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Estimation of fetal weight: reference range at 20–36 weeks' gestation and comparison with actual birth-weight reference range

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KEYWORDS: birth weight; EFW; France; reference ranges; *Z*-scores

ABSTRACT

Objectives *To formulate reference charts and equations for estimated fetal weight (EFW) from a large sample of fetuses and to compare these charts and equations with those obtained for birth weight during the same study period and in the same single health authority.*

Methods *Biometric data were obtained at 20–36 weeks' gestation from routine screening examinations spanning 4 years. Exclusion criteria were a known abnormal karyotype or congenital malformation and multiple pregnancy. No data were excluded on the basis of abnormal biometry. EFW was calculated based on Hadlock's formula. We used a polynomial regression approach (mean and SD model) to compute a new reference chart for EFW. This chart was compared with that of birth weight at 25–36 weeks' gestation during the same study period and in the same health authority.*

Results *18 959 fetuses were included in the study. New charts and equations for Z-score calculations at 20–36 weeks' gestation are reported. Comparison with the birth-weight chart showed that the EFW was noticeably larger at 25–36 weeks' gestation. At 28–32 weeks' gestation, the 50th centile for birth weight compared approximately with the 10th centile for EFW.*

Conclusion *We present new reference charts and equations for EFW. EFW is computed throughout gestation based on measurements in healthy fetuses. However, before full term, birth-weight charts reflect a significant proportion of growth-restricted fetuses that deliver prematurely. We provide additional evidence that comparing EFW with birth-weight charts is misleading. Copyright © 2007 ISUOG. Published by John Wiley & Sons, Ltd.*

INTRODUCTION

The screening and management of abnormal fetal growth, whether it be macrosomia or growth restriction, remain important objectives of prenatal care. In a low-risk and unselected population, such screening is based mainly on a series of ultrasound examinations[1–4]. The measurement of fetal biometry in the second and third trimesters is an important part of these examinations and biometric measurements are combined routinely in order to calculate the estimated fetal weight (EFW)[5].

EFW is a useful parameter with which to predict birth weight and outcome when it is calculated a few days before delivery. It has an accuracy similar to that of clinical ultrasound examination for delivery at or beyond 37 weeks' gestation, whereas it is significantly superior to clinical estimates of weight for preterm birth[6]. When EFW is calculated prior to delivery in order to help in decision-making, it can be compared to birth-weight reference charts and, in experienced hands, nearly 80% of EFWs are within 10% of the actual birth weight, with most of the remainder being within 20% of actual birth weight[7].

EFW can also be used earlier in gestation to monitor fetal growth. It is a simple and straightforward indicator of global growth that is easy to use for doctors and easy to understand for patients. However, in such cases, EFW should not be compared directly with the distribution of birth-weight measurements, as a large number of premature births are related to factors that affect fetal growth. Indeed, such a process may lead to an inaccurate assessment of fetal weight and inappropriate counseling and planned location for preterm delivery. This highlights the need for specific reference ranges, which ideally should also be specific for gender[8] and ethnicity[9].

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The aims of this study were: (1) to establish French EFW reference charts and equations in full accordance with the recommended method of analysis[10,11] and (2) to highlight the differences between EFW and birth-weight reference ranges constructed during the same study period, in the same health authority and using similar statistical methods.

METHODS

This study was conducted over a 4-year period in a population of pregnant women undergoing routine second- or third-trimester ultrasound examination at 20–36 weeks' gestation as part of routine antenatal care in France. Data were obtained from the largest screening center of Yvelines, a territorial division containing 1.4 million people. Yvelines has a density of around 600 inhabitants per square kilometer and women between 15 and 45 years old represent 43% of the total female population[12]. Over the same period, the birth registry of Yvelines was used to compute new reference charts for weight at birth based on appropriate statistical modeling[10,11,13,14]. All measurements were carried out to the nearest mm by one of four trained sonographers, with no time constraints, using the same probe and ultrasound machine (3.5–5-MHz curvilinear abdominal transducer, General Electric Voluson 730 Expert, GE Medical System Europe, Buc, France), with cineloop facilities. Gestational age based on crown–rump length (CRL) and measurements of head circumference, abdominal circumference and length of femoral diaphysis were collected in all cases. Exclusion criteria were known abnormal karyotype or congenital malformation, multiple pregnancy and lack of first-trimester dating based on CRL[15]. No exclusion was made on the basis of abnormal fetal biometry or birth weight. Gestational age was measured in weeks; fractions of weeks were computed to the nearest week, with fractions of ≤ 4 days and > 5 days being assigned to the nearest lowest and highest week, respectively. Fetal gender was considered only when this was confirmed by neonatal examination. Statistical analysis were performed using Stata 9.2 for Windows (StataCorp LP, TX, USA) and Statistica data analysis software system (version 6 (2001), Statsoft, Inc., Tulsa, OK, USA).

All biometric measurements were performed according to the methodology published together with the reference charts[16–21]. Head circumference was measured on a transverse view of the fetal head in an axial plane at the level where the continuous midline echo is broken by the septum pellucidum in the anterior third, as described by Campbell and Thoms[22]. It was derived from the measurements of the occipital–frontal diameter and the biparietal diameter using the formula: $\pi(d_1 + d_2)/2$, where d is diameter. Abdominal circumference was measured on a transverse circular plane of the fetal abdomen, just above the level of the cord insertion, as described by Campbell and Wilkin[23] and was also derived from the two maximum diameters of the circumference. Femoral length was measured on a plane showing the entire femoral diaphysis, with both ends clearly visible and a $< 45°$ angle to the horizontal. At 30–34 weeks' gestation, particular care was taken not to include the epiphysis. EFW was calculated in all cases using the following formula:

$$\log_{10} \text{EFW} = 1.326 + 0.0107\ \text{HC} + 0.0438\ \text{AC} + 0.158\ \text{FL} - 0.00326\ \text{AC} \times \text{FL}^{5},$$

where HC is head circumference, AC is abdominal circumference and FL is femoral length.

The data were analyzed as reported previously[10,11,13]. The normality of EFW at each week of gestation was assessed using the Kolmogorov–Smirnov and Shapiro–Wilks W-tests. Given the large sample size, statistically significant non-normality was accepted unless the normal plot showed clear deviation from a straight line[11]. The mean EFW was fitted using the polynomial $y = a + \Sigma b_i x^i$ where x denotes gestational age and i takes values from 1 to n[11,13]. Increasing order terms (1 to n) for gestational age were added to the model as long as they were significant, as based on a sequence of the likelihood-ratio tests. R^2 statistics and/or the subjective aspect of the fitted curve were also studied to assess the quality of fit, together with Z-score distributions[11,13]. The variability (SD) of EFW at each week of gestation was modeled by first computing the mean week-specific absolute scaled residuals (absolute difference between the measurements and the predicted mean multiplied by $\sqrt{(\pi/2)}$) and then regressing them against gestational age. Once again, degrees higher than 1 for gestational age were added to the model only if they were significant as based on likelihood-ratio tests. The data were analyzed first globally and then separately for males and females.

From the polynomial models of the mean and SD of EFW, it was possible to calculate the required centiles for any given gestational age (GA) by using the formula:

$$\text{centile}_{GA} = \text{mean}_{GA} + \text{K}\ \text{SD}_{GA},$$

where K is the corresponding centile of the Gaussian distribution (e.g. determination of the 10th and 90th centiles requires $K = \pm 1.28$; determination of the 5th and 95th centiles requires $K = \pm 1.645$; determination of the 2.5th and 97.5th centiles requires $K = \pm 1.96$, etc.) and 'mean' and 'SD' are the predicted values obtained from modeling the original data.

This approach also allows for the calculation of *Z*-scores using the formula:

$$Z\text{-score} = (Y_{GA} - M_{GA})/SD_{GA},$$

where Y_{GA} is the measured EFW at a known gestational age, M_{GA} is the mean EFW obtained with the reference equation used at this gestational age, and SD_{GA} is the standard deviation associated with the EFW value at this gestational age obtained with the reference equation.

Global and gender-specific charts were computed by plotting predicted means together with 3rd, 10th, 90th and 97th centiles across gestational age. In order to compare our new reference equations for EFW with our new reference for birth weight[14], we superimposed on the same figure the mean, 3rd and 97th centiles obtained from the EFW and birth-weight references.

RESULTS

Biometric measurements (head and abdominal circumferences and femoral length) were obtained for 18 959 fetuses at 20–36 weeks' gestation. The median (interquartile range (IQR)) ± SD number of examinations performed at each week of gestation was 134 (25;1602) ± 1230. In 9577 (50.5%) cases, information about gender at birth was available. There were 4708 (49.2%) female and 4869 (50.8%) male newborns. In the remaining 9382 cases, information on fetal gender was not used because it was not confirmed at birth.

Raw EFWs were fitted satisfactorily with a quartic polynomial model as follows (all EFW in g and gestational age (GA) in exact weeks).

Global equation ($R^2 = 0.9983$):

$$\text{EFW} = -26256.56 + 4222.827 \times \text{GA} - 251.9597 \times \text{GA}^2 + 6.623713 \times \text{GA}^3 - 0.0628939 \times \text{GA}^4.$$

In males ($R^2 = 0.9909$):

$$\text{EFW} = -46656.04 + 7225.698 \times \text{GA} - 414.9255 \times \text{GA}^2 + 10.48948 \times \text{GA}^3 - 0.0967309 \times \text{GA}^4.$$

In females ($R^2 = 0.9979$):

$$\text{EFW} = -21772.08 + 3608.945 \times \text{GA} - 221.592 \times \text{GA}^2 + 5.982965 \times \text{GA}^3 - 0.0580884 \times \text{GA}^4.$$

SDs of EFW across gestational age were fitted using a quadratic fit. Fits for SDs were as follows (all SD in g and gestational age (GA) in exact weeks).

Global equation ($R^2 = 0.9567$):

$$\text{SD EFW} = 155.6617 - 19.36351 \times \text{GA} + 0.6699863 \times \text{GA}^2.$$

In males ($R^2 = 0.8174$):

$$\text{SD EFW} = 317.3749 - 32.69943 \times \text{GA} + 0.9348581 \times \text{GA}^2.$$

In females ($R^2 = 0.7129$):

$$\text{SD EFW} = -580.4873 + 39.23006 \times \text{GA} - 0.4522264 \times \text{GA}^2.$$

Table 1 shows the predicted mean and SD for EFW globally, as well as in males and in females, at 20–36 weeks' gestation. Table 2 shows the mean, 3rd, 10th, 90th and 97th centiles for EFW at 20–36 weeks.

Table 1 Predicted mean and SD for estimated fetal weight overall, as well as in males and females, at 20–36 weeks' gestation, from a French population of 18 959 fetuses

	Estimated fetal weight (g)					
	Overall		*Males*		*Females*	
GA (weeks)	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
20	343	36	327	37	340	23
21	419	44	432	43	405	44
22	493	54	518	50	473	64
23	572	65	596	60	551	83
24	662	77	677	71	642	101
25	767	90	771	84	750	118
26	890	105	882	99	876	134
27	1031	121	1015	116	1021	149
28	1192	139	1171	135	1184	163
29	1369	158	1349	155	1362	177
30	1561	178	1546	178	1552	189
31	1761	199	1756	202	1748	201
32	1964	222	1972	228	1944	212
33	2162	246	2183	256	2131	222
34	2345	272	2377	286	2301	231
35	2503	299	2539	318	2442	239
36	2624	327	2652	352	2542	246

GA, gestational age (weeks): fractions of weeks were computed to the nearest week, with fractions of ≤ 4 days and > 5 days being assigned to the nearest lowest and highest week, respectively.

Table 2 Mean, 3rd, 10th, 90th and 97th centiles for estimated fetal weight (in g) at 20–36 weeks' gestation, from a French population of 18 959 fetuses

	Centile				
GA (weeks)	*3rd*	*10th*	*50th*	*90th*	*97th*
20	274	296	343	389	411
21	335	362	419	476	503
22	392	424	493	562	595
23	451	489	572	655	694
24	518	564	662	760	806
25	597	651	767	882	937
26	692	755	890	1024	1087
27	803	876	1031	1187	1259
28	931	1014	1192	1369	1453
29	1073	1168	1369	1571	1666
30	1227	1333	1561	1788	1895
31	1386	1506	1761	2016	2136
32	1546	1680	1964	2248	2382
33	1699	1847	2162	2477	2625
34	1834	1997	2345	2693	2856
35	1942	2121	2503	2886	3065
36	2009	2205	2624	3042	3238

GA, gestational age (weeks): fractions of weeks were computed to the nearest week, with fractions of ≤ 4 days and > 5 days being assigned to the nearest lowest and highest week, respectively.

Figure 1 shows the global charts for the mean, 3rd, 10th, 90th and 97th centiles of EFW. Figure 2 illustrates the same charts for males and females separately. Figure 3 illustrates the quality of fit of our model with the distribution of Z-scores that we calculated based on the fitted equations. The mean and SD of this Z-score distribution were −0.002 and 0.98, respectively; these values were very close to the theoretical values of 0 and 1, respectively[10].

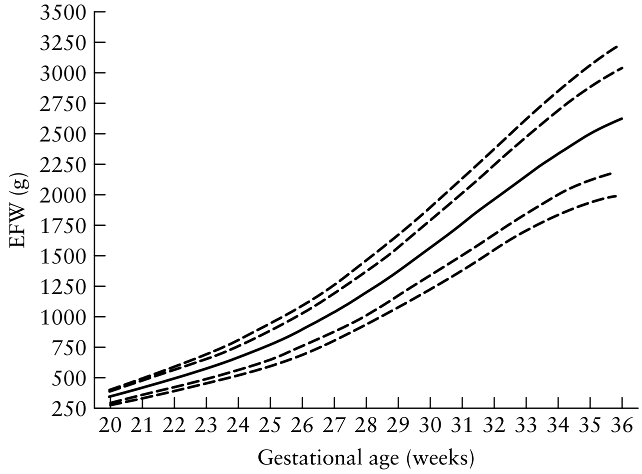

Figure 1 Estimated fetal weight (EFW) charts, constructed from a French population of 18 959 fetuses, with 3rd, 10th, 50th, 90th and 97th fitted centiles.

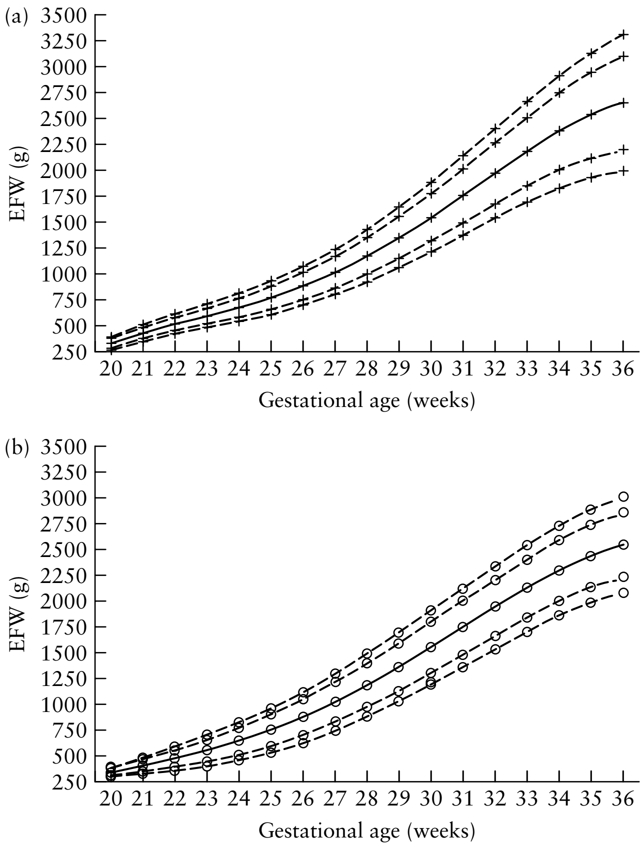

Figure 2 Gender-specific estimated fetal weight (EFW) charts, constructed from a French population of 18 959 fetuses, with 3rd, 10th, 50th, 90th and 97th fitted centiles: (a) males; (b) females.

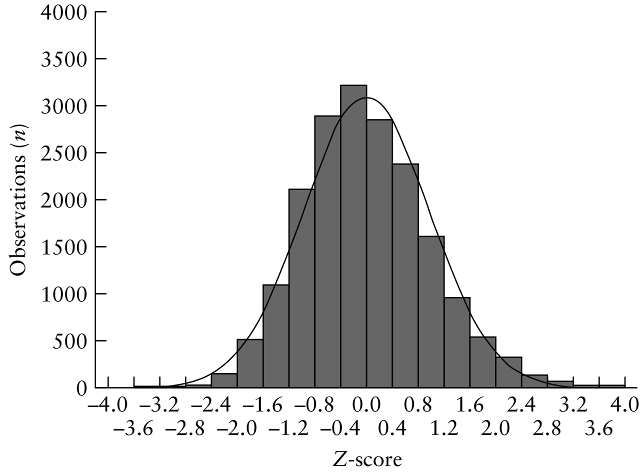

Figure 3 Distribution of Z-scores obtained based on our fitted model constructed from a French population of 18 959 fetuses. The observed distribution (mean, −0.002; SD, 0.98) is very close to the standard normal distribution, illustrating the quality of fit of our model.

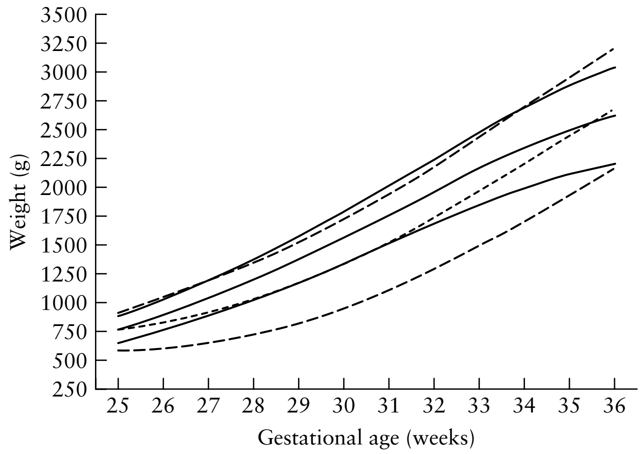

Figure 4 Comparison of our new estimated fetal weight (EFW) reference chart (solid lines), in a French population of 18 959 fetuses, with the birth-weight reference chart (dashed lines) obtained in the same territorial division over the same study period[14], from 25 to 36 weeks' gestation. 10th, 50th and 90th centiles are shown. The mean EFW was noticeably larger than was the actual mean birth weight. At 28–32 weeks' gestation, the 50th centile for birth weight compared approximately with the 10th centile for EFW.

Table 3 shows the predicted mean, 3rd and 97th centiles for birth weight and EFW. Between 25 and 35 weeks' gestation, the mean EFW was noticeably larger than was the actual mean birth weight, with discrepancies of up to 16% of birth weight at 30 weeks (predicted birth weight = 1341 g, predicted EFW = 1561 g). This discrepancy was even greater when the predicted 3rd centiles were compared, with discrepancies of up to 62% of birth weight at 29 weeks; i.e. for a predicted 3rd centile for birth weight of 663 g, the predicted 3rd centile for EFW was 1073 g. Between 28 and 32 weeks, the 50th percentile for birth weight compared approximately with the 10th centile for EFW. Figure 4 shows the discrepancy between

Table 3 Predicted mean, 3rd and 97th centiles for birth weight (BW) and estimated fetal weight (EFW) (in g), from a French population of 18 959 fetuses

	Centile					
	3rd		*50th*		*97th*	
GA (weeks)	*BW*	*EFW*	*BW*	*EFW*	*BW*	*EFW*
25	512	597	752	767	991	937
26	508	692	825	890	1142	1087
27	531	803	919	1031	1307	1259
28	582	931	1035	1192	1489	1453
29	663	1073	1176	1369	1689	1666
30	775	1227	1341	1561	1907	1895
31	915	1386	1529	1761	2142	2136
32	1083	1546	1738	1964	2393	2382
33	1274	1699	1964	2162	2654	2625
34	1484	1834	2203	2345	2922	2856
35	1706	1942	2448	2503	3191	3065
36	1933	2009	2693	2624	3453	3238

GA, gestational age (weeks): fractions of weeks were computed to the nearest week, with fractions of ≤ 4 days and > 5 days being assigned to the nearest lowest and highest week, respectively.

the predicted mean, 10th and 90th centiles for birth weight and EFW.

DISCUSSION

Estimating fetal weight is an easy and straightforward way in which to monitor fetal growth and to screen for intrauterine growth restriction (IUGR)[24]. However, our study demonstrates that EFW needs to be compared to an adequate and specific reference range. It is tempting in our daily practice to compare the EFW with the distribution of birth weight, with which we are more familiar. However, because IUGR is over-represented in premature deliveries, the use of birth weight curves may miss the diagnosis of IUGR. We highlight the important discrepancy between birth weight and EFW at the same gestational age in fetuses which eventually deliver at term. This is consistent with several previous reports which suggested that preterm infants are somewhat smaller than are fetuses of the same gestational age while still *in utero*[25–29]. The association between fetal growth and gestational age at birth is therefore complex. Specific conditions, such as multiple pregnancy, pre-eclampsia or placental insufficiency, are related to both altered fetal growth and preterm delivery[30,31]. It is interesting to note that the EFW and birth-weight charts tend to merge by the end of pregnancy. It is well known that, at term, EFW provides a good estimate of actual birth weight[32].

More importantly, our study provides sonographers with new reference equations compatible with their practice. These equations also allow for gender adjustment. Since EFW is based on anthropometric parameters, these findings support the idea that fetal growth curves should be gender-specific[8]. Our study demonstrates that there are differences in EFW of up to 100 g between males and females at 35 weeks' gestation. Although fetal biometric values may differ between ethnic groups[33], these reference charts and equations may also be used in other countries with the same ethnic background once they prove to fit with such populations[34]. Finally, the charts can be used in daily practice to plot measurements on gestational age-based reference curves in order to visualize individual measurements in comparison to the population distribution. The reference equations for the mean and SD also provide sonographers with the formulae needed to calculate any predicted percentile or Z-score.

There have been numerous studies concerning EFW within 2 weeks of delivery, with the main interest lying in the accurate prediction of actual birth weight[35]. There are far fewer studies on EFW across different gestational ages with which to compare our results. To our knowledge, this is the first study in which EFW is compared directly to birth-weight charts computed from the same population during the same study period. Lombano and Block[36] provided equations required for Z-score calculation. However, their calculations were based on charts and tables previously published by other authors. Ott[24] published EFW with predicted centiles across different gestational ages that were very similar to the ones we report here, but unfortunately, they were not published with the corresponding equations. Hadlock *et al.*[37] defined normal predicted values and confidence limits for EFW *in utero* on ultrasound examination but they did not provide standard errors for the parameters of their curve.

We paid particular attention to the methodology used to construct our new ranges, following the recommendations made by the authors of previous methodological reviews[10,11,13]. However, we must acknowledge several weaknesses in our study. The first concerns the population sample: because it reflected daily practice, the 20- to 24-week and 30- to 34-week examinations were more frequent than were others and we were not able to include patients beyond 36 weeks because routine examinations were too few at this gestational age. Second, we based our work on only one formula for EFW. We chose the formula of Hadlock *et al.*[5] because it was demonstrated that compared with other formulae, this one generally provides more consistent mean (systematic) errors, with comparable random errors (SD)[35]. Finally, only four sonographers performed all the examinations: this may have impacted slightly on the variability of the measurements. However, it is not likely to have introduced major bias because good reproducibility has been shown for biometric measurements[38].

In conclusion, we provide new charts and equations for EFW, based on a very large sample of fetuses. These charts and equations should be used prenatally because comparing EFW with birth-weight charts could be highly misleading. They provide sonographers with the tools needed for an easy and straightforward assessment of fetal growth and allow them to use Z-scores for this measurement.

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