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Ultrasonographic estimation of fetal weight: development of new model and assessment of performance of previous models

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Short title: Estimated fetal weight

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This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/uog.19066

Acknowledgement: This study was supported by a grant from the Fetal Medicine Foundation (Charity No: 1037116).

Keywords: Estimated fetal weight, Birthweight, Fetal biometry, Systematic review

ABSTRACT

Objective: To develop a new formula for ultrasonographic estimation of fetal weight (EFW) and evaluate the accuracy of this and all previous formulas in the prediction of birthweight.

Methods: The study population consisted of 5,163 singleton pregnancies with fetal biometry at 22-43 weeks' gestation and livebirth of phenotypically normal neonates within 2 days of the ultrasound examination. Multivariable fractional polynomial analysis was used to determine the combination of variables that provided the best-fitting models for EFW. A systematic review was also carried out of articles reporting formulas for EFW and comparing EFW to actual birthweight. The accuracy of each model for EFW was assessed by comparing the mean percentage error (MPE), absolute mean error (AE), proportion of pregnancies with an AE ≤10% and Euclidean distance.

Results: The most accurate models, with the lowest Euclidean distance and highest AE ≤10%, were provided by the formulas incorporating ≥3 rather than <3 biometrical measurements. The systematic review identified 45 studies describing a total of 70 models for EFW by various combinations of measurements of fetal head circumference (HC), biparietal diameter (BPD), femur length (FL) and abdominal circumference (AC). The most accurate model with the lowest Euclidean distance and highest AE $\leq$10% was provided by the formula of Hadlock *et al*, published in 1985, which incorporated measurements of HC, AC and FL; there was a highly significant linear association between EFW with birthweight (r=0.959; p<0.0001) and the EFW was within 10% of birthweight in 80% of cases. The performance of the best model developed in this study, utilizing HC, AC and FL, was very similar to that of Hadlock *et al*.

Conclusion: Despite many efforts to develop new models for EFW, the one reported in 1985 by Hadlock *et al,.* from measurements of HC, AC and FL, provides the most accurate prediction of birthweight and can be used for assessment of all babies as well as those suspected to be either small or large.

Introduction

Ultrasonographic estimation of fetal weight (EFW) is an essential part of fetal medicine and prenatal care, allowing the identification of appropriately grown for gestational age (AGA), small (SGA) and large (LGA) fetuses. The EFW is derived from various combinations of measurements of fetal head circumference (HC), biparietal diameter (BPD), femur length (FL) and abdominal circumference (AC). However, there is no universally accepted formula for EFW and in the last six decades >60 formulas have been reported, which were mainly derived from the study of a very small number (<300) of fetuses.

The objective of this study of 5,163 pregnancies, with fetal biometry at 22-43 weeks' gestation and livebirth of phenotypically normal neonates within 2 days of the ultrasound examination, was to develop a new formula for EFW and evaluate the accuracy of this and all previous formulas in the prediction of birthweight.

Methods

Study population

The data for this study were derived from ultrasound examination in women attending the fetal medicine units at King's College Hospital, London, UK and Medway Maritime Hospital, Kent, UK (between January 2006 and December 2017). The fetal databases were searched to identify pregnancies fulfilling the following criteria: singleton pregnancy, dating by fetal crown-rump length at 11-13 weeks' gestation, ultrasound examination at 22-43 weeks' gestation and available measurements of fetal HC, BPD, AC and FL, livebirth of phenotypically normal neonate, and birth within 2 days of the ultrasound examination.

The ultrasound scans were carried out by sonographers who had the FMF Certificate of Competence in Fetal Abnormalities. The BPD and occipito-frontal diameters (OFD) were measured at the level of the transventricular plane from the outer bone margin to the outer bone margin and the HC was calculated [HC = $\pi \times (OFD + BPD)/2$]. The fetal abdomen was measured in a cross-sectional view with visible stomach bubble and umbilical vein in the anterior third at the level of the portal sinus; the transverse and anterior-posterior diameters (ATD, APD) were measured and the AC was calculated [AC = $\pi \times (ATD + APD)/2$]. The FL was measured with calipers placed on the outer borders of the diaphyses.

Maternal demographic characteristics, obstetric and medical history, and fetal biometry were stored in a fetal database. Pregnancy outcome, including indication and method of delivery, birthweight and findings from examination of the neonate were obtained from computerized records in each labor ward.

Identification of formulas for EFW

A systematic review was carried out of articles reporting formulas for EFW and comparing EFW to actual birthweight. The inclusion criteria were singleton human pregnancies, ultrasound measurements of fetal HC, BPD, AC and FL, individually or in combination, and interval between ultrasound examination and birth of $\leq$15 days. The term 'fetal weight' was searched through PubMed and Cochrane CENTRAL library from 1964, when the first paper was published,[1] to January 2018 and from references of other systematic reviews. No language restrictions applied.

All citations were examined to identify potentially relevant studies; the abstracts of these were then revised by two independent reviewers (AH and AMZ) who selected eligible studies for full assessment of the complete article. Any disagreements were resolved by discussion and the opinion of a third party (KN).

Statistical analysis

Development of new model for EFW

The potential variables for prediction of birthweight were measurements of BPD, HC, AC, FL in cm and gestational age in days. The data for birthweight were logarithmically transformed to achieve Gaussian normality which was assessed by inspection of histograms and probability plots. The study population was divided into a testing dataset (n=3,000) and a validation set (n=2163). In the testing dataset, multivariable fractional polynomial analysis was used to determine the combination of variables that provided the best-fitting equation using a combination of powers ranging from -3 to 3. We examined each biometric parameter using a combination of linear and fractional polynomial terms and identified formulas that provided a significant contribution in the regression analysis. For each group, we selected the two best models based on the model R^2, root mean square error (RMSE), residual standard deviation

(SD) and mean percentage error (MPE) the absolute mean error (AE), proportion of pregnancies with an AE $\leq$10% and Euclidean distance.[2]

The MPE provides a measure of the systematic deviation of the EFW from the birthweight [MPE = 100 x (EFW – birthweight) / birthweight]. The AE measures the absolute value of the deviation of EFW from the actual birthweight. The SD of the MPE and AE provides a measure of the variation of the prediction error and reflects precision of the formula in calculation of EFW. The Euclidean distance, calculated from $\sqrt{(MPE^2 + MPESD^2)}$ provides a measure of accuracy of prediction of the model.

Assessment of accuracy of published models for EFW

All models were compared for accuracy in prediction of birthweight by assessing the MPE with 95% limits of agreement (mean $\pm$ 1.96 x SD of MPE), AE, proportion of pregnancies with error $\leq$10% and Euclidian distance. We also examined the proportion of pregnancies with error $\leq$10% and Euclidian distance in the cases where the birthweight was <2,500 g and those with birthweight >4,000 g.

The statistical software package SPSS 24.0 (IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp, 2013) and StatsDirect version 3.1.11 (StatsDirect Ltd, Cheshire, UK) were used for the data analyses.

Results

Study population

The entry criteria were fulfilled by 5,163 pregnancies. Pregnancy characteristics and indications for delivery are summarized in Table 1. The ultrasound examinations were performed by 419 examiners.

New model for EFW

The new models for EFW derived from the testing dataset and assessed in the validation set of the study population are shown in Table 2. The most accurate models, with the lowest Euclidean distance and highest AE $\leq$10%, were provided by the formulas incorporating $\geq$3 rather than <3 biometrical measurements.

Literature search

The literature search identified 4,770 citations and 148 of these were selected for further evaluation (Figure 1). There were 48 articles reporting formulas for EFW and comparing EFW to actual birthweight.[1,3-49] However, in three cases the AE was >50%; it is possible that in these articles there was an error in the formula and they were not included in the further analysis of data.[47-49] Details of the 45 included studies on a total of 70 formulas for EFW are provided in Table 3.[1,3-46] In 33 (71.7%) of the 46 studies the number of patients used for development of the formulas was <200 and in most cases the populations examined were unselected, but a few studies were confined to the examination of small or large fetuses. In most studies the interval between ultrasound examination and birth was ≤7 days, but in one it was <14 days[30] and in another ≤15 days.[34]

Accuracy of EFW formulas

The accuracy of each published model for EFW in the prediction of birthweight in our 5,163 pregnancies, assessed by comparing the MPE, AE, proportion of pregnancies with an AE ≤10% and Euclidean distance, is shown in Table 4.

Overall results

The most accurate models, with the lowest Euclidean distance and highest AE ≤10%, were provided by the formulas of Hadlock *et al*, which incorporated measurements of HC, AC, FL with or without the addition of BPD.[15] There was a highly significant linear association between EFW, derived by the measurement of HC, AC and FL, with birthweight (r=0.959; p<0.0001; Figure 2) and the EFW was within 10% of birthweight in 80% of cases.

The performance of the best models developed in this study, utilizing HC, AC and FL, with or without BPD, was very similar to those of Hadlock *et al.*[15] High performance was also achieved by the models of Ott *et al.*, which incorporated measurements of HC, AC, FL,[38] Sabbagha *et al.,* which incorporated measurements of BPD, HC, AC, FL and gestational age,[46] and Ben-Haroush *et al.*, which incorporated measurements of AC and FL, with or without the addition of BPD or BPD and HC.[19]

In papers reporting models for different combinations of measurements, inclusion of HC and / or BPD improved the accuracy provided by measurement of AC and/or FL alone.[8,9,10,12,15,16,19] There are four papers reporting models for different combinations of measurements with and without FL; inclusion of FL improved the accuracy of the models in two,[26,29] and produced similar results in the other two.[16,27]

Small babies

In the subgroup of babies with birthweight <2,500 g, the most accurate models of EFW, with the lowest Euclidean distance and highest AE $\leq$10%, were provided by the formula of Hadlock *et al.,* [15] Dudley *et al.,*[40] and Scott et al.,[41] all of which used measurements of HC, AC and FL. However, the model of Scott *et al.,*[41] was specifically developed for the assessment of small babies and performed poorly in the whole population and especially in the subgroup of large babies. The performance of the model of Dudley *et al.,*[40] was poorer than that of Hadlock *et al.,*[15] in the whole population and especially in large babies. In the model by Hadlock *et al.,*[15] the EFW was within 10% of birthweight in 73% of cases of small babies, compared to 80% for the whole population.

Large babies

In the subgroup of babies with birthweight ≥4,000 g, the most accurate prediction was provided by the models of Ferrero *et al.*, which used measurements of AC and FL,[18] Merz *et al.,* which used measurements of BPD and AC,[12] and Chen *et al.,* and Souka *et al.,* which used measurements of BPD, HC, AC and FL.[44,45] However, these models performed poorly in the whole population and especially in the subgroup of small babies. The models reported by Hadlock *et al.,* were among the best ones also for the prediction of large babies; however, in common with our models, the accuracy of the model combining BPD, AC and FL was superior to that combining HC, AC and FL.[15] In the model by Hadlock *et al.,* using HC, AC and FL[15] the EFW was within 10% of birthweight in 76% of cases of large babies, compared to 80% for the whole population.

Two-stage screening

In this study the model with the highest performance for babies with birthweight <2,500 g was that of Scott *et al.,* which used measurements of HC, AC and FL,[41] and the best model for babies with birthweight ≥4,000 g was that of Ferrero *et al.*, which used measurements of AC and FL.[18] First-line screening was carried out by the model of Hadlock *et al.,* using HC, AC and FL,[15] and on the basis of the EFW the population was divided into three groups. In the group with EFW <2,500 g the model of Scott *et al.,*[41] was applied to derive a new EFW, in the group with EFW ≥4,000 g the model of Ferrero *et al.*,[18] was applied to derive a new EFW, and in the group with EFW 2,500 to 3,999 g the values obtained from the model of Hadlock *et al.,*[15] were retained. The accuracy of the new combined EFW in the prediction of birthweight was then examined (Table 4).

Discussion

Principal findings of this study

This study has demonstrated that first, there is a high association between EFW and birthweight, and second, the most accurate model for prediction of birthweight is one that includes measurements of the fetal head as well as AC and FL. The study has also demonstrated that there are large variations in the accuracy of 70 previously reported models of EFW in the prediction of birthweight. The most accurate model was that of Hadlock *et al*,[15] and it is rather disappointing but impressive that the prediction of a model reported from the study of 276 patients in 1985,[15] could not be improved by our study of several thousands of patients in 2018. In both the model of Hadlock *et al*[15] and the one developed in this study the EFW, derived from measurements of HC, AC and FL, was within 10% of birthweight in 80% of cases.

In the assessment of small or large babies, some models were better than that of Hadlock *et al.*[15] However, a two-stage strategy, whereby the model of Hadlock *et al*,[15] is first applied in the whole population and those with EFW below or above certain cut-offs have their EFW recalculated using other models, failed to improve the accuracy of prediction of birthweight either in the whole population or in subgroups of small or large babies.

Strengths and limitations of the study

Strengths of our study include the large population examined covering a wide range of gestational ages and birthweights, pregnancy dating based on fetal crown-rump length, proximity of the ultrasound examination to delivery, trained sonographers that carried out fetal biometry according to a standardized protocol, We adopted the pragmatic approach of utilizing all measurements obtained from a large number of appropriately trained sonographers providing a routine clinical service rather than a small number of highly skilled specialists. Another strength is the systematic review of the literature that identified a large number of previously reported models for EFW, derived from fetal HC, BPD, AC and FL, individually or in combination and assessment of the accuracy of these models for the prediction of birthweight both in the whole study population and also in small and large babies.

A potential limitation is the retrospective nature of the study which inevitably introduces bias in favor of high-risk pregnancies; this is for example reflected in the high proportion of babies with birthweight <2,500 g. However, the large sample size included a high number of appropriate, small and large fetuses to allow adequate assessment of the EFW models for such pregnancies. Although the precise performance of each model would vary with the characteristics of a given study population, our study allows comparison of the relative performance between the different models.

Comparison with previous studies

Studies describing new models often reported that their model was superior to previously published ones but this is an inevitable consequence of deriving and testing a model in the same population. In general, previous studies assessing the accuracy of different models for EFW in the prediction of birthweight reached the conclusion that either the most or among the most accurate models were those reported by Hadlock *et al.*[15] in all pregnancies but also in those with only small or only big babies.[50-57]

There is controversy as to whether use of FL in models for EFW improves the accuracy of prediction of birthweight. [16,26,27,29] We found that the models providing the most accurate prediction included measurements of HC and / or BPD, as well as AC and FL. A small study investigating 43 SGA fetuses with abnormal umbilical artery Doppler that were born at <33 weeks' gestation, reported that although in symmetrical smallness models using FL were more accurate than those without, the opposite was true in the case of asymmetrical smallness.[58]

Attempts at improving the prediction of birthweight by the addition of maternal characteristics, such as height, weight, parity, and racial origin, to fetal biometry[59] have not been found to be successful.[60] A study of over 9000 singleton pregnancies investigated the effect of maternal age, weight, height, parity, diabetes, fetal sex, presentation, amniotic fluid index and sonographer experience; it was concluded that although some of these factors had a significant effect on EFW, their contribution was small and of questionable clinical significance.[61] There is some contradictory evidence that the precision of EFW can be improved by 3D ultrasound volumetry.[62-64] Recent evidence suggests that EFW using MR imaging may be more accurate that ultrasound in the prediction of both small and large for gestational age neonates.[65,66] Assessment of the value of 3D ultrasound and fetal MRI were beyond the scope of our study.

Conclusions

Despite many efforts to develop new models for EFW, the one reported in 1985 by Hadlock *et al,*.[15] from measurements of HC, AC and FL, provides the most accurate prediction of birthweight and can be used for assessment of all babies as well as those suspected to be either small or large.

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Table 1: Characteristics of study population of 5,163 pregnancies.

Characteristic	**Median (range) or n (%)**
Maternal age (y)	31 (16 to 52)
Maternal height (m)	165 (122 to 198)
Maternal weight (kg)	80 (43 to 175)
Maternal racial origin	
- White	3,579 (69.3)
- Black	1,104 (21.4)
- South Asian	268 (5.2)
- East Asian	62 (1.2)
- Mixed	150 (2.9)
Conception	
- Spontaneous	4,990 (96.6)
- Assisted	173 (3.4)
Cigarette smoker	630 (12.2)
Parity	
- Nulliparous	2,503 (48.5)
- Parous	2,660 (51.5)
Gestational age (w)	
- At ultrasound	39.3 (22.3 to 43.3)
- At delivery	39.4(22.6 to 43.4)
<28 w	95 (1.8)
$28\text{-}33^{+6}$ w	370 (7.2)
$34\text{-}36^{+9}$ w	677 (13.1)
$37\text{-}39^{+6}$ w	1,738 (33.7)

≥40 w	2,283 (44.2)
Birthweight (g)	3,200 (440 to 5,688)
<2,500 g	1,148 (22.2)
2,500-3,999 g	3,404 (65.9)
≥4,000 g	611 (11.8)
Interval between ultrasound scan and delivery (d)	1 (0 to 2)
Indication for delivery	
- Spontaneous	2,435 (47.2)
- Iatrogenic	2,728 (52.8)
Preterm	
- SGA, PE, PIH, or CH	521 (10.1)
- LGA, polyhydramnios DM or GDM	44 (0.9)
- Maternal medical condition or cholestasis	10 (0.2)
- Previa, accreta, vasa previa, abruption, or APH	45 (0.9)
- Poor obstetric history	4 (0.1)
- Red blood cell or platelet alloimmunization	19 (0.4)
- Reduced FM, abnormal Doppler or CTG	20 (0.4)
Term	
- Breech or unstable lie	90 (1.7)
- SGA, PE, PIH, or CH	613 (11.9)
- LGA, polyhydramnios DM or GDM	253 (4.9)
- Maternal medical condition or cholestasis	70 (1.4)
- Maternal request, age, IVF, or previous CS	139 (2.7)
- Previa, accreta, vasa previa, abruption, or APH	33 (0.6)
- Poor obstetric history	29 (0.6)
- Red blood cell or platelet alloimmunization	6 (0.1)

- Reduced FM, abnormal Doppler or CTG	269 (5.2)
Postdates	563 (10.9)

SGA = small for gestational age; LGA = large for gestational age; PE = preeclampsia, PIH = pregnancy induced hypertension; CH = chronic hypertension; DM = diabetes mellitus; GDM = gestational diabetes mellitus; APH = antepartum hemorrhage; FM = fetal movements; CTG = cardiotocography.

Table 2. New formulas for estimated fetal weight developed in the study population from measurements of biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC) and femur length (FL) using combinations of fractional polynomial terms. The models are compared for adjusted R^2, residual standard deviation (SD), root mean square error (RMSE), mean percentage error (MPE), absolute mean error (AE), proportion of pregnancies with an AE ≤10% and Euclidean distance (ED).

Model	Adjusted R^2	Residual SD	RMSE	MPE	AE	≤10%	ED
Abdominal circumference (AC)							
2.[illegible]7 + (0.03754 * AC)	0.91	344.78	0.0516	0.76	8.94	68.84	10.99
1.23636 + (0.10475 * AC) - (0.00111 * AC^2)	0.94	276.93	0.0428	0.34	7.36	77.48	8.58
Femur length (FL)							
1.[illegible]1 +(0.43698 * FL) - (0.01792 * FL^2)	0.86	430.66	0.0629	-0.01	10.96	56.91	13.05
3.76[illegible]3 + (-0.82298*FL) + (0.18904*FL^2) - (0.01109*FL^3)	0.87	422.29	0.0618	0.18	10.78	56.87	12.98
AC and FL							
1.[illegible]493 + (0.02431*AC) + (0.31364*FL) - (0.01779*FL^2)	0.95	258.89	0.0382	0.27	6.66	81.04	7.61
[illegible]7 + (0.04951*AC) - (0.00038*AC^2) + (0.20222*FL) - (0.01014*FL^2)	0.95	255.66	0.0378	0.60	6.62	81.51	7.58
Head circumference (HC) and AC							
[illegible] (0.03706*HC) - (0.00033*HC^2) + (0.06305*AC) - (0.00057*AC^2)	0.95	258.43	0.0387	0.93	6.77	82.02	7.80
1.353[illegible]6 + (0.01600*HC) + (0.07192*AC) - (0.00071*AC^2)	0.95	258.64	0.0388	-0.34	6.70	82.43	7.61
HC, AC, FL							

1.216[illegible]3 + (0.06076*HC) - (0.00075*HC^2) + (0.02107*AC) + (0.05261*FL)	0.95	247.40	0.0361	-0.66	6.29	84.65	7.12
1.42482 + (0.01165*HC) + (0.03949*AC) - (0.00028*AC^2) + (0.14147*FL) - (0.00662*FL^2)	0.96	243.39	0.0357	-0.29	6.21	84.93	7.02
Biparietal diameter (BPD) and AC							
[illegible]04 + (0.29764*BPD) - (0.01347*BPD^2) + (0.02677*AC)	0.94	266.93	0.0399	0.87	6.95	80.77	8.05
[illegible]0 + (0.14816*BPD) - (0.00574*BPD^2) + (0.06410*AC) - (0.00057*AC^2)	0.95	256.68	0.0388	0.92	6.74	81.92	7.78
BPD, AC and FL							
1.27303 + (0.20358*BPD) - (0.00912*BPD^2) + (0.02168*AC) + (0.05366*FL)	0.96	247.49	0.0363	0.50	6.33	85.53	7.23
1.31192 + (0.08652*BPD) - (0.00300*BPD^2) + (0.03839*AC) - (0.00025*AC^2) + (0.12769*FL) - (0.00559*FL^2)	0.96	242.33	0.0358	0.41	6.22	85.71	7.05
BPD, HC, AC and FL							
1.87409 + (0.01783*BPD) + (0.01088*HC) + (0.02000*AC) + (0.05837*FL)	0.95	257.08	0.0369	0.50	6.51	82.99	7.57
1.43237 + (0.01660*BPD) + (0.00745*HC) + (0.03876*AC) + (0.14005*FL) - (0.00027*AC^2) - (0.00663*FL^2)	0.96	240.71	0.0354	0.16	6.17	85.39	6.97
BPD, HC, AC, FL and GA							
1.857[illegible]5 + (0.01583*BPD) + (0.01028*HC) + (0.01966*AC) + (0.04836*FL) + (0.00051*GA)	0.95	252.47	0.0365	0.69	5.98	83.31	7.52
[illegible]542676 + (0.014694*BPD) + (0.007436*HC) + (0.037447*AC) + (-0.000257*AC^2) + (0.169354*FL) + (-[illegible]406*FL^2) + (-0.001519*GA) + (0.000004*GA^2)	0.96	243.02	0.0350	3.43	6.39	80.44	8.02

In each section the second of the two models was considered to be superior and was analyzed further in Table 4

Table 3. Articles reporting formulas for estimated fetal weight (EFW) derived from various combinations of ultrasonographic measurements of fetal head circumference (HC), biparietal diameter (BPD), femur length (FL) and abdominal circumference (AC). The interval in days is between the gestational age at ultrasound examination and birth.

Footnote:

GA = gestational age, DM = diabetes mellitus, GDM = gestational diabetes mellitus.

Please not that some models were specifically developed for the assessment of large or small fetuses; these are indicated by the note (large) or(small) after the author in the first column.

	N	Population	GA (w)	Interval (d)	Biometry	EFW	Formula for EFW
BPD							
Willocks et al., 1964[1]	152	Unselected	NR	≤7	cm	g	(-177 + 30 * BPD) * 28,3495
Thompson et al., 1965[3]	85	Unselected	>28	≤1	cm	g	-6575 + 1060 * BPD
Kohorn et al., 1967[4]	89	Unselected	>28	≤7	cm	g	-2569 + 613 * BPD
Hellman et al., 1967[5]	164	Unselected	24-40	NR	cm	g	-3973.8 + 772.2 * BPD
AC							
Campbell et al., 1975[6]	140	Unselected	32-38	≤2	cm	kg	Exp (- 4.564 + 0.282 * AC - 0.00331 * AC^2)
Higginbottom et al., 1975[7]	50	Unselected	NR	≤2	cm	g	0.0816 * AC^3
Warsof et al., 1977[8]	85	Unselected	17-41	≤2	cm	kg	10^(-1.8367 + 0.092 * AC - 0.019 * AC^3 / 1000)
[illegible] 1983[9]	98	Unselected	26-41	≤3	cm	g	10^(0.6328 + 0.1881 * AC - 0.0043 * AC^2 + 0,000036239 * AC^3)
Hadlock et al., 1984[10]	167	Unselected	NR	≤7	cm	g	Exp (2.695 + 0.253 * AC - 0.00275 * AC^2)
Hill et al., 1985[11]	103	Unselected	25-40	≤3	cm	g	-2883.6 + 181.39 * AC
Merz et al., 1988[12]	167	BW 2000 - 4520 g	24-42	<7	cm	g	0.1 * AC^3
Pedersen et al., 1992 (large)[13]	43	DM or GDM	NR	≤2	cm	g	Exp (1.4146 + 0.3371 * AC - 0.004082 * AC^2)
FL							
Warsof et al., 1977[8]	85	Unselected	17-41	≤2	cm	kg	Exp (4.6914 + 0.151 * FL^2 - 0.0119 * FL^3)
Honarvar et al., 2001[14]	900	Unselected	25-40	≤3	cm	kg	-1.36 + 0.042 * FL^2 + 0.32 * FL
AC, FL							

Hadlock et al., 1985[15]	276	Unselected	NR	≤7	cm	g	10^(1.304 + 0.05281 * AC + 0.1938 * FL - 0.004 * AC * FL)
Woo et al., 1985[16]	125	Unselected	25-42	≤7	cm	g	10^(0.59 + 0.08 * AC + 0.28 * FL - 0.00716 * AC * FL)
Warsof et al., 1986[17]	101	Unselected	22-43	≤3	cm, mm	kg	Exp (2.792 + 0.108 * FL + 0.0036 * AC^2 - 0.0027 * FL* AC)
Ferrero et al., 1994[18]	93	Unselected	NR	≤7	cm	g	10^(0.77125 + 0.13244 * AC - 0.12996 * FL - 1.73588 * AC^2 / 1000 + 3.09212 * FL * AC / 1000 + 2.18984 * FL / AC)
Ben-Haroush et al., 2008[19]	5449	Unselected	24-42	≤7	mm	g	10^(-2.543 + 1.747 * LogAC + 0.876 * LogFL)
Akhtar et al., 2010[20]	66	Unselected	37-42	≤4	cm	g	10^(-3.548 + 0.204 * AC + 0.935 * FL - 0.027 * AC * FL)
BPD, AC							
Warsof et al., 1977[8]	85	Unselected	17-41	≤2	cm	kg	10^(-1.599 + 0.144 * BPD + 0.032 * AC - 0.000111 * AC * BPD^2)
Shepard et al., 1982[21]	73	Unselected	17-41	≤2	cm	kg	10^(1.2508 + 0.166 * BPD + 0.046 * AC - 0.002646 * AC * BPD)
Jordaan, 1983[9]	98	Unselected	26-41	≤3	cm	kg	10^(-1.1683 + 0.0377 * AC + 0.0950 * BPD - 0.0015 * BPD *AC)
Thurnau et al., 1983 (small)[22]	62	BW <2500 g	26-36	≤7	cm	g	- 229 + 9.337 * BPD * AC
Hadlock et al., 1984[10]	167	Unselected	NR	≤7	cm	g	10^(1.1134 + 0.05845 * AC - 0.000604 * AC^2 - 0.007365 * BPD^2 + 0.000595 * BPD * AC + 0.1694 * BPD)
Weinberger et al.,1984 (small)[23]	41	BW ≤2000 g	NR	≤7	cm	g	– 481 + 10.1 * AC * BPD
Campbell et al.,1985[24]	85	Preterm	23-36	≤7	cm	g	10^(-1.8131 + 0.1630 * BPD + 0.048 * AC - 0.002447 * AC * BPD)
Tamura et al., 1985 (large)[25]	34	BW ≥3500 g	36-41	≤7	cm	g	10^(1.2659 + 0.02597 * AC + 0.2161 * BPD - 0.1999 * AC * BPD^2 / 1000)
Woo et al., 1985[16]	125	Unselected	25-42	≤2	cm	g	10^(1.63 + 0.16 * BPD + 0.00111 * AC^2 - 0.0000859 * BPD * AC^2)
Woo et al., 1986[26]	98	Unselected	25-42	≤2	cm	g	– 1480 + 15.2 * BPD * AC
Merz et al., 1988[12]	167	BW 2000 - 4520 g	24-42	<7	cm	g	-3200.40479 + 157.07186 * AC + 15.90391 * BPD^2

Hsien et al., 1987[27]	86	Unselected	NR	≤5	cm	g	10^(2.1315 + 0.0056541 *AC *BPD – 0.00015515 * AC^2 *BPD +0.000019782 * AC^3 +0.052594 * BPD)
Vintzileos et al., 1987[28]	89	Unselected	24-42	≤3	cm	g	10^(1.879 + 0.084 * BPD + 0.026 * AC)
Akh[illegible] al., 2010[20]	66	Unselected	37-42	≤4	cm	g	10^(0.949 + 0.056 * BPD + 0.099 * AC - 0.001 * AC^2)
HC							
Jordaan, 1983[9]	98	Unselected	26-41	≤3	cm	g	10^(0.9119 + 0.0488 * HC + 0.0824 * AC - 0.001599 * HC * AC)
Hadlock et al., 1984[10]	167	Unselected	NR	≤7	cm	g	10^(1.182 + 0.0273 * HC + 0.07057 * AC - 0.00063 * AC^2 - 0.0002184 * HC * AC)
Weiner et al., 1985 (small)[29]	33	BW ≤2340 g	≤34	≤2	cm	g	10^(1.6575 + 0.04035 * HC + 0.01285 * AC)
Stirnemann et al., 2017[30]	2404	Unselected	22-40	≤14	cm	g	Exp (5.084820 - 54.06633 * (AC/100)^3 - 95.80076 * (AC/100)^3 * Ln(AC/100) + 3.136370 * HC / 100)
BPD, AC, FL							
Hadlock et al., 1985[15]	276	Unselected	NR	≤7	cm	g	10^(1.335 + 0.0316 * BPD + 0.0457 * AC + 0.1623 * FL - 0.0034 * AC * FL)
Woo et al., 1985[16]	125	Unselected	25-42	≤2	cm	g	10^(1.54 + 0.15 * BPD + 0.00111 * AC^2 - 0.0000764 * BPD * AC^2 + 0.05 * FL - 0.000992 * FL * AC)
Hill et al., 1986[31]	103	Unselected	25-40	≤3	cm	g	Exp (-4.7208 + 1.1933 * BPD - 0.0613 * FL * BPD + 5.9509 * FL / BPD + 0.3339 AC / BPD)
Woo et al., 1986[26]	98	Unselected	25-42	≤2	cm	g	– 200 + 1.4 * BPD * AC * FL
Bens[illegible] al., 1987 (large)[32]	80	DM or GDM	NR	≤7	cm	kg	10^(-2.08 - 0.00638 * AC * FL + 0.00265 * BPD^2 + 0.0623 * AC + 0.255 * FL)
Hsien et al., 1987[27]	86	Unselected	NR	≤5	cm	g	10^(2.7193 + 0.0094962 * AC * BPD - 0.1432 * FL - 0.00076742 * AC * BPD^2 + 0.001745 * FL * BPD^2)
Shinozuka et al., 1987 (small)[33]	657	Unselected	21-41	≤7	cm	g	0.23966 * FL * AC^2 + 1.6230 * BPD^3

Nzeh et al., 1992[34]	104	Unselected	37-42	≤15	cm	g	10^(0.47 + 0.488 * LogBPD + 0.554 * LogFL + 1,377 * LogAC)
Halaska et al., 2006[35]	86	Unselected	≥37	≤11	cm	g	10^(0.64041 * BPD - 0.03257 * BPD^2 + 0.00154 * AC * FL)
Ben-Haroush et al., 2008[19]	5137	Unselected	24-42	≤7	mm	g	10^(-2.804 + 0.629 * LogBPD + 1.572 * LogAC + 0.59 * LogFL)
Siemer et al., 2009 (small)[36]	130	BW ≤2500 g	21-41	≤7	cm	g	-5948.336 + 2101.261 * LnAC + 15.613 * FL^2 + 0.577 * BPD^3
Akl[illegible]., 2010[12]	66	Unselected	37-42	≤4	cm	g	10^(-2.213 + 0,147 * AC + 0.088 * BPD + 0.652 * FL - 0.020 * AC * FL)
Kehl et al., 2012 (small)[37]	215	AC ≤ 29cm	22-41	≤7	cm	g	10^(1.766 + 0.026 * AC + 0.081 * FL + 0.038 * BPD)
HC, AC, FL							
Hadlock et al., 1985[15]	276	Unselected	NR	≤7	cm	g	10^(1.326 – 0.00326 * AC * FL + 0.0107 * HC + 0.0438 * AC + 0.158 * FL)
Weiner et al., 1985 (small)[29]	33	BW ≤2340 g	≤34	≤2	cm	g	10^(1.6961 + 0.02253 * HC + 0.01645 * AC + 0.06439 * FL)
Ott et al., 1986[38]	464	Unselected	20-43	≤3	cm	kg	10^(-2.0661 + 0.04355 * HC + 0.05394 * AC – 0.0008582 * HC * AC + 1.2594 * FL / AC)
Combs et al., 1993[39]	380	Unselected	NR	≤3	cm	g	0.23718 * FL * AC^2 + 0.03312 * HC^3
Dudley, 1995[40]	388	Unselected	NR	≤10	cm	g	0.32 * AC^2 * FL + 0.053 * HC^2 * FL
Scott et al., 1996 (small)[41]	142	BW <1000 g	NR	≤7	cm	g	10^(0.66 * LogHC + 1.04 * LogAC + 0.985 * LogFL)
Schild et al., 2004 (small)[42]	84	BW ≤1600 g	21-37	≤7	cm	g	5381.193 + 150.324 * HC + 2.069 * FL^3 + 0.0232 * AC^3 - 6235,478 * LogHC
BPD, HC, AC, FL							
Hadlock et al.,1985[15]	276	Unselected	NR	≤7	cm	g	10^(1.3596 + 0.0064 * HC + 0.0424 * AC + 0.174 * FL + 0.00061 * BPD * AC - 0.00386 * AC * FL)
Roberts et al., 1985 (small)[43]	50	BW <2400 g	<37	≤2	cm	g	10^(1.6758 + 0.01707 * AC + 0.042478 * BPD + 0.05216 * FL + 0.01604 * HC)
Ben-Haroush et al., 2008[19]	5083	Unselected	24-42	≤7	mm	g	10^(-2.869 + 0.585 * LogBPD + 1.562 * LogAC + 0.077 * LogHC + 0,581 * LogFL)
Chen et al., 2011[44]	1034	Unselected	26-43	≤3	cm	g	10^(0.18 * HC + 0.00628 * AC - 0.00318 * HC^2 + 0.00173 * AC * FL + 0.0000430 * BPD *

							HC^2)
Chen et al., 2011 (small)[44]	262	BW <2500 g	26-41	≤3	cm	g	Exp (1.47 * BPD + 0.0169 * HC – 0.0873 * BPD^2 + 0.00518 * AC * FL)
Chen et al., 2011 (large)[44]	120	BW >4000 g	37-42	≤3	cm	g	10^(0.730 * BPD - 0.0375 * BPD^2 + 0.000264 * AC * FL)
Souka et al., 2014[45]	1407	Unselected	30-40	≤7	mm	g	-3466.586 + 14.43568 * BPD + 3.167604 * HC + 29.2856 * FL + 192.3903 * (AC/100)^2
Souka et al., 2014 (large)[45]	1407	Unselected	30-40	≤7	mm	g	-5569.561 + 5.0013 *HC + 12.74294 * AC + 42.52311 *FL
Souka et al., 2014 (small)[45]	1407	Unselected	30-40	≤7	mm	g	-3900.726+5.538388 * HC + 368.0494 * (AC/100)^3-242.061 * (AC/100)^3 * Ln(AC/100)+26.1955 *FL
BPD, HC, AC, FL, GA							
Sabbagha et al., 1989[46]	194	AC 5th to 95th	24-41	≤7	cm	g	-55.3 - 16.35 * (GA + HC + 2 * AC + FL) + 0.25838 * (GA + HC + 2 * AC + FL)^2
Sabbagha et al., 1989 (large)[46]	194	AC >95th	24-41	≤7	cm	g	5426.9 - 94.98 * (GA + HC + 2 * AC + FL) + 0.54262 * (GA + HC + 2 * AC + FL)^2
Sabbagha et al., 1989 (small)[46]	194	AC <5th	24-41	≤7	cm	g	1849.4 - 47.13 * (GA + HC + 2 * AC + FL) + 0.37721 * (GA + HC + 2 * AC + FL)^2

Table 4. Performance of models for estimated fetal weight in the prediction of birthweight reported in the literature and those developed in this study. The models are compared for mean percentage error (MPE), absolute mean error (AE), proportion of pregnancies with an AE ≤10% and Euclidean distance (ED).

Author	All pregnancies				BW <2,500 g		BW ≥4,000 g	
	MPE (%)	AE (%)	≤10%	ED	≤10%	ED	≤10%	ED
BPD								
Willocks et al., 1964[1]	-3.2 (-42.9 to 36.6)	14.3 (14.7)	44.6	20.5	25.0	35.0	13.1	20.9
Thompson et al., 1965[3]	8.7 (-43.2 to 60.6)	17.9 (21.3)	41	27.9	11.9	51.4	59.1	12.2
Kohorn et al., 1967[4]	9 (-41.3 to 59.3)	18 (20.3)	43.6	27.2	2.8	52.7	12.8	18.5
Hellman et al., 1967[5]	9.7 (-32.5 to 51.8)	16.6 (16.8)	45	23.6	6.4	43.7	34.7	15.2
AC								
Campbell et al., 1975[6]	1.4 (-18 to 20.9)	7.8 (6.3)	70.0	10.0	50.9	14.1	52.7	11.2
Higginbottom et al., 1975[7]	-1.9 (-23.7 to 19.9)	9.0 (6.8)	63.2	11.3	53.1	13.4	65.6	10.6
Warsof et al., 1977[8]	8.0 (-8 to 23.9)	10.0 (5.4)	48.3	11.4	8.6	15.4	75.3	9.4
Jordaan, 1983[9]	-3.9 (-27.4 to 19.5)	10.1 (7.5)	56.1	12.6	49.7	16.4	9.7	17.8
Hadlock et al., 1984[10]	2.7 (-16 to 21.4)	7.8 (6.2)	70.1	9.9	53.7	13.2	78.4	8.1
Hill et al., 1985[11]	2.2 (-19.8 to 24.2)	8.5 (7.7)	68.2	11.4	39.1	18.7	59.1	10.5
Merz et al., 1988[12]	20.2 (-6.5 to 47)	21.0 (12.4)	21.7	24.4	36.1	19.8	14.6	26.6
Pedersen et al., 1992 (large)[13]	5.1 (-15.4 to 25.6)	9.2 (7.2)	63.2	11.6	44.9	15.8	81.5	7.6
This study	0.3 (-18 to 18.6)	7.4 (5.7)	72.5	9.3	60.8	11.9	70.2	9.3
FL								
Warsof et al., 1977[8]	2.0 (-26.7 to 30.7)	11.4 (9.4)	53.0	14.8	34.6	21.7	14.7	17.7
Honarvar et al., 2001[14]	1.5 (-30.6 to 33.7)	12.6 (10.6)	49.5	16.5	21.7	26.3	10.1	19.6
This study	0.2 (-26.9 to 27.3)	10.8 (8.7)	55.5	13.8	47.1	17.7	27.5	16.9
AC, FL								
Hadlock et al., 1985[15]	1.9 (-14.6 to 18.4)	6.9 (5.2)	75.7	8.6	67.5	10.0	79.9	7.7
Woo et al., 1985[16]	13.9 (-8.4 to 36.3)	15.5 (9.2)	31.9	18.0	40.1	17.2	45.5	14.1

Warsof et al., 1986[17]	6.4 (-12.3 to 25.2)	9.0 (7.2)	63.5	11.5	45.6	15.6	75.9	9.0
Ferrero et al., 1994[18]	9.5 (-9 to 28)	10.9 (7.8)	52.8	13.4	39.0	17.0	91.5	5.8
Ben-Haroush et al., 2008[19]	0.7 (-16.4 to 17.8)	6.9 (5.4)	76.0	8.7	62.7	11.6	66.3	9.4
Akhtar et al., 2010[20]	-5.7 (-40.8 to 29.5)	13.1 (13.5)	52.0	18.8	31.2	31.8	0.8	24.5
This study	0.6 (-15.6 to 16.8)	6.6 (5)	77.2	8.3	69.8	9.6	74.5	8.5
BPD, AC								
Warsof et al., 1977[8]	2.3 (-15.8 to 20.4)	7.4 (5.9)	72.5	9.5	64.1	11.8	77.3	8.4
Shepard et al., 1982[21]	7.5 (-11.8 to 26.9)	9.8 (7.6)	58.6	12.4	45.4	15.7	75.0	9.0
Jordaan, 1983[9]	7.7 (-13.5 to 28.9)	9.9 (8.8)	61.5	13.3	28.0	21.9	81.2	7.8
Thurnau et al., 1983 (small)[22]	-10.0 (-35.9 to 15.9)	14.3 (8.3)	32.0	16.6	60.5	15.8	0.5	24.4
Hadlock et al., 1984[10]	7.0 (-10.7 to 24.8)	9.1 (6.9)	62.4	11.5	47.1	15.0	84.6	7.3
Weinberger et al.,1984 (small)[23]	-11.4 (-32.2 to 9.4)	13.6 (7.6)	34.2	15.6	73.4	10.2	0.7	23.7
Campbell et al.,1985[24]	16.8 (6.1 to 39.7)	17.5 (10.6)	27.1	20.4	37.3	19.0	29.3	19.9
[illegible]amura et al., 1985 (large)[25]	23.1 (-9.1 to 55.3)	23.5 (15.8)	20.7	28.3	2.4	44.6	76.8	8.4
Woo et al., 1985[16]	-3.1 (-20.7 to 14.5)	7.6 (5.7)	71.3	9.5	69.2	11.0	46.0	12.4
Woo et al., 1986[26]	5.1 (-20.5 to 30.6)	9.9 (9.9)	61.8	14.0	36.5	23.2	82.5	7.5
[illegible]rz et al., 1988[12]	10.5 (-15 to 36)	12.9 (10.6)	46.3	16.7	15.8	27.0	90.5	6.1
Hsieh et al., 1987[27]	7.3 (-12.5 to 27.1)	9.7 (7.9)	60.6	12.5	36.2	18.2	76.6	8.7
Vintzileos et al., 1987[28]	13.8 (-8.8 to 36.5)	14.8 (10.3)	37.0	18.0	40.3	17.3	35.4	19.6
Akhtar et al., 2010[20]	47.7 (12.6 to 82.8)	47.9 (17.4)	3.0	50.9	12.7	38.8	0	53.2
This study	0.9 (-15.7 to 17.5)	6.7 (5.2)	76.8	8.5	69.2	10.4	74.6	8.3
HC, AC								
Jordaan, 1983[9]	5.7 (-15.4 to 26.9)	9.4 (7.8)	62.0	12.2	35.5	18.2	73.5	8.9
Hadlock et al., 1984[10]	0.6 (-16.2 to 17.5)	6.8 (5.2)	75.9	8.6	67.3	10.6	66.4	9.4
Weiner et al., 1985 (small)[29]	-14.2 (-32.8 to 4.3)	15.0 (8.1)	29.5	17.1	49.2	13.0	13.4	21.2
Stirnemann et al., 2017[30]	-3.3 (19.5 to 12.9)	7.2 (5.3)	73.2	8.9	66.7	10.0	55.6	11.0
This study	-0.3 (-16.7 to 16.1)	6.7 (5)	77.2	8.4	71.5	9.8	69.1	9.2
BPD, AC, FL								
Hadlock et al.. 1985[15]	4.3 (-11.6 to 20.2)	7.3 (5.5)	73.3	9.2	64.2	10.8	84.9	7.1

Woo et al.. 1985[16]	5.1 (-12.8 to 23)	8.2 (6.5)	68.5	10.4	49.2	14.5	83.6	7.1
Hill et al.. 1986[31]	5.4 (-15.9 to 26.8)	9.3 (7.9)	63.1	12.2	39.0	17.4	78.9	8.2
Woo et al.. 1986[26]	-4.9 (-21.5 to 11.7)	7.7 (6)	69.5	9.8	65.9	11.4	38.8	13.5
Benson et al.. 1987 (large)[32]	10.1 (-8.4 to 28.7)	11.5 (7.8)	48.5	13.9	38.7	17.1	85.3	7.2
Hsieh et al.. 1987[27]	7.5 (-13.1 to 28.2)	9.8 (8.4)	60.3	12.9	39.9	19.7	82.8	7.6
Shinozuka et al.. 1987 (small)[33]	7.0 (-12.1 to 26.1)	9.4 (7.6)	61.9	12.0	29.5	18.6	83.6	7.3
Hsieh et al.. 1992[34]	8.1 (-14.6 to 30.8)	10.4 (9.5)	60.5	14.1	12.9	25.1	81.8	7.2
Halaska et al.. 2006[35]	4.7 (-20 to 29.4)	10.0 (9)	61.8	10.5	19.3	23.3	46.3	12.1
Ben-Haroush et al.. 2008[19]	2.8 (-13.9 to 19.4)	7.0 (5.6)	75.6	8.9	54.1	12.9	74.6	8.1
Siemer et al., 2009 (small)[36]	-11.1 (-35 to 12.8)	14.3 (8.2)	32.7	16.5	66.6	11.8	0.0	26.9
Akhtar et al., 2010[12]	-21.2 (-48.5 to 6.1)	21.7 (13.2)	19.4	25.4	40.5	28.2	0.3	37.1
Kehl et al., 2012 (small)[37]	21.9 (-4 to 47.8)	22.2 (12.6)	19.1	25.6	45.7	16.8	8.5	30
This study	0.4 (-14.8 to 15.6)	6.2 (4.7)	80.3	7.8	75.4	8.9	75.0	8.2
HC, AC, FL								
Hadlock et al., 1985[15]	0.7 (-14.5 to 16)	6.3 (4.7)	79.9	7.8	72.8	9.1	76.4	8.2
Weiner et al., 1985 (small)[29]	-8.1 (-23.5 to 7.2)	9.5 (6.2)	57.0	11.3	57.4	11.1	45.7	13.3
[illegible] et al., 1986[38]	2.1 (-14.3 to 18.6)	6.8 (5.3)	76.4	8.7	57.1	12.1	72.0	8.6
Combs et al., 1993[39]	0.6 (-16.9 to 18.1)	7.0 (5.5)	74.7	9.0	54.0	12.7	56.8	10.6
Dudley, 1995[40]	-4.0 (-19.1 to 11.1)	7.1 (5)	73.7	8.7	75.2	8.7	53.8	11.1
Scott et al., 1996 (small)[41]	-12.3 (-29.6 to 5)	13.3 (7.2)	34.7	15.1	77.8	8.3	0.7	23.2
Schild et al., 2004 (small)[42]	-18.1 (-33.9 to -2.2)	18.3 (7.5)	14.5	19.8	51.5	11.7	0	27.4
This study	-0.3 (-15.4 to 14.8)	6.2 (4.6)	80.3	7.7	75.8	8.5	72.2	8.7
BPD, HC, AC, FL								
Hadlock et al.,1985[15]	2.7 (-12.8 to 18.1)	6.7 (5)	77.7	8.3	69.8	9.8	82.8	7.4
Roberts et al., 1985 (small)[43]	15.3 (-5.9 to 36.5)	15.9 (9.9)	31.6	18.8	41.6	16.5	35.7	18.8
Ben-Haroush et al., 2008[19]	2.8 (-13.8 to 19.4)	6.9 (5.6)	75.6	8.9	53.8	12.9	74.8	8.1
Chen et al., 2011[44]	12.9 (-6 to 31.7)	13.6 (8.5)	38.1	16.1	26.0	19.5	66.0	10.7
Chen et al., 2011 (small)[44]	-12.6 (-39.4 to 14.2)	15.7 (10.1)	33.4	18.6	66.0	11.4	0.7	29.3
Chen et al., 2011 (large)[44]	35.6 (-27.7 to 98.9)	36.5 (31.3)	18.4	48.0	0	87.9	89.4	6.3

Souka et al., 2014[45]	0.2 (-30.6 to 30.9)	8.5 (13.2)	73.9	15.7	46.8	30.3	71.4	8.7
Souka et al., 2014 (large)[45]	4.5 (-40.1 to 49.1)	12.3 (19.7)	57.4	23.2	30.8	45.1	89.4	6.2
Souka et al., 2014 (small)[45]	-19.4 (-60 to 21.3)	21.1 (19)	27.7	28.4	66.9	36.9	0	41.9
This study	0.2 (-14.9 to 15.2)	6.2 (4.6)	80.4	7.7	75.2	8.6	74.3	8.3
BPD, HC, AC, FL, GA								
Sabbagha et al., 1989[46]	-1.3 (-18.7 to 16.1)	7.1 (5.5)	74.9	9.0	62.8	11.7	41.1	12.4
Sabbagha et al., 1989 (large)[46]	4.3 (-28.7 to 37.2)	9.4 (14.5)	71.5	17.3	36.3	34.0	64.8	9.6
Sabbagha et al., 1989 (small)[46]	-2.8 (-18.8 to 13.3)	6.9 (5.1)	75.4	8.6	73.2	9.4	44.5	12.4
This study	0.6 (-15.2 to 16.4)	6.5 (4.9)	79.0	8.1	76.3	8.9	77.6	8.2
Two stage screening								
Hadlock (HC, AC, FL),[15] Scott (HC, AC, FL),[41] Ferrero (AC, FL).[18]	0.2 (-16.1 to 16.5)	6.5 (5)	77.3	8.3	70.5	9.4	77.1	8.2

Figure legends

Figure 1: Selection tree for included articles.

Figure 2: Association between estimated fetal weight. derived from the model of Hadlock et al using the measurements of head circumference. abdominal circumference and femur length.[15] and birthweight in the study population (r=0.959; p<0.0001).

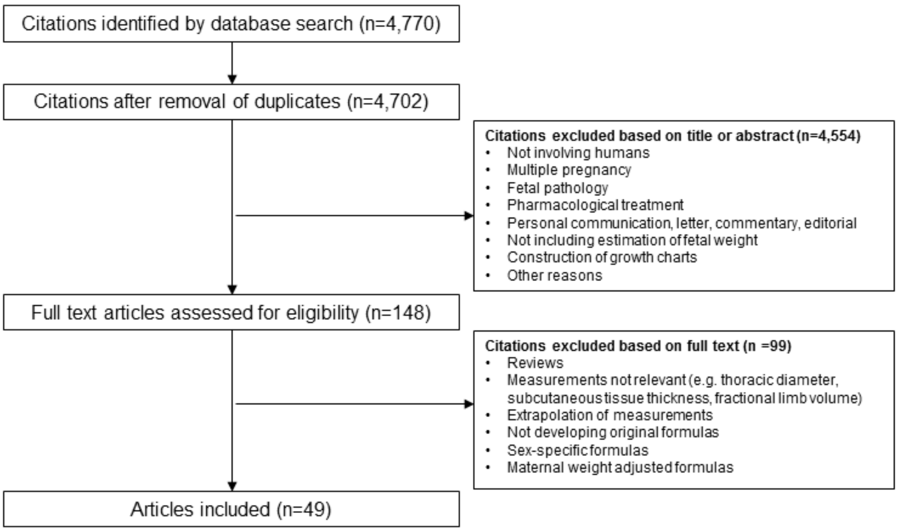
Citations identified by database search (n=4,770)
Citations after removal of duplicates (n=4,702)
Citations excluded based on title or abstract (n=4,554)
• Not involving humans
• Multiple pregnancy
• Fetal pathology
• Pharmacological treatment
• Personal communication, letter, commentary, editorial
• Not including estimation of fetal weight
• Construction of growth charts
• Other reasons
Full text articles assessed for eligibility (n=148)
Citations excluded based on full text (n =99)
• Reviews
• Measurements not relevant (e.g. thoracic diameter, subcutaneous tissue thickness, fractional limb volume)
• Extrapolation of measurements
• Not developing original formulas
• Sex-specific formulas
• Maternal weight adjusted formulas
Articles included (n=49)

Figure 1

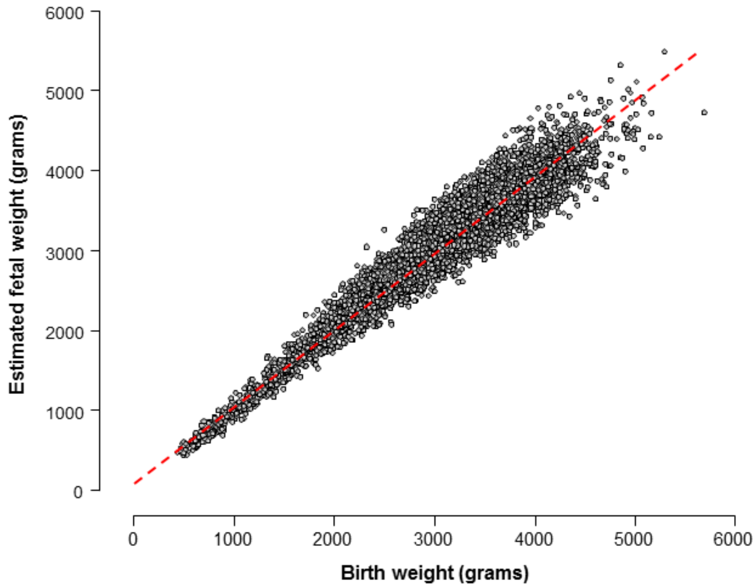
6000
5000
4000
3000
2000
1000
0
Estimated fetal weight (grams)
0
1000
2000
3000
4000
5000
6000
Birth weight (grams)

Figure 2