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Accuracy of sonographic fetal weight estimation of fetuses with a birth weight of 1500 g or less

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ABSTRACT

Objective: To compare 35 commonly used formulae for small and average sized fetuses on their accuracy in estimating the birth weight in fetuses of 1500 g or less.
Study design: For this retrospective study a database search was performed for all singleton pregnancies without structural or chromosomal defects and with a birth weight of 1500 g or less where the last ultrasound examination was performed within seven days before delivery. Percentage error and absolute percentage error were calculated based on 35 different weight estimation formulae. Multiple regression analysis was used to determine the significant contributors to the absolute percentage error.
Results: One hundred and ninety-three cases fulfilled the inclusion criteria. The median birth weight was 990 g. The percentage error ranged between −15.2% (underestimation with the Merz I formula) and 37.4% (overestimation with the Jordaan formula) and the respective standard deviations between 10.5% (Mielke I) and 54.0% (Schillinger), respectively. The absolute percentage error was between 8.5% and 37.6%. The most accurate weight estimation was achieved with the formula from Mielke (percentage error 1.8% and absolute percentage error 8.5%). Multiple regression analysis showed that significant contributors to the percentage error of the Mielke formula were biparietal diameter (OR = −0.206, $p = 0.045$), occipitofrontal diameter (OR = 0.765, $p < 0.0001$), abdominal circumference (OR = −2.953, $p < 0.0001$), femur length (OR = −0.903, $p < 0.0001$), head to abdomen ratio (OR = −1.080, $p < 0.0001$) and fetal weight (OR = 2.847, $p < 0.0001$).
Conclusion: When estimating fetal weight in fetuses weighing 1500 g or less, one has to be aware of the great differences in accuracy among the formulae.

1. Introduction

Accurate prenatal fetal weight estimation is crucial for the pre- and peri-natal management of pregnancies. It is generally based on the combination of several two-dimensional biometric parameters which are reproducible and easy to assess, such as the head circumference, the abdominal circumference and the femur length. Most of the currently used formulae were described within the last four decades and were based on a relatively small number of term fetuses [1–20]. Therefore, these formulae are most accurate in estimating fetal weight between 2500 g and 4000 g [21,22]. In a recent review by Melamed et al., several commonly used fetal weight estimation formulae were compared on 3705 mainly average sized term fetuses. The absolute percentage error ranged between 6.4% and 10.7% [23].

For small fetuses, these formulae are not as precise as for average sized term fetuses, most probably due to different morphological characteristics and a different body composition [2,24]. Siemer et al. compared eleven weight estimation formulae for term fetuses in 160 fetuses weighing 2500 g or less [25]. The inaccuracy of the estimated fetal weight was between 8% and 22%. To improve the accuracy, several authors have introduced specific weight estimation formulae for small fetuses to account for their morphologic differences [26–33]. With these formulae, the absolute percentage error was reduced to about 7–16% [24,25,30].

In this study we compare 35 commonly used formulae for small and average sized fetuses on their accuracy in estimating the birth weight in fetuses of 1500 g or less, and assess the significant contributors to their inaccuracy.

2. Material and methods

As part of the routine peri-natal management at the department of obstetrics and gynaecology of the University of Tuebingen, every pregnant woman receives an ultrasound examination before delivery. In general, during this examination fetal presentation is confirmed, amniotic fluid volume is assessed and fetal weight is estimated (EFW) on the basis of one of the common weight

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Table 1
Regression models for fetal weight estimation (units are given for each formula).

Author	Components	Formula
General formulae for normal sized term fetuses		
Birnholz [1]	BPD, OFD, AD	3.42928 * (BPD * OFD/1.264)^0.5 * AD^2/1000 + 41.218 [g, mm]
Campbell [2]	AC	e^(−4.564 + 0.282 * AC − 0.00331 * AC^2) [g, cm]
Combs [3]	HC, AC, FL	0.23718 * AC^2 * FL + 0.03312 * HC^3 [g, cm]
Ferrero [4]	AC, FL	10^(0.77125 + 0.13244 * AC − 0.12996 * FL − 1.73588 * AC^2/1000 + 3.09212 * FL * AC/1000 + 2.18984 * FL/AC) [g, cm]
Hadlock I [5]	BPD, HC, AC, FL	10^(1.3596 + 0.0064 * HC + 0.0424 * AC + 0.174 * FL + 0.00061* BPD * AC − 0.00386 *AC * FL) [g, cm]
Hadlock II [5]	AC, FL	10^(1.304 + 0.05281* AC + 0.1938 * FL − 0.004 * AC * FL) [g, cm]
Hadlock III [5]	BPD, AC, FL	10^(1.335 − 0.0034 * AC * FL + 0.0316 * BPD + 0.0457 * AC + 0.1623 * FL) [g, cm]
Hadlock IV [5]	HC, AC, FL	10^(1.326 − 0.00326 * AC * FL + 0.0107 * HC + 0.0438 * AC + 0.158 * FL) [g, cm]
Hadlock V [5]	BPD, AC	10^(1.1134 + 0.05845 * AC − 0.000604 * AC^2 − 0.007365 * BPD^2 + 0.000595 * BPD * AC + 0.1694 * BPD) [g, cm]
Hadlock VI [6]	HC, AC, FL	10^(1.5662 − 0.0108 * HC + 0.0468 * AC + 0.171 * FL + 0.00034 * HC^2 − 0.0003685 * AC * FL) [g, cm]
Halaska [7]	BPD, AC, FL	10^(0.64041 * BPD − 0.03257 * BPD^2 + 0.00154 * AC * FL) [g, cm]
Hansmann [8]	BPD, AD, GA	−0.001665958 * AD^3 + 0.4133629 * AD^2 − 0.5580294 * AD − 0.01231535* BPD^3 + 3.702 * BPD^2 − 330.1811 * BPD − 0.4937199 * (GA + 1)^3 + 55.958061 * (GA + 1)^2 − 2034.3901 * (GA + 1) + 32768.19 [g, mm]
Higginbottom [9]	AC	0.0816 * AC^3 [g, cm]
Jordaan [10]	BPD, HC, AC	10^(2.3231 + 0.02904 * AC + 0.0079 * HC − 0.0058 * BPD) [kg, cm]
Persson [26]	BPD, AD, FL	BPD^0.972 * ((AD1 + AD2)/2)^1.743 * FL^0.367 * 10^(−2.646) [g, cm]
Merz [11]	BPD, AC	−3200.40479 + 157.07186 * AC + 15.90391 * BPD^2 [g, cm]
Merz II [11]	AC	0.1 * AC^3 [g, cm]
Ott [12]	HC, AC, FL	10^(−2.0661 + 0.04355 * HC + 0.05394 * AC − 0.0008582 * HC * AC + 1.2594 * FL/AC) [kg, cm]
Rose [13]	BPD, AD, FL	e^(0.143* (BPD + AD + FL) + 4.198) [g, cm]
Sabbagha [14]	GA, HC, AC, FL	−55.3 − 16.35 * (GA + HC + 2 * AC + FL) + 0.25838 * (GA + HC + 2 * AC + FL)^2 [g, cm]
Schild I sex specific [29]	Female BPD, AC, FL	−4035.275 + 1.143 * BPD^3 + 1159.878 * AC^0.5 + 10.079 * FL^3 − 81.277 * FL^2 [g, cm]
Schild I sex-specific [29]	Male BPD, HC, AC, FL	1913.853 * log10(BPD) + 0.01323 * HC^3 + 55.532 * AC^2 − 13602.664 * AC^0.5 − 0.721 * AC^3 + 2.31 * FL^3 [g, cm]
Schillinger [15]	BPD, ATD	397.7 * BPD + ATD − 4387 [g, cm]
Shepard [17]	BPD, AC	10^(−1.7492 + 0.166 * BPD + 0.046 * AC − 0.002546 * AC * BPD) [kg, cm]
Shinozouka [16]	BPD, AC, FL	1.07 * BPD^3 + 3.42 * ATD^2 * FL [g, cm]
Warsof [18]	BPD, AC	10^(−1.599 + 0.144 * BPD + 0.032 * AC − 0.000111 * BPD^2 * AC) [kg, cm]
Woo [20]	BPD, AC, FL	10^(1.13705 + 0.15549 * BPD + 0.0464 * AC − 0.00279682 * BPD * AC + 0.037769 * FL − 0.000494529 * AC * FL) [g, cm]
Vintzileos [19]	BPD, AC	10^(1.879 + 0.084 * BPD + 0.026 * AC) [g, cm]
Specific formulae for small for gestational age, preterm or growth restricted fetuses		
Schild II [30]	HC, AC, FL	5381.193 + 150.324 * HC + 2.069 * FL^3 + 0.0232 * AC^3 − 6235.478 * log10(HC) [g, cm]
Scott [31]	HC, AC, FL	10^(0.66 * log10(HC) + 1.04 * log10(AC) + 0.985 * log10(FL)) [g, cm]
Siemer [25]	BPD, AC, FL	−5948.336 + 2101.261 * ln(AC) + 15.613* FL^2 + 0.0577 * BPD^3 [g, cm]
Thurnau [32]	BPD, AC	(9.337 * BPD * AC) − 229 [g, cm]
Weiner I [33]	HC, AC, FL	10^ (1.6961 + 0.02253 * HC + 0.01645 * AC + 0.06439 * FL) [g, cm]
Weiner II [33]	HC, AC	10^(1.6575 + 0.04035 * HC + 0.01285 * AC) [g, cm]
Mielke I [28]	BDP, ATD, FL	e^(3.067510 + 0.01677 * BPD + 0.000412 * ATD^2 + 0.040611 * FL − 0.000000006027957 * BPD^2 * ATD^2 − 0.000005086 * ATD^2 * FL) [g, cm]
Mielke II [28]	BPD, ATD,FL	e^(3.704706 + 0.033276 * BPD + 0.000093048 * ATD^2 + 0.010570 * FL − 0.00000002477864 * BPD^2 * ATD^2 + 0.000002009 * ATD^2 * FL) [g, cm]

AC = abdominal circumference, HC = head circumference, FL = femur length, BPD = biparietal diameter, AD = abdominal diameter, and GA = gestational age.

estimation formulae. The biparietal and occipitofrontal diameters are measured at the transventricular level from the outer edge to the outer edge of the skull bone. The head circumference (HC) is either measured or calculated (HC = 2.325 × ((occipitofrontal diameter)^2 + (biparietal diameter)^2)^1/2). The fetal abdominal transverse and antero-posterior diameters are measured at the level of the stomach and umbilical vein–ductus venosus complex. The abdominal circumference (AC) is calculated (AC = π × (trans-(transverse diameter + antero-posterior diameter)/2). The femur length (FL) is measured from the proximal end of the greater trochanter to the distal metaphysis. The individual measurements (in millimetres), the birth weight (BW) (in grams) and the maternal demographic characteristics are recorded into a peri-natal computer database.

For this retrospective study, the peri-natal computer database was searched for all singleton pregnancies that resulted in a liveborn fetus without structural or chromosomal defects with a birth weight of 1500 g or less. In each of these pregnancies the last ultrasound examination was identified that included the measurement of the biparietal and frontooccipital diameter of the head, the antero-posterior and the transverse diameter of the abdomen and the femur length. Pregnancies with incomplete data or those pregnancies where the last ultrasound examination was not performed within seven days before delivery were excluded from the further analysis.

Each pregnancy that fulfilled the inclusion criteria was included only once in the analysis. The pregnancies were dated according to the last menstrual period. If the dates were uncertain or the estimated gestation by crown rump length was discordant by more than seven days from the estimated gestation by dates, the crown rump length was used to date the pregnancy. Birth centiles were computed according to the results of Voigt et al., who based their study on more than 500,000 singleton neonates in Germany from 22 weeks of gestation [34].

2.1. Statistical analysis

In each case EFW was calculated on the basis of the published formulae from Birnholz, Campbell, Combs, Ferrero, Hadlock, Halaska, Hansmann, Higginbottom, Jordaan, Persson, Merz, Mielke,