneous vaginal delivery and 26 (34.67%) women underwent induction of labour (table 1).

With regard to neonatal outcome, 72% and 81% of the neonates had Apgar score of ≥7 at one minute and five minutes, 57.50% of the neonates were boys with boy to girl ratio of 1.35:1. Out of 200, 22 (11%) of the neonates were admitted in NICU due to neonatal jaundice.

Table 1: Baseline, clinical, maternal and fetal data

Parameters	Findings	Distribution (n=200)	
		Number	Percentage
Maternal age in years	≤20	31	15.50
	21 to 25	110	55.00
	26 to 30	45	22.50
	31 to 35	11	5.50
	> 35	3	1.50
Socio -economic class	I	17	8.50
	II	43	21.50
	III	86	43.00
	IV	19	9.50
	V	35	17.50
Gravida	1	66	33.00
	2	75	37.50
	3	43	21.50
	4	10	5.00
	5	5	2.50
	6	1	0.50
Body Mass Index	Underweight (<18.5 Kg/m^2)	7	3.50
	Normal weight (<18.5 to 24.90 Kg/m^2)	148	74.00
	Over weight (<25.00 to 29.99 Kg/m^2)	32	16.00
	Obese (>30.00 Kg/m^2)	13	6.50
Mode of delivery	Vaginal	75	37.5
	LSCS	121	60.5
	Instrumental	4	2
Vaginal delivery	Spontaneous FTVD	49	65.33
	Induced FTVD	26	34.67
LSCS	Emergency	38	31.40
	Elective	83	68.60
NICU admission	Neonatal jaundice	22	11.00
	Respiratory distress syndrome	11	5.50
	Low birth weight	9	4.50
	Neonatal sepsis	2	1.00
	Meconium aspiration syndrome	2	1.00
	Not required	154	77.00
Birth weight in grams	1500 - 2000	5	2.50
	2001-2500	61	30.50
	2501-3000	87	43.50
	3001-3500	40	20.00
	>3500	7	3.50

FTVD – Full term vaginal delivery, NICU – Neonatal intensive care unit

The EFW based on clinical examination ranged from 2015 to 4805 gms with mean and median weight of 2997.30±420.06 gms and 3100 gms (IQR 465.00) respectively, and most of the neonates had EFW between 3001 to 3500 gms (41%) (table 2). Similarly, EFW based on USG ranged from 1614 to 3725 gms with mean and median weight of 2768.91±412.01 gms and 2792.50 gms (IQR 577.75) respectively, and most of the neonates had EFW between 2501 to 3000 gms (42%). Further, the ABW ranged from 1500 to 3810 gms with mean and median ABW of 2765.05±412.89 gms and 2750 gms (IQR 500.00) respectively, and most of the neonates had ABW between 2501 to 3000 gms (43.50%). The difference between ABW, uEFW and cEFW was statistically significant (p<0.001). The kappa agreement between ABW and uEFW was 0.532 with

Table 2: Maternal and fetal clinical profile

Parameters	Mean (n=200)		Median	IQR	Range		*p value
	Mean	SD			Min	Max	
Maternal age (years)	23.74	3.60	23.00	3.00	18.00	39.00	<0.001
Body mass Index (Kg/m2)	24.34	3.29	23.90	2.58	16.70	34.20	<0.001
Symphysio fundal height (cms)	31.26	2.81	31.50	3.00	24.00	43.00	<0.001
EFW by Johnsons formula(gms)	2997.30	420.06	3100.00	465.00	2015.00	4805.00	<0.001
EFW by USG (gms)	2768.91	412.01	2792.50	577.75	1614.00	3725.00	0.279
Actual birth weight (gms)	2765.05	412.89	2750.00	500.00	1500.00	3810.00	0.227
Difference in ABW and cEFW	232.25	353.99	160.00	435.00	-540.00	1670.00	<0.001
% Difference in ABW and cEFW	9.43	14.26	5.54	17.28	-17.88	70.76	<0.001
Difference in ABW and uEFW	3.86	223.32	10.00	248.75	-771.00	636.00	<0.001
% Difference in ABW and uEFW	0.45	8.15	0.38	9.63	-22.03	24.52	0.022

ABW - Actual birth weight, cEFW - Estimated fetal weight by clinical method, uEFW - Estimated fetal weight by ultrasound method.
*p value for normality of data by Shapiro Wilk test; p value for the comparison of ABW, cEFW and uEFW by Friedman's two way analysis of variance by ranks.

standard error (SE) of 0.048 and it was 0.022 with 5.688 for cEFW respectively (table 3 and 4).

Table 3: Agreement between actual birth weight and EFW

Weight (gms)	Actual (n=200)		USG FW (n=200)			Clinical EFW (n=200)		
	No	%	No.	%	Diff.	No.	%	Diff.
1500 - 2000	5	2.50	8	4.00	-3	0	0.00	5
2001-2500	61	30.50	48	24.00	13	29	14.50	32
2501-3000	87	43.50	84	42.00	3	70	35.00	17
3001-3500	40	20.00	53	26.50	-13	82	41.00	-42
>3500	7	3.50	7	3.50	0	19	9.50	-12
Overall difference	-	-	-	-	32	-	-	108
Kappa agreement			0.535; SE=0.048			0.022; SE=5.688		

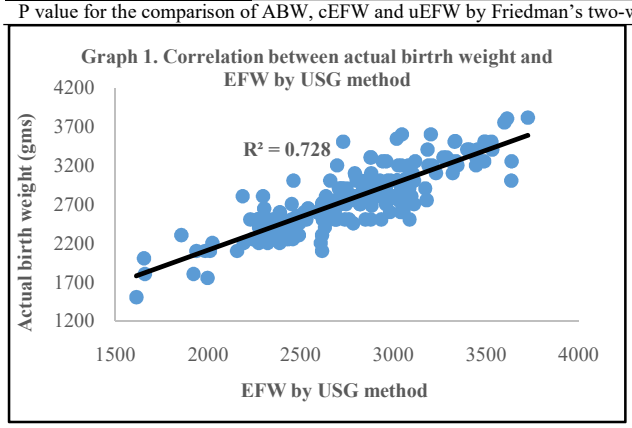
Diff - Difference in number of babies with respect to actual birth weight

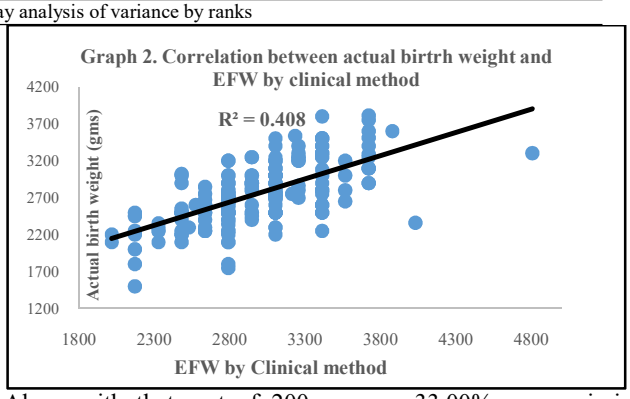
The mean and median percentage difference between cEFW and uEFW with ABW (9.43±14.26 vs 0.45± 8.15; p<0.001) (5.54 [IQR 17.28] vs 0.38 [IQR 9.63]; p<0.001) was statistically significant (table 5). There was significant strong positive correlation between ABW and uEFW (graph 1) and significant moderate positive correlation was noted between ABW and cEFW (graph 2).

Table 4: Comparison of EFW and actual birth weight

Categories	Birth weight by different methods (gms)		Median	IQR	Range	
	Mean	SD			Min	Max
EFW by Johnsons formula	2997.30	420.06	3100.00	465.00	2015.00	4805.00
EFW by USG	2768.91	412.01	2792.50	577.75	1614.00	3725.00
Actual birth weight	2765.05	412.89	2750.00	500.00	1500.00	3810.00
P value	<0.001					

P value for the comparison of ABW, cEFW and uEFW by Friedman's two-way analysis of variance by ranks





Discussion

The salient finding from the present study was that it showed both clinical and ultrasound method of estimation of EFW is within 10% of the actual birth weight but ultrasound method estimating EFW is highly accurate as the mean and median difference in EFW and ABW was less than 1% with strong correlation (ρ=0.836; R^2=0.7283; p<0.001) and moderate agreement (Kappa=0.535; SE= 0.048). In the present study, majority of the women (77.50%) were in the age group of 21 - 30 years, which was comparable to studies done by Bajaj P et al [21], Muralisree M et al [22] and Sowjanya R et al [23] and Raghuvanshi T et al [24]. Along with that, out of 200 women, 33.00% were primi gravida and 67% were multigravidas. Similar results were reported in a study by Muralisree M et al [22].

Estimating fetal weight is very important in obese women due to the increased risk of diabetes, macrosomia, shoulder dystocia, and perioperative complications from caesarean delivery. According to study done by Preyer O et al [25] and Lanowski JS et al [26], maternal body mass index (BMI) has been shown to affect the accuracy of estimated fetal weight, especially the measurement deviation is greater in pregnant women with a BMI ≥ 25. In the present study, majority of women (74.00%) had normal BMI, as there was a mixed population belonging to both rural and urban areas, who belonged to better socioeconomic strata.

In our study, majority of the women underwent LSCS (60.50%) and 39.50% were delivered vaginally suggesting higher rate of caesarean section. These observations were consistent with a study done by Muralisree M et al[22]. However, the higher rate of caesarean section noted in the present study may be explained by the fact that since, ours is a tertiary care centre with an emergency obstetrics unit where maximum pregnant women are referred with high-risk pregnancies and severe comorbid conditions like associated obstetric and medical complications and in some circumstances, it is imperative to terminate pregnancy immediately by emergency caesarean section so as to decrease mortality in such women.

There are significant differences in the intrauterine growth pattern between male and female foetuses.[27,28] Earlier, fetal sex was found to be the strongest predictor of accurate sonographic estimation, so the likelihood of a weight estimation within 10% of birth weight was 30% higher for male foetuses compared with female foetuses.[29] However this was not the case in the present study as although slightly more number of neonates were boys (57.50%) as compared girls (42.50%) the difference was very small.

In India, average birth weight of babies is 2500 to 3000 gms.[21] In the present study, neonates were distributed as per the birth weight into five groups. Birth weight range of 2500-3000 gms had maximum distribution (43.5%) of babies as compared to other groups, as majority of women had obstetric and medical complications that do not affect birth weight of babies like mild anaemia, hypothyroidism, pyrexia, epilepsy, bronchial asthma except few conditions that would affect birth weight like severe hypertension, oligohydramnios and maternal diabetes. The common birth weight range noted in the present study that is 2500 to 2500 gms (43.5%) was comparable to the other studies by Meena K and Jain D et al[30] (46%), Bajaj P et al [21] (46.5%), and Sowjanya R et al [23] (48%).

In the present study, EFW by ultrasound method not only correlates well with ABW but it has also moderate agreement with ABW with minimum mean and median difference in ABW [3.86±223.32 gm and 10 (IQR 248.75) gm respectively] as well as percentage difference that is 0.45±8.15 gm and 0.38 (IQR 9.63) percent respectively. Although, EFW it slightly over predicted among the neonates with ABW between1500 to 2000 gms (1.50%) and among those with ABW 3001 to 3500 gms (6.50%). EFW is underpredicted among the neonates with ABW from 2100 to 2500 gms (6.50%) and among those with 2501 to 3000 gms (1.50%). However, 100% agreement was noted between EFW and ABW among the neonates with ABW of > 3500 gms. The overall difference of ABW and EFW by USG was noted in 32 neonates that is 16.00%.

On the other hand, although EFW by clinical method correlated well with ABW it showed poor agreement with ABW with maximum mean and median difference in ABW [232.25±353.99 gm and 160 (IQR 435.00) gm respectively] as well as percentage difference that is 9.43±14.26 gm and 5.54 (IQR 17.28) percent respectively. Further it completely under predicted EFW among the neonates with ABW from 1500 to 2000 gms (2.5%). Also among the neonates with ABW from 2001 to 2500 gms, cEFW under predicted 32 (16.00%) neonates and in those with ABW from 2501 to 3000 gms in 8.50% of neonates. At the same time, it over predicted the EFW among the neonates with ABW from 3001 to 3500 gms (21%) and among those with ABW > 3500 gms (6.00%). The overall difference of ABW and EFW by clinical method noted among 108 neonates is 54.00%.

The correlation coefficients for the clinical and ultrasonic methods in this study showed significant moderate (+0.641) and strong (+0.836) correlation respectively with actual birth weight and both correlated positively. These observations were similar to the results by Njoku C et al [31] where authors reported clinical and ultrasonic methods of EFW compared to actual birth weight, as +0.740 and +0.847, respectively, and both correlated positively with the actual birth weight. The study by Njoku C et al [31] showed that the mean errors for both clinical and ultrasound methods were 299±338 gm and -101±189 gm. The mean percentage errors for clinical and ultrasound methods were 9.20±10.44 gm and -3.10±9.67 gm % respectively. The mean absolute percentage errors of both clinical and ultrasound methods were 11.16±9.48 gm and 9.04±7.61 gm, respectively and the mean absolute percentage error was lower in ultrasound method though the difference was not statistically significant. Thus, the

ultrasound method is more sensitive to the changes in the ABW than the clinical method.

Another important observation from the present study was that the USG estimation of EFW was accurate within birth weight range of 2500 gm to 3000 gm and among those with ABW > 3500 gm. Apart from that, it slightly over predicted the EFW among the neonates with Low birth weight (<2000 gm) which prompts a high suspicion of perinatal morbidity and mortality to the obstetrician and allows timely awareness as well as preparedness for further uneventful consequences.

In this study, error difference up to 200 gm was estimated in 46.5% of women with Johnson's formula, whereas 69.5% of women with ultrasound, this was comparable to the study done by Sowjanya R et al[23] which estimated error difference of 48% with Johnsons formula and 59% with ultrasound. According to the present study, ultrasound did not have significant error in estimating fetal weight when there was error up to 500gm. Ultrasound estimated error > 500 gm in only 5% women, when compared to Johnson's formula where error estimated was 22%. The finding is comparable to the study done by Sowjanya R et al[23] which estimated error >500 gm in only 6% women with ultrasound, whereas Johnson's formula estimated the same in 11%. Hence ultrasound estimation is more accurate when errors are lesser than 500 gm when compared with clinical method.

In the present study the total number of women with no error in fetal weight estimation was more in USG method and over estimation was lesser in USG method than Johnson's formula. These results are comparable to the studies done by Aruna S et al [32] and Joshi A et al [33]. According to their studies, when the tendency to overestimate or underestimate the fetal weight was considered, Johnson's formula had a tendency to overestimate the fetal weight.

Among term singleton cephalic pregnancies studied, fetal weight estimation using Johnson's formula is comparable to ultrasound estimates for predicting the actual birth weight within 10%. This study also revealed that there was no significant difference found between the mean weight obtained through clinical and ultrasound assessments and actual birth weight. Clinical estimation of foetal weight is good enough for screening of the birth weight as it has higher sensitivity and negative predictive value than the ultrasonic estimation, while specificity and positive predictive value of ultrasonic estimation were higher than clinical estimation. Thus, keeping in view that the clinical procedure by Johnson's method is easy to perform, it can be included in routine training of medical personnel.

According to the findings of this study Johnson's formula had a tendency to overestimate foetal weight when it was above 3000 gm. We regard the overestimation of fetal weight by the clinical method, as a positive factor since it will enhance the sensitivity of health workers at peripheral centres if properly taught to them for earlier referral of mothers with macrosomic foetuses, thus contributing to reduction of obstructed labour and its sequelae.

Fetal weight estimation requires expensive sonographic equipment and specially trained personnel, expertise and its availability is difficult in developing nations like India. Therefore, development and validation of simple, inexpensive, accurate and effective clinical methods are important and relevant even to this date. Using the estimates within 10% of the actual birth weight, it is concluded that overall, ultrasound fetal weight estimation, has higher accuracy than the clinical estimation. It is therefore recommended that the ultrasound method should be used in estimating the birth weight whenever accessible. However, the clinical method should remain a valuable alternative where ultrasound is unavailable and also for screening as it also has strong correlation with the actual birth weight. The subjectivity of the clinical estimation, use of only one sonographic model to derive estimates of foetal weight was the potential limitations of this study. But as multiple foetal parameters were considered in Hadlock's formula these errors in result would have minimised as observed by Njoku C et al in their study.[31]

Conclusion

Antenatal fetal weight can be estimated with reasonable accuracy based on clinical method by Johnson's formula as well as by ultrasound with Hadlock's formula. Johnson's formula is a quick, easy, simple, accurate, reliable and cost-effective method for estimating the foetal weight but is limited by poor agreement with ABW. Ultrasonography method of estimation is superior but it is expensive and expertise is needed. Hence, clinical method of predicting fetal weight is of great value in screening the patients for possible abnormalities in foetal weight, whereas the ultrasound derived EFW seems to be more valid and accurate.

Conflict of interest: None. **Disclaimer:** Nil.

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