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# Role of fetal thigh circumference in estimating fetal birth weight

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## Abstract

**Background:** Various methods are available to estimate in utero weight to judge fetal wellbeing but we are still in search of most accurate one.

**Objective**: To study the importance, usefulness and accuracy of the fetal thigh circumference in predicting the actual fetal birth weight by ultrasound and to compare it with other conventional methods like Hadlock's and Johnson's.

**Material And Methods:** In 161 pregnant women of gestational age between 34-41 weeks, ultrasonographic measurement of mid- thigh circumference, along with Biparietal diameter (BPD), Femur length (FL), Head circumference (HC) and Abdominal circumference (AC) were measured using standard techniques. Fetalweights were estimated within 48 hours before delivery of the fetus and compared with actual weight at birth. Statistical analysis of various ultrasound birth weight formulae in different weight categories was done and compared with each other, and also with the clinical method.

**Results:** Mean of actual birth weight is 2.91 kg which is different from the mean of EFW by Vintzileos i.e. 2.57 kg and Johnson's i.e. 3.73 kg whereas it is quiet similar to the mean of Hadlock's formula i.e. 3.12 kg. Correlation between EFW by Vintzileos' formula and the actual birth weight is 0.701 and that of Hadlock and Johnson's is 0.713 and 0.955 respectively.

**Conclusion:** Hadlock's formula is more accurate in predicting the actual birth weight than the Vintzileos' formula. Although, due to stronger correlation with birth weight thigh circumference can be used as an alternative parameter to biparietal diameter for birth weight estimation at or near term when fetal head position down to pelvic bone and it becomes difficult to measure biparietal diameter.

**Keywords:** BPD, FL, HC, AC.

## Introduction

Knowledge of the weight of fetus and its development in utero is important for the obstetrician to decide upon the optimum time for delivery of the fetus and also to decide on the mode of delivery.[1]

EFW is a very important tool for identifying and managing both small fetuses (BW ≤ 2500 g) and enormous fetuses (BW ≥ 4000 g).

A fetus with growth restriction is at increased risk of hypoxia and perinatal death, and a new born with Low birth weight carry greater risk of neonatal morbidity and mortality with substandard growth and development in later life. They are prone to develop asphyxia, hypothermia, pulmonary syndrome, cerebral haemorrhage, fetal shock, heart failure, oliguria, anuria, infection, dehydration and academia, anaemia and retinopathy of prematurity.

These low birth and growth retarded neonates are prone to develop malnutrition, recurrent infection and neurodevelopmental handicaps, Diabetes, Hypertension and Coronary heart disease in later life.

On the other hand a macrocosmic fetus is associated with an increased risk of prolonged labour, shoulder dystocia, higher incidence of caesarean section, fetal injury and maternal complications.[2]Macrosomic fetuses are more prone to birth injuries like brachial plexus injuries, fracture of clavicle and metabolic complications like hypoglycaemia, electrolyte imbalance and neonatal jaundice. Whenever induction of labor is planned it is a standard practice to take into account estimated fetal birth weight to decide the time and mode of delivery. In this quest various methods have been studied from time to time to find out accurate method like clinical and ultrasound method.[3]

**Clinical methods** include models incorporating height of the uterus and girth of the abdomen measured at the level of umbilicus. Worldwide this method is used extensively because it is both convenient and virtually costless. But they are subjected to significant margin of error and are not useful in malpresentations, maternal obesity, multifetal pregnancy, Polyhydramnios and oligohydramnios.[4-5]Among term pregnancies with weight range of 2500-4000 gm, clinical palpation method is considered to be better among all with the accuracy of ±7.5-19.8%.[6-7]

**Vintzileos et al** reported that the model incorporating five parameters viz. HC, BPD, AC, FL, and TC; gave the needful results in predicting the fetal weight actually seen post-delivery within ± 5% in 54% of the cases, and within ± 10% in 80.3% of the cases.

**Hoffbauer and co-worker** were among the primary to incorporate the fetal thigh diameter with in a weight formula. They draw the conclusion that circumference measurements of fetal thigh might be made in a reliable manner and may be used to detect changes in the soft tissue mass and hence can improve fetal weight estimation.[8]

We will carry out this study to see whether the addition of fetal thigh circumference improves the accuracy in predicting of the birth weight or not, as compared to more commonly used Hadlock's method and the clinical palpation method to prevent complications of low birth weight.

## Materials and Methods

It is a cross sectional prospective observational study of 161 patients done at the tertiary referral unit in the Department of Obstetrics and Gynecology and Radio diagnosis, Mahatma Gandhi Medical College and Hospital, Jaipur, Rajasthan from January 2019- June 2020.

Ethical committee clearance was taken for the study; post which all women were examined with the history taking with emphasis on the maternal age, parity, gestational age, obstetric, menstrual and past histories including height, weight, cardiovascular and respiratory system. Per abdominal followed by the pelvic examination was done if needed.

The inclusion criteria was all the singleton pregnancy between 34-41 weeks of gestational age confirmed retrospectively by the recorded crown-rump length(CRL) before 12 weeks of gestation with the high risk pregnancy who were ready for the follow up and were willing to give the consent.

The exclusion criteria included:

- Patient in labor
- Multiple pregnancies
- Pregnancy with <34 weeks gestation
- Patient with congenital anomalies in fetus
- Fetal demise (IUFD), and
- Patients not willing to give consent and not ready for the follow up.

Following parameters were taken by ultrasonography within 24 hrs of the delivery in all pregnant women:

- Biparietal diameter,
- Abdominal circumference,
- Femur length, and
- Thigh circumference.

The ultrasound machine used was- Siemens Acuson 300 premium ultrasound machine (using 5 MHZ convex transducer) and GE Voluson S6 ultrasound machine.

Birth weights were estimated using Hadlock's, Vintzileos', and Johnson's equation.

**Measurement of thigh circumference**

Patient was placed in supine position and a 2D ultrasonographic examination was performed with Siemens Acuson 300 premium ultrasound machine using 5 MHZ convex transducer and GE Voluson S6 ultrasound machine. After measuring all the parameters the Thigh circumference (TC) was taken using caliper on screen. To measure TC whole length of femur from greater trochanter to the distal metaphysis was visualized on the monitor. Transducer was then rotated by 90 degree to obtain a cross sectional profile of the middle of the thigh at a position that the thigh profile was as round as possible and the boundary of the thigh profile was well defined.

**Results**

Out of 161 patients examined, 59.62 % were Nulli Para, 30.43 % were second Para, and 9.93 % were multi Para.

Twenty eight neonates weighed less than 2500 grams, seventy seven between 2501-3000 grams, forty four between 3001-3500 grams; twelve weighed more than 3500 grams.

The age of patients ranged between 19-35 years, and the mean age of patients were 25.78±3.30.

Among them 68.94 % were from urban class with the average birth weight of 2.95 kg and 31.05 % were from rural class with the average birth weight of 2.82 kg.

Hundred and eight (67.08 %) were booked patients with the mean birth weight of 2.96 kg, and fifty three (32.91 %) were unbooked patients with the mean birth weight of 2.82 kg.

Hindu and other religion comprised of 151 patients (93.78 %) with the mean birth weight of 2.90 kg, and Muslims comprised of 10 patients (6.21%) with the mean birth weight of 2.82 kg.

Total delivered comprised of 79 male children (49.06 %) with mean birth weight of 3.02 kg and 82 comprised

of female children (50.93%) with the mean birth weight of 2.81 kg.

The patients landing up in LSCS were 83 (51.55 %) with the average birth weight of 2.88 kg, and those delivered vaginally were 78 (48.44%) with the average birth weight of 2.94 kg.

Formula table for calculation of estimated birth weights

| Methods | Parameters | Formulae |
|---|---|---|
| Johnson R.W(1957) | SFH | BW=(SFH-K)*155<br>K=13( fetal head at minus station)<br>K=12 ( fetal head at zero station)<br>K=11( fetal head at plus station) |
| Hadlock et al(1985) | BPD,AC and FL | Log 10 weight=1.3596-0.00386 AC*FL+0.0064 HC+0.00061 BPD*AC+0.0424 AC+0.714 FL |
| Vintzileos et al(1987) | BP,AC,FL and TC | Log13 (birth weight) = 1.897 + 0.015 * AC + 0.057 * BPD + 0.054 * FL + 0.011 * TC. |

Table1: Demonstrates the mean birth weight predicted by Hadlock was closest to actual birth weight. Hadlock's method also produced a lower mean residual than Vintzileos' and Johnson's. The mean absolute error and mean absolute percentage error were lowest with Hadlock's method and significantly better than Vintzileos' and Johnson's method.

Table 1: Comparison of fetal weight estimation formulae

| Method | Mean (g) | Mean Residual (g) | Mean absolute error (g) | Mean absolute percentage error (%) | Mean Deviation | Mean deviation (%) |
|---|---|---|---|---|---|---|
| Hadlock | 3121 | -206 | 293 | 6.60 | 0.331224 | 64.100 |
| Vintzileos' | 2576 | 339 | 385 | 13.16 | 0.215021 | 53.055 |
| Johnson's | 3739 | -824 | 826 | 22.04 | 0.194789 | 68.952 |

Table 2: Shows the mean, standard deviation and standard error mean by pairing the actual birth weight with EFW by Hadlock's formula, with EFW by Vintzileos' formula and with EFW by Johnson's formula. Mean of actual birth weight is 2915 ± 0.418904 which is different from the mean of EFW by Vintzileos i.e. 2576 ± 0.373013 whereas it is closer to mean of Hadlock's formula i.e. 3121 ± 0.410761.standard error mean of EFW by Hadlock's formula is 0.0324 which is almost same to actual birth weight's standard error mean i.e. 0.0330 whereas standard error mean of EFW Vintzileos' formula is 0.0294 and of Johnson's is 0.0189.

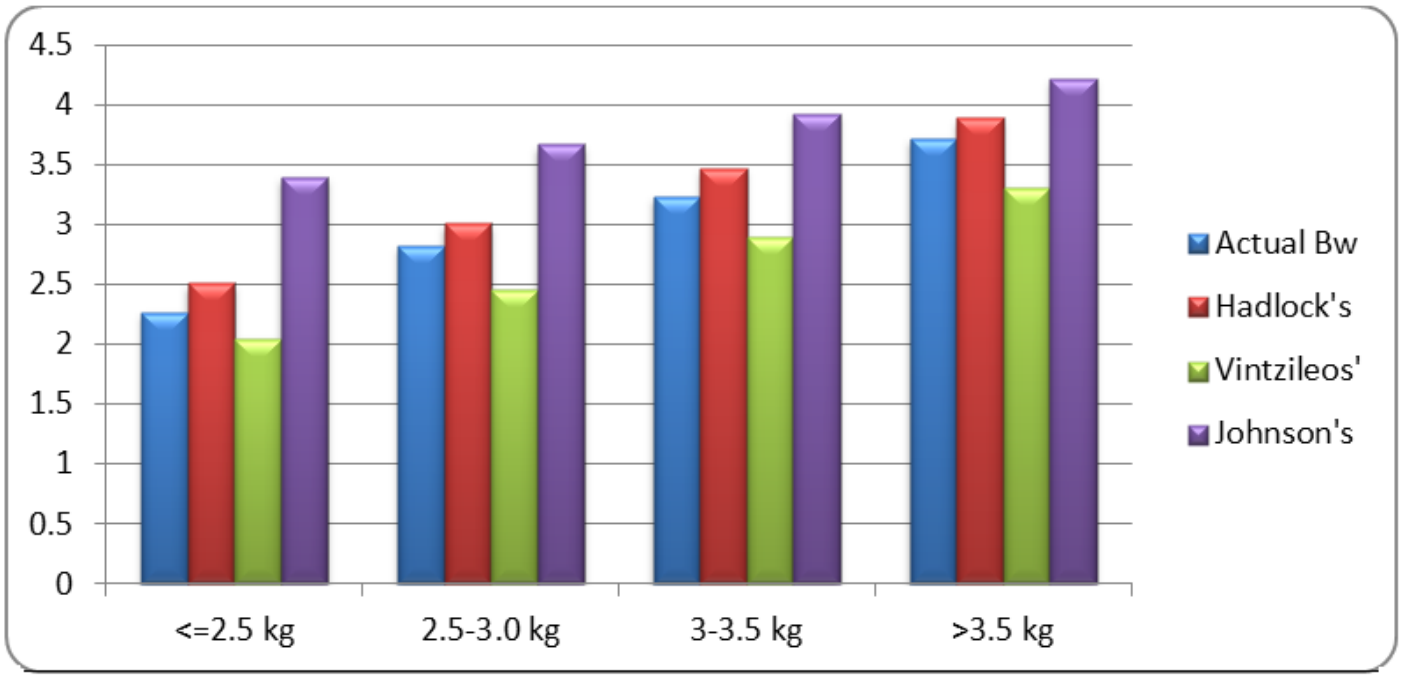
| Table 2 : Paired Samples Statistics | | | | |
|---|---|---|---|---|
| Method | Mean | N | Standard Deviation | Standard Error Mean |
| Actual birth weight | 2915 | 161 | 0.418904 | 0.0330 |
| Hadlock's | 3121 | 161 | 0.410761 | 0.0324 |
| Vintzileos' | 2576 | 161 | 0.373013 | 0.0294 |
| Johnson's | 3739 | 161 | 0.240415 | 0.0189 |

Table 3: Gives the report of EFW by Hadlock's formula, EFW by Vintzileos' formula, Johnson's formula and actual birth weight birth weight including their mean, standard deviation, minimum, maximum, and median values.

| Table 3: Report | | | | |
|---|---|---|---|---|
| | EFW by Hadlock | EFW by Vintzileos' | EFW by Johnson's | Actual birth weight |
| Mean | 3.121 | 2.576 | 3.739 | 2.915 |
| N | 161 | 161 | 161 | 161 |
| Standard Deviation | 0.410761 | 0.373013 | 0.240415 | 0.418904 |
| Minimum | 2.230 | 1.778 | 3.250 | 1.900 |
| Maximum | 4.430 | 3.695 | 4.340 | 4.050 |
| Median | 3.095 | 2.523 | 3.720 | 3.000 |

| Table 4: Comparative analysis of birth weights in different weight groups | | | | | |
|---|---|---|---|---|---|
| Method | ≤2500 | 2501-3000 | 3001-3500 | >3500 | Overall |
| | N=28 | N=77 | N=44 | N=12 | N=161 |
| Actual birth weight | 2277 | 2832 | 3246 | 3724 | 2915 |
| Hadlock's | 2517 | 3016 | 3477 | 3898 | 3121 |
| Vintzileos | 2052 | 2466 | 2899 | 3318 | 2576 |
| Johnson's | 3409 | 3673 | 3935 | 4220 | 3739 |

Table 4 and 5: shows the actual birth weight in comparison with the predicted birth weight in different weight categories.




Pictorial representation of the comparative analysis of the birth weight in different weight categories.

In category 1st (≤2500 gm, N=28)

The mean Birth weight of actual birth weight was 2.27 kg, with Hadlock's method was 2.51 kg; whereas Vintzileos' was 2.05 kg and Johnson's was 3.4 kg.

The mean of difference from actual birth weight of Vintzileos' was better as compared to the Hadlock's and Johnson's i.e. ± 225.

Although Hadlock's was comparable with the actual birth weight and Vintzileos'; Johnson's was of very less appreciable.

Hence, we can say in SGA Vintzileos method is a much better option in predicting estimated birth weight.

In category 2nd (2501-3000 gm , N=77)

The mean birth weight of actual birth weight was 2.83 kg in this category. Hadlock's method was 3.01 kg, Vintzileos' was 2.46 kg and Johnson's was 3.67 kg.

The mean of difference from the actual birth weight in Hadlock's category was ± 184; which was much better than Vintzileos and Johnson's i.e. ± 366 and ± 841 respectively.

So, we concluded that in category 2nd with maximum sample size Hadlock's method gives better results as compared to Vintzileos' and Johnson's method.

Similarly, in category 3rd (3001-3500 gm , N=44)

The mean birth weight with actual birth weight was 3.24 kg, with Hadlock's method was 3.47 kg, with Vintzileos' was 2.89 kg and with Johnson's was 3.93 kg.

The mean of difference from actual birth weight was lowest in Hadlock's method i.e. ± 231.

Other both methods were incomparable.

So we can say alike in category 2nd, in category 3rd too Hadlock's method came out to be better.

In category 4th (>3500 gm, N=12)

The mean birth weight with actual birth weight was 3.72 kg, Hadlock's method was 3.89 kg, Vintzileos' was 3.3 kg and Johnson's was 4.22 kg.

The mean of difference from actual birth weight in Hadlock's method was very low i.e. ± 174 and highly incomparable to Vintzileos' ± 406 and Johnson's ± 496.

Hence, here too Hadlock's method proved to be much more relevant as compared to other two methods.

| Table 5: Mean of difference from actual birth weights in different weight categories | | | | | | |
|---|---|---|---|---|---|---|
| Method | ≤ 2500 gms | 2501-3000 gms | 3001-3500 gms | >3500 gms | $X^2$ | P-value |
| Hadlock | ±240 | ±184 | ±231 | ±174 | 8.199 | 0.953 |
| Vintzileos' | ±225 | ±366 | ±347 | ±406 | 10.835 | 0.923 |
| Johnson's | ±1132 | ±841 | ±689 | ±496 | 48.692 | 0.816 |

Table 5: From chi square analysis, it was found that mean birth weight predicted by Hadlock's method was most non-significant from the actual birth weight (X2 =8.199, p= 0.953).

Table 6: Paired samples correlations

| | | N | Correlation |
|---|---|---|---|
| Pair 1 | EFW Hadlock and Actual birth weight | 161 | 0.713 |
| Pair 2 | EFW Vintzileos and Actual birth weight | 161 | 0.701 |
| Pair 3 | EFW Johnsons and Actual birth weight | 161 | 0.955 |

**Discussion**

The fetal biometery is essential in the current era to assess fetal growth abnormalities, fetal growth restriction, big baby and ultimately survival of the fetus.

Estimation of birth weight has great significance in detecting the growth restriction, prematurity and the state when clinical decision involving induction of labor or deciding the mode of delivery is to be taken.[9]

Estimating fetal weight is a controversial subject for which various regression equations through studies like Liang et al(1997), Lee et al(2006), Lindel et al(2009), Bennini et al(2010), Yang et al(2011) are used. [10-14]

We most commonly use Hadlock with parameters – BPD, FL, AC, and HC.[15-18]

Vintzileos et al generated an alternative equation for the fetal birth weight estimation using the thigh circumference as an added parameter to Hadlock's equation.[19-21, 2]

**Krishna Dahiya et. al (2010)**[2] stated that mean absolute percentage error is being highest with Johnson's and lowest with Vintzileos' formula.

Through Vintzileos' method, mean absolute error of 167 gm, the coefficient of correlation was 0.954, and mean absolute percentage error 5.8%.

With Hadlock's method, mean absolute error of 237 gm, coefficient of correlation was 0.872, and mean absolute error percentage 8.3%.

With Johnson's method, mean absolute error of 563 gm, coefficient of correlation was 0.739, and mean absolute percentage error 20.7%.

In our study the coefficient of correlation was 0.701, mean absolute error of 385 gm, and the mean absolute percentage error of 13.16 % with Vintzileos'; With Hadlock's method coefficient of correlation was 0.713; mean absolute error 293 gm, and the mean absolute error percentage 6.60 % (lowest).

With Johnson's method coefficient of correlation was 0.955, mean absolute error 826, and the mean absolute percentage error 22.04 %( highest).

They concluded that incorporating the fetal thigh circumference measurement along with BPD, FL, and AC significantly improves the accuracy of the birth weight estimation by the ultrasound; except in category >3500 gms, where it was comparable to Johnson's and Hadlock's method.

This finding was in complete discordance with the results of our study. We concluded Hadlock to be more accurate in estimating the birth weight by ultrasonography except in ≤2500 gms category where Vintzileos' proved to be much more efficient.

This discrepancy might be due to the low sample size of the study taken by Krishna Dahiya et. al compared to us and the interobserver variability for HC and AC measurements, which increases with the gestation due to the fetal position, reduced liquor, or fetal breathing movements that makes obtaining correct ultrasound measurement planes difficult. [22]

**Song et. al (2002)** [23]said that during the third trimester of pregnancy the three- dimensional ultrasound is a better option for predicting the fetal weight.[24]

The result of this study was in alignment with our study; indicating that the fetal thigh circumference measurements can add further to the accuracy of birth weight estimation in obstetric practice, especially in babies of <2.5 kg with 88.5 % predictability. They said that IUGR results in decreased muscle and fat proportion of the fetus. In such cases, diameter measurement of thigh circumference is less sensitive to change and has better potential for estimating fetal weight. [25-26]

**Shripad Hebbar et al (2005)** [3]conducted a study comprising 110 patients to check the efficiency of the fetal thigh circumference in birth weight estimation by ultrasonography. They had 55 % primigravidae and 45% multigravidae. Whereas, in our conducted study of 161 patients 59.62 % primipara, 30.43 % as second Para, and 9.93 % multipara.

Comparative analysis of **Shripad Hebbar et al** study proved Vintzileos' to be a better method up to 3500 gms, however it was comparable to Hadlock's, Johnson's and Insler's in weight group >3500 gms.

In our study, Vintzileos' method was statistically significant in ≤2500 gms weight group and was comparable in >3500 gms group with Johnson's. But the best among all the methods was Hadlock's method in all weight groups except in ≤2500 gms.

In their study, compared to the other three methods Vintzileos' produced the least mean difference from the actual birth weight. It was found from chi square analysis, that the birth weight predicted by Vintzileos' model was not significantly different from the actual birth weight($x^2$=2.7, p=0.26), although difference was significant in birth weight prediction in other three methods. (Insler, p=0.002, Johnson, p=0.003, Hadlock, p=0.04).

Whereas in our study, the least difference from the actual birth weight was seen in Hadlock's method as compared to other two methods.

From chi square analysis, it was very much evident that Hadlock's method ($x^2$=8.199, p=0.953) is a better option for the prediction of EFW among all other model. (Vintzileos, p=0.923, Johnson, p=0.816).

There is a disparity between Shripad Hebbar et. al and our result. They concluded that the birth weight prediction with the thigh circumference measurement increases the accuracy when combined along with BPD, HC, AC, and FL measurements. We on other hand, states thigh circumference importance in SGA

fetus (<=2500 gms). In rest of all, Hadlock has a better use.

The reason for this disparity may be due to the low sample size taken by them as compared to us.

Another reason for this may be due to the interobserver error in estimation of the fetal birth weight a week prior to the delivery through ultrasonography and measurement error of the TC at the correct plane. We on other hand kept this window short i.e. within 48 hrs before the delivery.

But, Shripad Hebbar et. al study says that the birth weight estimation is increased with fetal thigh circumference especially in babies of <2.5 kg with 95% predictability; which goes hand in hand with our study.

**Maryam Tahira et. al (2019)** [27]did a cross sectional analytical study involving 238 patients to correlate the fetal thigh circumference at 36-40 weeks ultrasonographically with the birth weight.

They stated that fetal birth weight by Hadlock's method was more relatable to actual birth weight, for which they calculated mean of actual birth weight to be 3.3424±0.42374 comparable to mean of Hadlock's formula i.e. 3.3199+-0.35452. Whereas, by Vintzileos' method mean of EFW i.e. 3.4504+-0.08968 was widely different from the mean of actual birth weight.

However, when they calculated correlation between EFW by Vintzileos' and the actual birth weight, it was 0.319; much more significant when compared to Hadlock's formula i.e. 0.300.

So they concluded due to stronger correlation between Vintzileos' method and the actual birth weight; the fetal thigh circumference can be used as an alternative parameter to BPD.

Alike them, we have also proved Hadlock's method to be more preciseful in estimating fetal birth weight as compared to Vintzileos' method. For the same we calculated the mean of the actual birth weight was 2.915±0.418904 resembling to the mean of Hadlock's formula i.e. 3.121+-0.410761. It was although widely different from the mean of EFW by Vintzileos' i.e. 2.576±0.373013.

The correlation between the EFW by Hadlock's formula and the actual birth weight i.e. 0.713 much more significant than correlation between the EFW by Vintzileos' formula and the actual birth weight i.e. 0.701.

**Conclusion**

We observed that the importance of Vintzileos in SGA fetuses. Fetal growth aberrations , such as IUGR , are associated with the changes in the soft tissue mass, errors of which is decreased with Vintzileos' method as the thigh circumference is preferred over diameter measurement as it is less sensitive to changes in the shape.

We conclude Hadlock's formula is more efficient in predicting the actual birth weight than the Vintzileos' formula. But, correlation and p value of Vintzileos' formula (i.e. 0.701 and 0.923 respectively) is significantly comparable to Hadlock's formula (i.e. 0.713 and 0.953 respectively). Hence, at or near term; when BPD becomes difficult to measure because of the fetal head position to pelvic bone, as an alternative parameter to BPD the thigh circumference can be used for estimating the birth weight. Also in brachycephalic or dolicocephalic, BPD measurements would overestimate or underestimate the gestational age and fetal weight estimation will be hampered.

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