Can the anterior-posterior thigh diameter be used as an indicator for fetal age using two-dimensional sonography?

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Abstract: This study evaluates the usefulness and direct correlation of a new method of predicting fetal age by the measurement of the anterior-posterior thigh diameter (APTD) in normal 18 to 28 week pregnancies using two-dimensional sonography. Little published research exists in the area of fetal thigh biometry, specifically in the use of the APTD. The only study the author found was that of fetal thigh circumference. Continuing review of existing practices needs to be coupled with evaluation of alternate or additional methodology.
Material and methods: This was a quantitative prospective study of 55 patients in a hospital in Alberta, Canada. APTDs were sonographically measured. The normal range for each week of pregnancy was determined for reliability.
Results: Significant correlation was found between the APTD and fetal age from simple line regression analysis, with 99.9% confidence intervals at each week from 18 to 28 weeks gestation. There was a correlation of 1 mm APTD per one week of fetal age. In addition R >0.93, P< than 0.001. The residual scatter plots confirmed the APTD validity.
Conclusion: APTD is a reliable and valid method for assessing fetal age in a normal pregnancy and may be particularly useful when other parameters are unable to accurately predict fetal age. An accurate linear measurement of multiple fetal parameters allows a more complete profile of fetal growth and estimated date of delivery. APTD may also be useful in identifying fetal growth problems. All of the values of fetal age lie directly on the best-fit regression line. Since the coefficient of determination (Rsq) is very high, this model is very effective.
Keywords: APTD, parameters, weight estimation, biometry.

Introduction

There is no existing literature regarding fetal thigh diameter *versus* fetal age and estimated date of delivery. There are many parameters that can be used in sonography, including biparietal diameter (BPD), abdominal circumference (AC), head circumference (HC), and femur length (FL). It is important to find a new parameter to measure fetal growth that correlates with fetal age so that fetuses that are not growing well can be identified and treated [1]. Multiple factors may influence the fetal biometry including, for example, pathology factors that affect the fetal head meauserments [1]. Fetal organ sizes remain small during early pregnancy, followed by a period of rapid growth and the rate and time vary for individual organs [2]. Studies have shown that this period of growth can be affected by external and internal factors [3, 4]. The reason for choosing the second trimester for this study is that it is more convenient to the patient and provides an excellent window to the fetal thigh.

The reliability of multiple parameters

Studies have supported the use of multiple parameters to improve the accuracy of fetal age and weight estimation [5]. Studies have provided a logical explanation for the necessity to measure the fetal leg. It is suggested that at times measuring the fetal head is impossible, such as when it is too low in the pelvic cavity and therefore alternate methods must be used [6]. Formula of FL multiplied by the square root of the cross sectional area of thigh has shown a significant correlation with fetal weight [6]. The validity of estimated fetal weight is reported to be either below or above the normal limits by using fetal biometry formulae [7].

Multiple measurement formulae of fetal weight show more accuracy than single measurement [8]. Fetal thigh calf circumference ratios show excellent results in evaluating fetal growth in high-risk patients with unknown due dates [9 ,10,11]. Using more than one fetal biometry can increase the reliability and accuracy in determining fetal age and estimated date of delivery especially in using long bone biometry from 12 to 40 weeks gestation [12,13]. The limb volume has been found to be a reliable predictor of intrauterine growth restriction [14]. FL is a reliable measurement but it can be affected by skeletal dysplasias [14].

Fetal pathology and biometry

With the use of fetal measurements, wide ranges of pathological conditions can be demonstrated, among these are chromosomal abnormalities, such as trisomy 21, and fetal nasal pathology [15]. The ratio of femur to foot length has proven a useful parameter in assessing dysplastic limb reduction and fetal growth [16, 17, 18,21]. Studies by Goldstein *et al* show that there is significant correlation between FL and orbital diameter (OD); this may aid in future research regarding fetal orbital abnormalities [19]. The fetal kidney length, between 24 to 38 weeks gestation, is a more accurate fetal biometry than biparietal diameter and head circumference [20]. A combination of more than one parameter should be used to increase the reliability, sensitivity, and accuracy of fetal biometry.

Fetal macrosomia can be predicted by using single ultrasonic biometry [21, 22]. Gestational diabetes mellitus can affect the fetal weight [23]. Accurate measurement of fetal age is the most useful contribution sonography has made to obstetric practice [24]. Up to now the crown rump length (CRL), BPD, and FL have been considered the measurements of choice [25, 26]. However as all of these measurements were acquired before 1985 and, in some cases before electronic calipers were available, there is a need to update these procedures by using new sonographic equipment in determining fetal age.

Limitations

Before a new parameter can be used it must be shown to correlate with fetal age in normal pregnancies. Some fetal positions can reduce the ability to measure specific areas of the fetal body; for example, in the occipital anterior or occipital posterior position it will not be possible to obtain a BPD. Serial measurements of BPD and/or head circumference alone are of no value because of the 'brain sparing' effect [27, 28,29].

The reliability of the ratio of head circumference to abdominal circumference to predict intrauterine growth restriction is limited [26, 27]. There are situations, for example, pre-term labour, diabetes, breech presentation, or previous caesarean section, when it is important for the attending physician to have a single estimate of the fetal size or weight at one point in time. Gestational diabetes mellitus can be associated with high birth weight thus can affect overall fetal measurements [23, 28,29]. Head measurements can be used as genetic markers for frontal lobe hypoplasia [30].

Material and method

Fifty-five uncomplicated pregnancies were studied prospectively and quantitatively at the High Level General Hospital (North-Western Health

Centre), High Level, Alberta, Canada, between 21 March 2005 and 10 May 2005. This study was approved by the Ethics Committee of Charles Sturt University, Australia.

The participants were chosen by randomized selection of normal pregnancies. All participants had an early (first trimester) sonogram at 12 week gestation to confirm the accuracy of the gestational age.

The author performed the study and compiled comparable data and tables with the Hadlock *et al* tables for FL [31, 32]. The growth of the APTD, outer to outer skin surface, was sonographically measured at the middle point of the fetal femur in the sagital section and compared with the fetal age from 18 to 28 weeks gestation. The second trimester period was chosen because soft tissue accretion of the fetal thigh begins to accelerate towards the end of this period.

The inclusion criteria for this study were: singleton uncomplicated pregnancies with a normal fetus, and an informed consent form, read and signed by the participants and approved by the hospital and Charles Sturt University Ethics Committee.

The participants' ages ranged between 18 and 35 years, with a mean age of 26.5. The study population was of different ethnic groups in Alberta, Canada, for example, Germans, natives Indians, Mennonites, Irish, Hispanics, Ukrainians and east Indians.

Radiologists reported major congenital malformations, chromosomal abnormalities, and maternal complications. The author did not release any pathology information to the participants as they were informed to obtain their reports from their physicians.

Routine transabdominal sonography was performed, including FL, BPD, AC, and head circumference (HC). In addition, the author measured the fetal APTD, from the middle point of the fetal femur in the sagittal section of the fetal thigh using the femur length as a landmark. The APTD measurements were analyzed and compared with fetal age using Hadlock *et al* tables for femur length [31, 32].

Equipment used in this study was ATL 5000 and Philips Alegra 4500 (Bothell, WA). With 5 to 3 MHz transducers the fetal age was determined by using measurements of the FL [31, 32].

A comparison was made between the APTD and the fetal age. The diameter of the fetal thigh was measured in the same portion of fetal thigh every time by measuring the mid-point of the femur. Eleven groups were studied. Each group comprised five participants who were all in the same pregnancy period, namely from 18 to 28 weeks.

Protocol used in this study

Starting with transducer at the fetal abdominal circumference.

1. Transducer was moved inferiorly to transect the fetal bladder.
2. Transducer was rotated 30 degrees to view the fetal femur.
3. Transducer was rotated until a sagittal view of the fetal thigh was obtained (Figure 1).
4. Distal femoral epiphyses which are usually present after 32 weeks gestation were excluded.
5. The fetal knee was identified.
6. In cases when a double line was seen in the fetal thigh the inner line was measured or the scan was repeated until a smooth (sagittal) line of the fetal thigh was obtained (Figure 2). Note that this double line can be corrected by obtaining a perfect sagittal view of the fetal thigh. Otherwise the curve of the thigh adds extra false line to the real outer skin surface of the fetal thigh in the lateral or medial section. The thigh is convex in the anterior part and concave in the posterior part so geometrically we are dealing with a cylinder and not a flat surface.
7. Real-time sonographic equipment was used with 3.0, 3.5, and 5.0 MHz transducers frequencies to obtain the images. Note that posterior shadowing from the femur bone is limited and will not affect the over all measurements.
8. Freeze-frame and electronic calipers were used as they are more sensitive tools to provide accurate measurements of the fetal thigh.
9. Zoom capability was used to outline the fetal thigh, namely the outer skin surface which allowed the author to see the skin surface better therefore the chances of errors were reduced.
10. Hadlock *et al* table for FL [31, 32] was used to compare with APTD

Measurements

The FL of the fetus was scanned in each of the pregnant participants as a sagittal view (Figures 1 and 2).

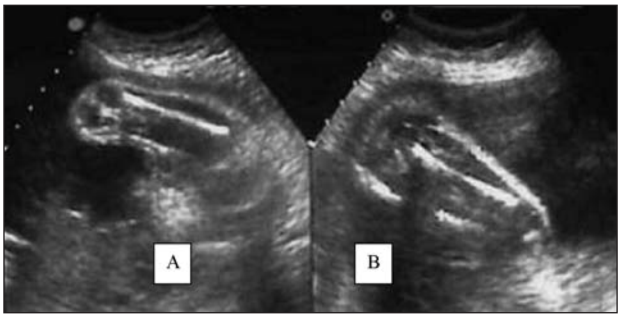


Figure 1. Label A is showing the wrong way to measure fetal thigh (coronal) and Label B is showing the correct way to measure the anterior-posterior thigh diameter (APTD) in sagittal plane (profile).

Figure 2. The white arrow is showing the double line of the fetal thigh. The correct measurement of the anterior-posterior thigh diameter would be the second line marked by the number (1) arrow in the real anterior wall of the fetal thigh; as this is the true skin line. The second line marked by number (2) arrow is part of the thigh tissue as the sound waves travels through the convex area can be corrected by scanning in a good sagittal plane.

Figure 3. The sagittal section of the fetal thigh is showing the measurement of the femur length. The arrow is showing the fetal knee. Magnification can be a helpful tool.

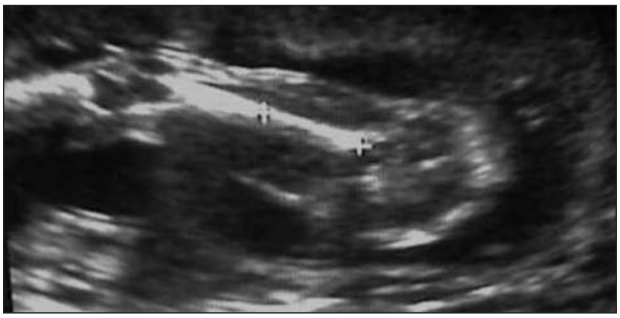


Figure 4. Sagittal plane of the fetal thigh is showing the femur length with one of the calipers in the mid point of the femur length.

Figure 5. The first caliper is moved to the real outer skin of the anterior wall of the fetal thigh.

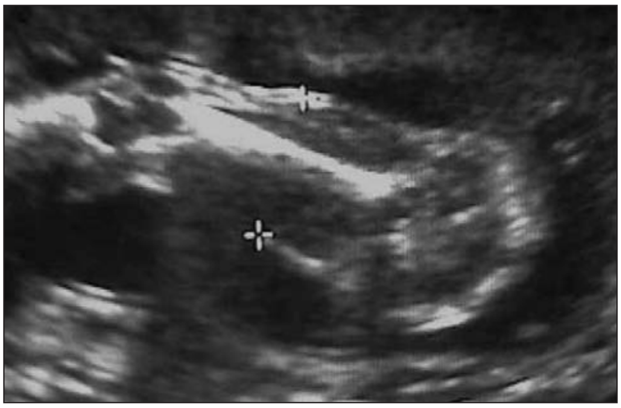


Figure 6. The second caliper is moved to the posterior wall of the fetal thigh. Enter and log the measurement of the anterior posterior thigh diameter (APTD).

1. The femur length was measured using callipers, namely first caliper placed in exact middle point of the fetal femur; for example, if the femur length was 2.4 cm then the first calliper was moved until the measurement read 1.2 cm (Figures 3 and 4).
2. The first calliper was carefully moved to the outer surface of the fetal anterior thigh (Figure 5); the skin surface was measured and not the extra double line created by the sound waves that travel through the convex part of the thigh in para-sagittal planes. Note that scanning the fetal thigh in the sagittal plane can make correction and smooth the skin surface of the fetal thigh. The second calliper was moved to the outer surface of the posterior thigh, and entered (Figure 6).

Calculations

Each one millimetre of the APTD, or the posterior-anterior thigh diameter (PATD) measurements was taken to be equal to one-week. For example, 1.90 cm will be equal to 19 weeks gestation, and 2.80 cm will be equal to 28 weeks gestation. Multiply 1.428 with any fraction of a millimetre. This number 1.428 was obtained from 10 mm divided by 7 days, for example, APTD of 2.68 cm (26.8 mm) calculates to 26 weeks plus 0.8 x 1.428 = 0.1424 day. This is added to the 26 weeks equalling 27.0 weeks and 1.4 day. The APTD was found to be relatively constant, one mm equal to one week.

Serial measurements should however be obtained. The measurements should be repeated with zooming capability and electronic callipers; the serial measurements range should be less than 1 mm. If these measurements do not match the fetal age obtained by using Hadlock *et al* tables for FL [31, 32] a follow-up scan should be recommended.

Results

Measurements of fetal femur lengths of the 55 pregnant participants who met the criteria were correlated with the APTD and used to construct tables and graphs. There was significant correlation between the APTD and fetal age. Using a simple linear regression for this study, more than 99.9 % confidence intervals were found at each week of the eleven groups from 18 to 28 weeks gestation ($R > 0.93$), and (p less than 0.001). The APTD was positively correlated with fetal age (Table 1 and Graphs 1, 2, 3 and 4). Eleven gestational periods from 18 to 28 weeks were analyzed, each period included five different measurements of the femur lengths compared to the fetal age and to the ATPD with mean +/-2SD. Femur length measured from 2.70 cm to 5.50 cm over all gestational periods, the mean being 4.3. Fetal weight ranged between 310 grams and 1400 grams, the mean being 629 grams. The APTD ranged between 1.80 to 2.87 cm, with the mean at 2.36 cm. Linear growth was obtained in each gestational period from 18 to 28 weeks, and compared with the Hadlock *et al* tables [31, 32]. In addition a linear growth of fetal weight was observed in the graphs (see Graph 1). The ATPD when converted to millimetres and compared with the fetal age, was found to be a consistent and valid measurement by using the scatter plots (Graphs 2 and 3). The standard error of estimates using the APTD was significantly lower at .08664 than that using femur length at .2436. The variability estimates from Hadlock *et al* table [31] for femur length *versus* fetal age from 18 to 30 weeks have indicated ±1.8 weeks to 2.4 weeks. The APTD table in this study shows ±3 days variability (see Table 1). Adjusted R square variance was >.99 for both models.

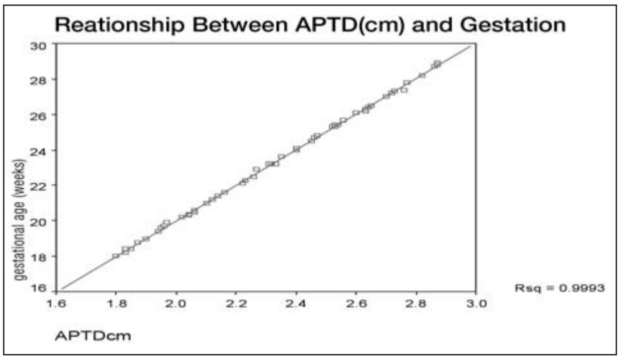
Statistical analysis

Regression: APTD (cm) and fetal age (weeks)

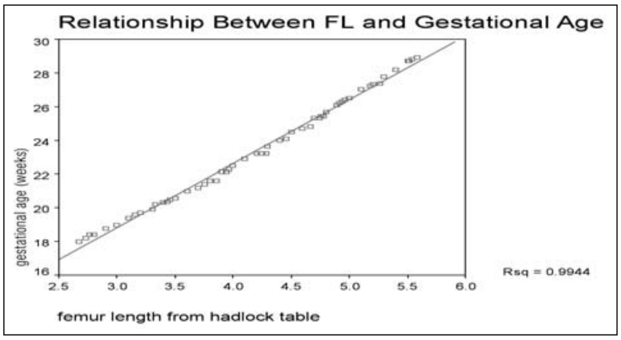
The standard error of estimation is very low at .08664. This indicates a strong good fit of this model. The spread of values for the dependent variable, fetal age, around the mean value of the independent variable is very narrow. About 70% of the values of fetal age will lie ± .08664 from the mean of APTD using a nova method.

Discussion

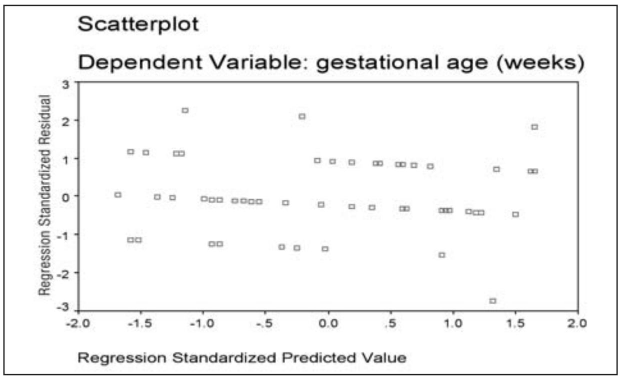
The simplicity of the application found by this study is really its greatest advantage. The idea is new as the only study done previously was the fetal



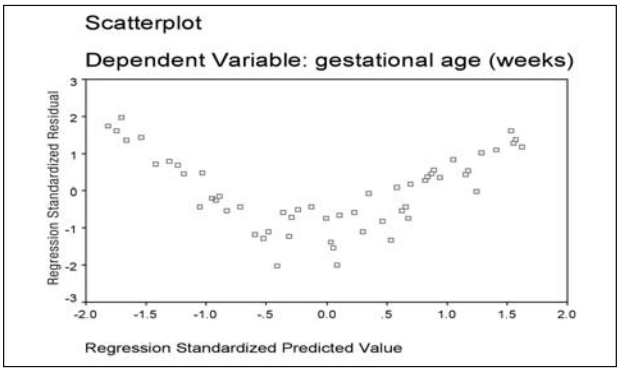
Graph 1: Regression Line for APTD
All of the values of fetal age lie directly on the "Best Fit" Regression Line.



Graph 2: Regression Line for Femur Length and Gestational age.67
Some of the values of fetal age in Dr Hadlock's model lie slightly above or slightly below the "Best Fit" Regression Line.
R Square was .994 and SEE was .24362.



Graph 3: the residual (error), scatter plot and validity of the APTD Normally distributed residuals scatter plot



Graph 4: Residual (error) scatter plot - femur length from Dr Hadlock's Table 67. Pattern of residuals show curvilinear relationship with regression line

thigh circumference and not the APTD. Accuracy of fetal age, weight, and estimated delivery date should be improved if multiple predictors are used, especially when it is difficult to obtain fetal head biometry; for example, when the head is too low in the pelvis, hydrocephalus, anencephaly, and fetal renal disease.

New methods for estimating fetal body weight and fetal age without head measurement are therefore required. Reliable new methods of fetal biometry could be very beneficial in reducing overall fetal biometry errors and increasing the reliability of fetal biometry. Results of this study show that the ATPD predicts second trimester growth with high validity and reliability.

The very simple correlation in this study of 1 mm APTD per week of fetal age is new and useful information. Measuring thigh parameter can be a convenient method for determining fetal growth in the second trimester. The APTD may have a role in quality control of second trimester sonogram examination and may help in the diagnosis of fetal growth abnormalities.

The APTD may be used as an indicator of fetal biometric disturbance enabling the physician to better manage the pregnancy. Diabetes mellitus is one cause of intrauterine growth restriction (IUGR), and may affect the femur length [10,23,27]. Diabetes mellitus may also affect the fetal body mass and consequently the abdominal circumference and fetal thigh [28] hence the APTD can be used not only as indictor for fetal age but also to detect IUGR. Renal pathology, such as hydronephrosis or congenital renal malformation, can affect the fetal abdominal circumference, making this measurement unreliable as an indicator of fetal age. Using combined parameters may be superior to the use of each measurement alone as a

Table I. Correlation between anterior-posterior thigh diameter (APTD-CM) and fetal age (GA-WK) 50th percentile values for fetal femur length are shown below, (n=55).

Femur Length (cm) From Hadlock Table[67, 68]	Fetal age (wk) using Hadlock Table	APTD (cm)	APTD (wk/days)	Femur Length (cm) From Hadlock Table[67, 68]	Fetal age (wk) using Hadlock Table	APTD (cm)	APTD (wk/days)
2.70	18.0	1.80	18.0	4.38	2.37	2.37	23.9
2.73	18.0	1.82	18.2	4.40	24.1	2.42	24.2
2.76	18.1	1.81	18.1	4.50	24.5	2.45	24.6
2.80	18.2	1.82	18.2	4.55	24.7	2.47	24.9
2.90	18.6	1.86	18.8	4.60	24.9	2.47	24.9
3.00	19.0	1.90	19.0	4.60	24.9	2.47	24.9
3.10	19.2	1.92	19.2	4.68	25.0	2.50	25.0
3.16	19.2	1.93	19.4	4.70	25.3	2.53	25.4
3.20	19.6	1.96	19.8	4.80	25.7	2.55	25.6
3.30	19.9	1.97	19.9	4.82	25.7	2.56	25.8
3.36	20.0	2.00	20.0	4.84	25.8	2.56	25.8
3.40	20.3	2.03	20.4	4.90	26.1	2.63	26.4
3.43	20.4	2.04	20.5	4.92	26.1	2.63	26.4
3.45	20.5	2.05	20.6	4.94	26.2	2.64	26.5
3.50	20.7	2.06	20.8	5.00	26.5	2.65	26.6
3.60	21.0	2.10	21.0	5.04	26.6	2.66	26.8
3.70	21.4	2.13	21.4	5.10	27.0	2.71	27.1
3.76	21.5	2.14	21.5	5.20	27.4	2.75	27.6
3.80	21.8	2.16	21.8	5.26	27.6	2.77	27.9
3.80	21.8	2.17	21.9	5.30	27.8	2.77	27.9
3.90	22.1	2.22	22.2	5.36	27.9	2.77	27.9
3.94	22.1	2.22	22.2	5.40	28.2	2.83	28.4
3.96	22.3	2.23	22.4	5.45	28.4	2.83	28.4
4.00	22.5	2.26	22.8	5.46	28.5	2.86	28.8
4.10	22.9	2.27	22.9	5.48	28.6	2.86	28.8
4.20	23.3	2.33	23.4	5.50	28.7	2.87	28.9
4.30	23.7	2.35	23.6				
4.31	23.7	2.36	23.8				
4.35	23.8	2.36	23.8				

marker of trisomy 21 [30]. In addition, it can be difficult in practice to obtain a good fetal thigh circumference, or fetal hands, feet and ears to obtain fetal biometry. This study shows that the fetal APTD provides a more accurate linear measurement of the fetus, thus generating a more complete profile of the fetus.

Significant correlations of APTD with fetal age indicate that this is a reliable method and is particularly useful when other fetal parameters may not accurately predict fetal age or if they are difficult to obtain. If the age predicted from the APTD does not match the age using the femur length, other factors, such as intrauterine growth restriction or maternal and fetal nutrition deficits, should be considered.

The soft tissue accretion of the fetal thigh also depends on the generalized nutritional status of the fetus but such increase in the soft tissue is usually more marked after the 30th week of gestation. The APTD measurements obtained from the 11 groups correlated well with the fetal age and repeated five times for each gestational group between 18 and 28 weeks.

Tables for femur length *versus* gestational age from 18 to 30 weeks were ± 1.8 to ± 2.4 weeks while the variability estimates in the APTD table was ± 3days. Both models predict the fetal age very well, but compared to FL using APTD produces a model with better goodness of fit based on differences in the standard error of estimates (SEE) between the two of them, and on interpreting the best fit regression lines for both models. The spread of values for the dependent variable is narrower around the mean of the independent variable in the APTD model and wider in the FL model.

The SEE of .2436 obtained for FL *versus* gestational age is higher than that obtained in the analysis with APTD. This indicates a weaker goodness of fit of this model. The spread of values for the dependent variable around the mean value of the independent variable is wider; 68% of the values of fetal age will lie ± .2436 from the mean of APTD. Model statistics (F, t, and standardized Beta) are significant for both models. Beta (APTD) = 10.0 (SEE = . 037), Beta (FL) = 3.79 (SE = . 039). T =273.07 for GA x APTD Model = 96.87 for GA x FL Model

Conclusion

APTD was found to be a valid and reliable index for estimating fetal age. Further research to study the relationship between APTD *versus* fetal weight and IUGR is needed. More research is also needed to study the APTD measurements from 12 to 40 weeks gestational age and in a larger population in order to be more statistically significant.

Declaration

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