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# Estimation of fetal weight with the use of head, body, and femur measurements—A prospective study

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In utero estimates of fetal weight were evaluated prospectively in 109 fetuses with the use of sonographic models developed in a previous study. This report confirms that the best in utero weight estimates result from the use of models based on measurements of head size, abdominal size, and femur length. Since the accuracy of these models (1 SD = 7.5%) is significantly better than those based on measurements of head and body (e.g., biparietal diameter, abdominal circumference), we recommend routine use of such models in obstetric sonography. (AM J OBSTET GYNECOL 1985;151:333-7.)

**Key words:** Fetal weight, ultrasound

In a previous report[1] we demonstrated that the most accurate estimates of fetal weight in utero are those based on at least three fetal measurements—biparietal diameter or head circumference as an index of head size, abdominal circumference as an index of body girth, and femur length as an index of crown-heel length. The purpose of the current study was to evaluate this method of estimating fetal weight prospectively in a new fetal population.

## Material and methods

The study population consisted of 109 predominately middle class Caucasian patients examined by physicians by means of commercially available linear-array real-time systems (ADR models 2130 and 4000, Siemen's model 2380, and Technicare model 256). The majority of patients were examined within 3 days of delivery, and all patients were examined within at least 1 week of delivery. The study population was unselected and included preterm, term, and postterm fetuses as well as fetuses that were growth retarded or macrosomic. The imaging and measurement techniques used have been previously described in detail.[1]

The fetal weight was estimated in this population by means of models from our previous study.[1] These estimates were compared with weight estimates with the use of the model of Shepherd et al.,[2] which is based on measurements of biparietal diameter and abdominal circumference. The errors in predicting fetal weight were expressed as a percentage of actual birth weight by means of the following method:

$$\text{Error (\%)} = \text{predicted weight} - \text{actual weight/actual weight} \times 100$$

The $t$ test was used to determine if the mean errors were different from zero, and the F test was used to determine if there were significant differences in the standard deviations of the mean errors.

## Results

The accuracy of our original models,[1] as well as the model of Shephard et al.,[2] are summarized in Table I. As noted in our previous study, the combination of abdominal circumference and femur length and all

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**Table I.** Summary of accuracy of models

| | | *Mean deviation ± SD (%)†* | | | | |
|---|---|---|---|---|---|---|
| *Parameters** | *Model* | *Total (N = 109)* | *<1500 gm (n = 13)* | *1500-2000 gm (n = 14)* | *2000-2500 gm (n = 15)* | *2500-3000 gm (n = 12)* |
| Biparietal diameter, abdominal circumference | Shepard et al.[2] | 1.3 ± 10.1 | −3.9 ± 10.0 | 1.2 ± 10.2 | 3.5 ± 15.1 | −0.2 ± 11.1 |
| Head circumference, abdominal circumference | Hadlock et al.[1] | 1.5 ± 9.8 | −0.6 ± 10.6 | −1.4 ± 12.9 | 4.9 ± 13.6 | −2.8 ± 8.8 |
| Abdominal circumference, femur length | Hadlock et al.[1] | 0.4 ± 7.7 | −3.9 ± 8.3 | 0.9 ± 8.5 | 1.6 ± 8.5 | 0.3 ± 7.6 |
| Biparietal diameter, abdominal circumference, femur length | Hadlock et al.[1] | 1.4 ± 7.3 | −5.3 ± 9.0 | 2.2 ± 7.0 | 3.2 ± 7.6 | 1.3 ± 7.7 |
| Head circumference, abdominal circumference, femur length‡ | Hadlock et al[1] | 2.3 ± 7.4 | −4.6 ± 9.7 | 2.5 ± 7.4 | 4.9 ± 7.3 | 1.7 ± 6.6 |
| Biparietal diameter, head circumference, abdominal circumference, femur length | Hadlock et al.[1] | −0.7 ± 7.3 | 5.4 ± 9.0 | −1.4 ± 7.0 | −2.6 ± 7.8 | −0.4 ± 7.4 |

*Fetal measurements in cm; fetal weight in gm.
†Deviation(%) = predicted weight − actual weight/actual weight × 100.
‡Mean difference statistically significant (p = 0.05).

**Table II.** New regression models based on an expanded sample population (n = 276 fetuses)

| *Fetal parameters* | *Regression equations** |
|---|---|
| Abdominal circumference, femur length | $\text{Log}_{10}$ weight = 1.304 + 0.05281 AC + 0.1938 FL − 0.004 AC × FL |
| Biparietal diameter, abdominal circumference, femur length | $\text{Log}_{10}$ weight = 1.335 − 0.0034 AC × FL + 0.0316 BPD + 0.0457 AC + 0.1623 FL |
| Head circumference, abdominal circumference, femur length | $\text{Log}_{10}$ weight = 1.326 − 0.00326 AC × FL + 0.0107 HC + 0.0438 AC + 0.158 FL |
| Biparietal diameter, head circumference, abdominal circumference, femur length | $\text{Log}_{10}$ weight = 1.3596 − 0.00386 AC × FL + 0.0064 HC + 0.00061 BPD × AC + 0.0424 AC + 0.174 FL |

*AC, abdominal circumference; FL, femur length; BPD, biparietal diameter; HC, head circumference.

combinations of three or more parameters resulted in significantly (p = 0.05) better weight estimates than those using measurements of head and abdomen (e.g., biparietal diameter and abdominal circumference, head circumference and abdominal circumference). The largest random errors (the standard deviation is an index of random errors) resulted from use of the model of Shephard et al.[2]; the size of the error (1 SD = 10.1%) is identical to the standard deviation of the regression originally reported by Warsof and associates[3, 4] with use of the biparietal diameter and abdominal circumference. The standard deviation for our head circumference and abdominal circumference model is slightly higher (9.8% versus 9.1%) than previously reported.[1] The standard deviation for our abdominal circumference and femur length model is slightly lower (7.7% versus 8.2%) than previously reported. These differences, and the minor differences in standard deviations for biparietal diameter, abdominal circumference and femur length (7.3% versus 7.7%), head circumference, abdominal circumference, and femur length (7.4% versus 7.6%), and biparietal diameter, head circumference, abdominal circumference, and femur length (7.3% versus 7.5%), are not statistically significant (p = 0.05).

Of some concern is the finding of small systematic errors (in this context the mean deviation is an index of systematic error) for several of the models (Table I). The largest systematic error was 2.3% for the head circumference, abdominal circumference, and femur length model. The reason for this systematic error is not readily apparent; it may be related to the fact that

| *Mean deviation ± SD (%†)* | | |
|---|---|---|
| *3000-3500 gm (n = 20)* | *3500-4000 gm (n = 16)* | *>4000 gm (n = 19)* |
| 1.5 ± 8.4 | 2.8 ± 8.8 | 2.5 ± 7.1 |
| −0.8 ± 6.6 | 4.2 ± 7.5 | 5.1 ± 5.9 |
| −1.9 ± 7.2 | −0.7 ± 6.8 | 5.2 ± 5.2 |
| 0.1 ± 6.0 | 1.4 ± 7.1 | 4.8 ± 5.1 |
| 0.2 ± 5.9 | 3.2 ± 6.9 | 6.3 ± 5.1 |
| 0.9 ± 5.9 | −1.2 ± 7.2 | −4.0 ± 5.2 |

**Table III.** Comparison of weight-estimating models derived from fetal populations of different sizes*

| *Fetal parameters* | *Mean deviation ± SD (%)* | *Coefficient of determination (%)* |
|---|---|---|
| Head circumference, abdominal circumference | | |
| Model 1 | 0.4 ± 9.1 | 95.2 |
| Model 2 | 0.4 ± 9.1 | 96.5 |
| Abdominal circumference, femur length | | |
| Model 1 | 0.3 ± 8.2 | 96.0 |
| Model 2 | 0.3 ± 8.0 | 97.3 |
| Biparietal diameter, abdominal circumference, femur length | | |
| Model 1 | 0.3 ± 7.7 | 96.5 |
| Model 2 | 0.3 ± 7.5 | 97.6 |
| Head circumference, abdominal circumference, femur length | | |
| Model 1 | 0.3 ± 7.6 | 96.5 |
| Model 2 | 0.0 ± 7.5 | 97.6 |
| Biparietal diameter, head circumference, abdominal circumference, femur length | | |
| Model 1 | 0.3 ± 7.5 | 96.5 |
| Model 2 | 0.1 ± 7.4 | 97.7 |

*Model 1 refers to our original study[1] (n = 167). Model 2 refers to a combined population (n = 276); the regression equations are listed in Table II.

many of the examinations in this study were performed by physicians with less experience than those in the previous study.

## Comment

Although the mean deviation and standard deviation of a regression model from a given population are useful indices of the magnitude of the systematic error and random error which one could expect using the model, it is important to keep in mind that there is an inherent bias in favor of the model, since it is in effect being tested on the population from which it was developed. It is appropriate therefore to initiate further testing of the model(s) in a new population of patients. The results from the 109 fetuses in this population indicate that the systematic and random errors for the models generated in our previous study are accurate estimates of these errors in our general population.

A second question that one should attempt to answer is whether the original sample population was large enough to be truly representative of a general population of fetuses. In order to answer this question, we combined the original study population (n = 167) with the current study population (n = 109) to form a composite population of 276 fetuses. We then evaluated the various combinations of fetal parameters previously reported,[1] using regression analysis to determine whether improvements in the accuracy of the weight-estimating procedure (as indicated by the standard deviation of the regression) could be achieved by the increased sample size. The differences in the accuracy of the old and new models, which are summarized in Tables II and III, are not statistically significant (p = 0.05). There was a slight increase in the coefficient of determination ($r^2$) for the models based on the population of 276 fetuses, which indicates that these models explain a slightly higher percentage of the observed variability than the previous models. We do not feel that these differences are clinically significant.

One fetus that we have evaluated subsequent to this study provides a useful example of why it is important to analyze head size, trunk size, and length when attempting to estimate fetal weight in utero. This fetus, which had profound microcephaly secondary to an early viral infection in utero, had the following measurements: biparietal diameter, 5.7 cm; head circumference, 21.3 cm; abdominal circumference, 28.5 cm; femur length, 7.5 cm. The weight estimation based on the model of Shepherd et al.[2] using biparietal diameter and abdominal circumference resulted in an error of

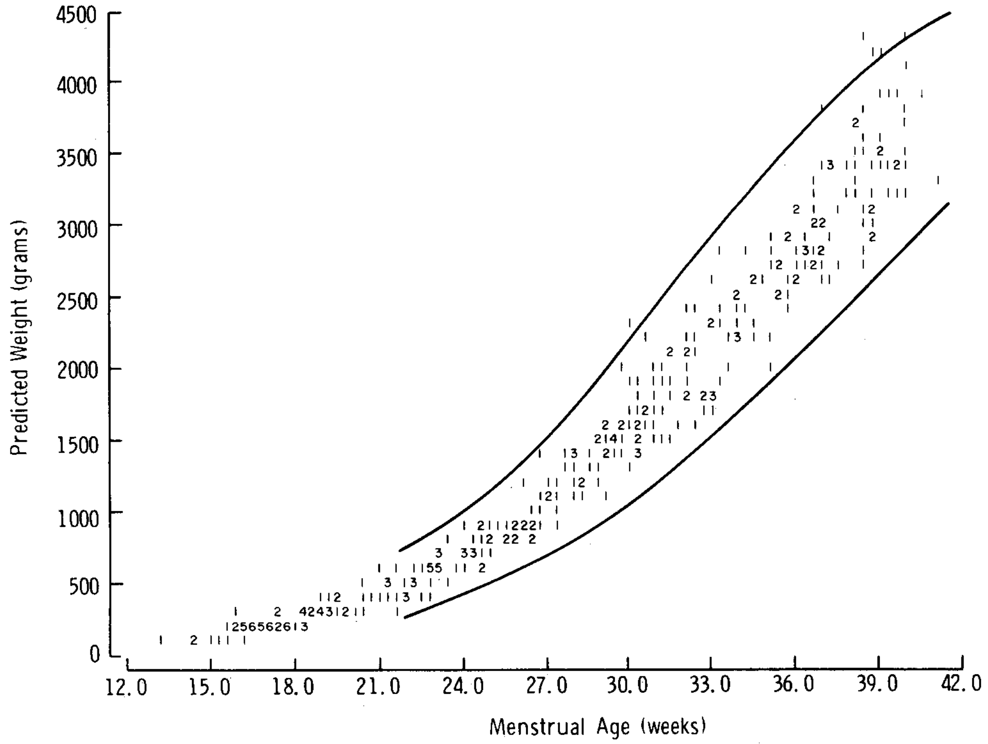

**Fig. 1.** Distribution of weight estimates in 361 normal pregnancies with the use of the head circumference, abdominal circumference, and femur length model.[1] The *solid lines* represent the 10th and 90th percentiles for birth weight based on the study of Williams et al.[6]

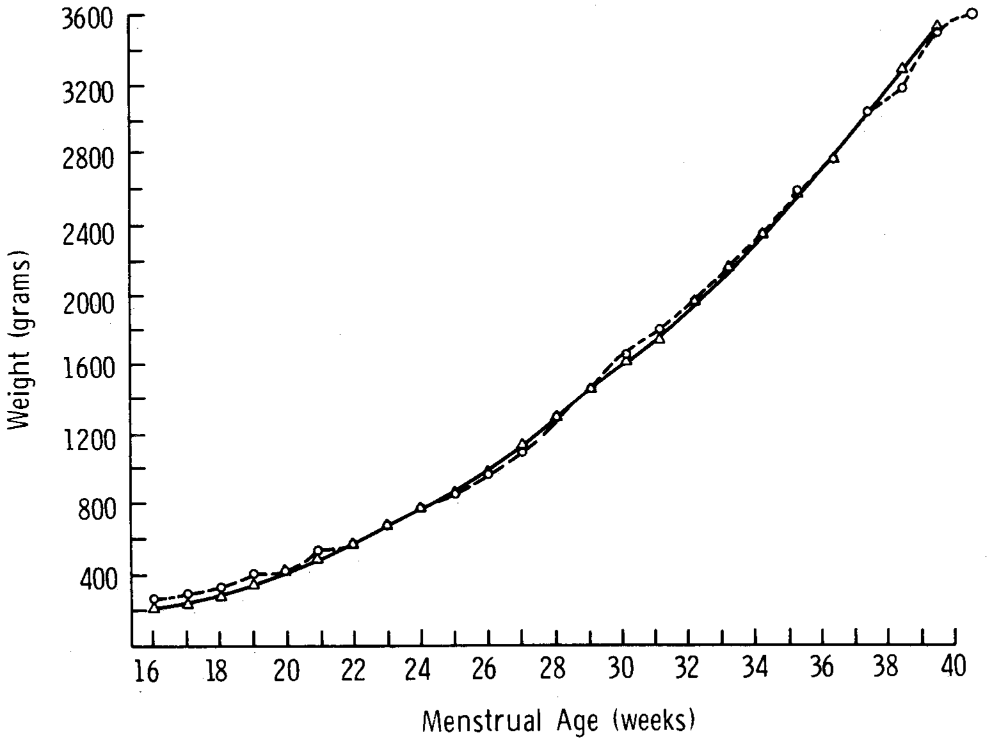

**Fig. 2.** Mean predicted weight at each week of gestation with use of the head circumference, abdominal circumference, and femur length model[1] in 361 normal pregnancies (o---o) compared with the expected weight at each week of gestation based on the longitudinal study of Deter et al.[7] (△——△).

1197 gm (46.8%), whereas the model using head circumference, abdominal circumference, and femur length resulted in an error of 165 gm (7.3%) when compared to the actual birth weight of 2250 gm.

A recent report[5] has questioned the validity of currently available in utero weight standards such as the study by Williams et al.[6] of over two million newborn infants. The argument against such standards is based on the premise that preterm deliveries (which are used in part to create these standards) are not normal physiologic events and that it may be erroneous to assume that these are normal fetuses. Ott and Doyle[5] has suggested the use of a new fetal weight standard based on in utero sonographic weight estimates of 186 fetuses by means of the model of Shephard et al.[1] (biparietal diameter and abdominal circumference). Given the inherent error in this weight-estimating procedure (2 SD = ±20%),[2-4] we feel that the weight standard suggested by Ott and Doyle[5] should not be substituted for standards such as those of Williams et al.[6] In fact, when we evaluated our optimal model[1] (head circumference, abdominal circumference, and femur length) on 361 normal fetuses in utero, the shape of the weight curve was identical to that reported by Williams et al.[6] (Fig. 1), and almost all data points fell within the normal range. Moreover, when we compared the mean weight estimate at weekly intervals in this population with the predicted weight based on the longitudinal study of Deter et al.,[7] the growth curves were virtually identical (Fig. 2). We conclude that weight standards such as those of Williams et al.[6] are appropriate standards of normal growth for the populations from which they were derived. When choosing such a standard for one's own population, it is of obvious importance to consider race, sex, socioeconomic factors, geographic locale, or any other factor that may influence the normal weight range in a given population of fetuses.[8]

In summary, our study establishes two points: (1) it confirms that the addition of femur length to head and abdomen measurements increases the accuracy of in utero weight estimates based on ultrasound studies, and (2) it demonstrates that the regression models from our original study[1] based on 167 fetuses are accurate estimators of weight in our general population. In our previous report we suggested that the head circumference is a better index of head size than the biparietal diameter (primarily because of its relative shape independence) and that the head circumference, abdominal circumference, and femur length model could be considered the best overall model. Because of the small systematic error observed in use of the original head circumference, abdominal circumference, and femur length model in our prospective population, we suggest that the new head circumference, abdominal circumference, and femur length equation in Table II be considered the optimal weight-estimating model for general use. Clearly, when a given measurement is technically inadequate or impossible to obtain (e.g., the head measurement when the head is deeply engaged), a model should be chosen based on the measurements available. Finally, it must be emphasized that population differences or subtle differences in imaging and measurement techniques may change the form of the optimal equation or the values of its coefficients.[1]

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