Estimation of Fetal Body Weight in Twins: A New Mathematical Model

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ABSTRACT

Objectives: Evaluation of a new mathematical formula (FEMUR 4) derived from twin population to estimate fetal weight in twins using ultrasound.

Design: retrospective analysis of ultrasonic measurements of 103 twins from 30 – 40 wks of gestation born within 3 days of ultrasonic examination.

Setting: Al Yarmouk Teaching Hospital, Baghdad, Iraq.

Methods: Between Sep. 2004 and Dec. 2005 at the Obstetric and Gynecological department in Al- Yarmouk Teaching Hospital a cross-sectional ultrasonic measures obtained from 107 twin pregnancies, estimated fetal weight was calculated using mathematical model of Campbell, Shepard, and Hadlock, the calculations were repeated for the model Femur 4, all models were compared against Femur 4.

Results: Femur 4 had been found to have positive correlation with actual birth weight with coefficient of determination of linear regression value of 0.859. It had the percent of estimation of fetuses within 10 percent of their actual BW (87.9 percent). It had the mean percentage error of 0.03 (6.52) compared to singleton derived formulae. In fetal growth deviation it had been found to have accuracy rate in detecting those below their 10th centile for gestational age of (90.8 percent) and (96.1 percent) in disclosing those who were growth discordant twins.

Conclusion: Femur 4 seems to be more reliable than singletone derived formulae in estimating fetal weight in twins, and in general, American population designed formulae are probably still applicable on our Iraqi people.

Key Words: twin pregnancy• new formula• estimated body weight• ultrasound

Introduction

The accuracy of ultrasonographic estimated fetal weight has reported to be lower for twin gestations than for singleton gestations.[1]

To evaluate the prenatal growth profile quantitatively, a set of measurements must be obtained. These measurements should be reliable, reasonably insensitive to technical errors, and can be obtained postnatally, the measurement include:

(1) Head size
(2) Trunk size
(3) Femur Length
(4) Estimation of fetal body weight: as fetal weight cannot be measured directly, it must be estimated with other anatomic parameters. A variety of weight estimation functions have been derived based primarily on head, abdomen, and limb measurements [2,3,4]. Increasing maternal obesity decreases the accuracy of sonographically determined fetal weight in twin gestations [5]
(5) Additional parameters: such as trunk length [6] and thigh circumference [7] have also been used.

In twin pregnancy, the increased risk of IUGR and preterm delivery makes accurate estimation of fetal weight a matter of further concern compared to singleton gestation. In 1993, an equation was derived from fetal measurement obtained from 73 twins they have called this model Femur 4, this formula incorporated (AC) and (FL) as shown below:

Log10 (BW) = 0.0259 (AC) + 0.6720 (FL) – 0.0475 (FL) ^ 2-2.7606 [8]

This study was conducted aiming at testing the validity of the Femur 4 model by comparing it to the conventional singleton – derived models in assessment of fetal body weight in twin.

Subjects and Methods

a cross-sectional ultrasonic study was conducted on 107 twin pregnancies, all were admitted to the labour room in early labour, or to the obstetric ward for preoperative preparation for elective caesarean section, as cases of threatened preterm labour and of the latter only those on whom medical treatment to inhibit labour was failed and they proceeded to active labour and delivered within 72 hours of ultrasonic measurements were chosen. Patients agreed to participate in this study by verbal consents.

Patients were included in the study follow the criteria of twin viable pregnancies, of gestational ages beyond potential viability (more than 28 weeks to term pregnancies, apparently healthy, had no obstetric or chronic medical complications that might affect fetal body weights as judged by their antenatal visit records (if any were available) and by history taking and thorough physical and obstetric examinations and simple investigations i.e. no evidence of diabetes mellitus, hypertension or severe anemia. All had no history of drug abuse and smoking, their fetuses were devoid of gross congenital anomalies as was declared by previously performed ultrasound, our scan, and postnatal infants clinical examinations by neonatologist and personally, and finally twin were regarded of discordant growth if the intra- pair difference in actual body weight >20%.

The interval from ultrasonographic examination to delivery was from hours to not more than 3 days, longer than this, patients were re-examined after their agreement then included in the study.

Thorough examination done for each fetus until the final measurement was fixed. Machine used was a real

time scanner (SIEMENS SONOLINE VERSA) with a 3.5 MHz transducer.

Biometric parameters obtained were including:

Biparietal diameter (BPD)

Head circumference (HC)

Abdominal circumference (AC)

Femur length (FL)

The obtained measures were in MMs, converted to CMs to be replaced in each of the chosen formula except for Hadlock's model which expresses BW in

gms, thus, the rest formulas were giving the BW in Kgs.

Shortly after birth, weight measured for each of the twins by a standard measuring device. The umbilical cord clamp was weighed and subtracted from the originally measured weight; the obtained body weight was approximated to nearest 10gms and regarded the actual birth weight throughout the study. The models used in our study are illustrated in table (1).

Table (I) The parameters (variables) used by each chosen model [9]

Model	Mathematical formula
Campbell	$\text{Log}_e(BW) = 4.564 + 0.282\,(AC) - 0.00331\,(AC)^2$
Shepard	$\text{Log}_{10}(BW) = -1.7492 + 0.166\,(BPD) + 0.046\,(AC) - 2.646\,(AC*BPD)/1000$
Hadlock	$\text{Log}_{10}(BW) = 1.326 - 0.00326\,(AC*FL) + 0.0107\,(HC) + 0.0438\,(AC) + 0.158\,(FL)$
Femur 4	$\text{Log}_{10}(BW) = 0.0259\,(AC) + 0.6720\,(FL) - 0.0475\,(FL)^2 - 2.7606$

Statistical analysis:

Applied on 103 twin pairs, 4 cases were excluded because incomplete measurements were obtained sufficient to be replaced in all models. For each equation, the coefficient of determination of linear regression (R^2) value {it is test to measure the degree of correlation relationship} between actual and predicted weight was calculated.

Infants categorized into 3 groups according to weight, those <2000gms, between 2000 and 3000gms, and > 3000gms.

Proportion of infants who had predicted weights within 10% of actual birth weight was calculated for each model and for varying birth weight categories.

For each equation, the mean percentage error and standard deviation (SD) between the actual and predicted weight were determined. The calculation was repeated again for different birth weight groups.

The 10th centile weight for gestational age was determined according to singleton weight chart.

A comparison in weight between the members of each twin was carried out and growth discordant pairs identified.

Results:

Total 103 cases (206) fetuses were included in the study.

Mean actual birth weight was 2.341± 0.412 kg (minimum birth weight was 1.450 Kg and maximum birth weight was 3.200 Kg).

Mean gestational age was 35.45 ± 2.08 weeks (minimum gestational age was 30 weeks, and maximum was 40 weeks).

The interval of gestational age in weeks and the number of fetuses born within this interval of the studied sample are shown in table 1.

Table 1: The number of twins born to each gestational age interval

Gestational age in Wks	No. of twins
30 -33 +6	25
34 – 36 +6	43
37 – 40	35
Total	103

Categorized actual birth weight into 3 birth weight groups: Those < 2000, 2000 – 3000, and > 3000 gms. Each birth weight group contained 47, 142, and 17 newborn babies respectively.

Forteen twins were diagnosed to be growth discordant, and 89 didn't show considerable intra-pair differences.

New borns who were below the 10th centile of weight for gestational age were 31, fetuses within 10th to 90th centile were172, and those >90th centile were 3.

When R^2 values were calculated for each formula, the following results obtained: for Femur 4, it was 0.859, for Hadlock's 0.857, for Shepard 0.790, and for Campbell was 0.739, as shown in table 2.

Table 2: The R^2 value for each of the chosen formula

Model	R^2 value
Campbell	0.739
Shepard	0.790
Hadlock	0.857
Femur 4	0.859

The percentages of fetuses lied within 10% of their actual birth weight of the total sample studied were: 87.9% for Femur 4, and 82%, 74.76%, and 66% for Hadlock, Shepard, and Campbell respectively.

According to birth weight groups:
Femur 4 had an 88.7% & 85.1% ability to diagnose fetuses within 10% of actual birth weight for fetuses with birth weight of 2000-3000 gm & those under 2000 gm respectively.

In the heaviest birth weight group i.e. >3000 gm, the action of all formula was comparable with 88.2% detection ability.

For both Femur 4 and Hadlock, their action was not significantly affected by birth weight groups with P value of 0.805 and 0.277 respectively, while for Campbell and Shepard, their ability to diagnose fetuses within 10 % of actual birth weight was significantly affected by birth weight groups with P value of 0.001 and 0.006 respectively, as shown in table 3.

Table 3: The proportions of babies estimated birth weights within 10% of actual weight.

Weight grams	Campbell	Shepard	Hadlock	Femur 4
All weights	66	74.76	82	87.9
< 2000	38.3	57.4	74.5	85.1
2000 – 3000	72.5	78.9	83.8	88.7
>3000	88.2	88.2	88.2	88.2
P value	0.001	0.006	0.277	0.805

* Values are given as % and corresponding significance for each formula to be affected by birth weight group

Table 5 illustrates the mean percentage error and standard deviation for all weights, and for each birth weight group. In babies who weighed between 2000 – 3000 grams Femur 4 yielded a mean percentage error of 0.49 and SD of 5.96 i.e. it systematically over estimate the body weight by 0.49 with random error of 5.96, Hadlock systematically over estimates the body weight by -3.60 with random error of 6.57, & 4.03 8.29 respectively, as shown in table 4.

Table 4: Errors in the prediction of fetal weights based on four equations.

Weight gms	Campbell	Shepard	Hadlock	Femur 4
All weights	2.61 (12.69)	- 0.16 (9.71)	- 3.70 (6.92)	0.03 (6.52)
< 2000	-0.50 (21.46)	-4.68 (10.77)	-3.83 (7.62)	0.85 (6.75)
2000 – 3000	4.03 (8.92)	1.78 (8.56)	- 3.60 (6.57)	0.49 (5.96)
> 3000	- 0.56 (8.83)	- 3.86 (11.07)	- 4.27 (8.09)	- 6.16 (7.42)

*Values are given as a mean percentage error (SD)

In the prediction of babies below 10th centile for weight, those who were really below their 10th centile were thirty-one in number (fifteen %), Femur 4 diagnosed 34 (16.5%), Hadlock detected 56 (27.2%), Shepard found 41 (19.9%) and Campbell found 38 (18.4%), thus, the sensitivity using Femur 4 was 74.2% the specificity, negative, and positive predictive values being of 93.7%, 95.3%, and 67.6% respectively, its accuracy 90.8% compared to Hadlock, Shepard, and Campbell with accuracies of 83%, 85.4%, 87.9% correspondingly as shown in table 5.

Table 5: PPV, NPV, and sensitivity, specificity, and accuracy rate for babies below 10th centile for weight,

	Campbell	Shepard	Hadlock	Femur 4
Below 10th centile	38 (18.4)	41 (19.9)	56 (27.2)	34 (16.5)
Sensitivity	71	67.7	83.9	74.2
Specificity	90.9	88.6	82.9	93.7
PPV	57.9	51.2	46.4	67.6
NPV	94.6	93.9	96.7	95.3
Accuracy (efficiency)	87.9	85.4	83	90.8

* Values *are given as % unless an otherwise indicated*

Twins who were actually growth discordant were 14 in number, the same number. Detected by Femur 4; those detected by Hadlock model were 11, by Shepard and Campbell 14 and 17 respectively.

Thus, the sensitivity in detecting growth discordance using Femur 4 was 85.7%. The overall accuracy rate for Femur 4 was 96.1%, which was little bit higher (statistically significant) than those of the rest of the formulae (table 6).

Table 6: Sensitivities, specificities, PPVs. and NPVs for growth discordance.

	Campbell	Shepard	Hadlock	Femur 4
Growth discordant set	17(16.5)	14(13.6)	11(11.2)	14(13.6)
Sensitivity	78.6	64.3	73.9	85.7
Specificity	93.3	94.4	94	97.8
PPV	64.4	64.3	60.7	85.7
NPV	96.5	94.4	96.6	97.8
Accuracy	91.3	90.3	91.8	96.1

*Values are given as % unless otherwise indicated

Discussion:

Previous investigations have shown fetal weight to be important in predicting morbidity and mortality and in assessing fetal growth [10].

A prediction of fetal weight derived from sonographic measurements of fetal anatomy is generally considered more accurate than one obtained by clinical examination [11].

Clinical estimates of fetal size, either subjective or by symphyseal-fundal height have a reported sensitivities and specificities vary widely with the former's sensitivity 30% and latter's sensitivity 27-86% respectively [12, 13].

In this study of total 103 twins included the mean gestational age was 35.45 weeks ± (2.08 SD), and it was close to the mean length of gestation in twins that is of 35 weeks [14].

The predicted fetal weight obtained by each model have positive correlation with actual birth weight, with Femur 4 and Hadlock's models having the highest R^2 values that is of 0.859 and 0.857 respectively, this were better yielding compared to Shepard and Campbell with R^2 values of 0.790 and 0.739 respectively. These results were similar to those which were obtained by Stephen Ong et al [9] with R^2 values of 0.852 for Femur 4 and 0.840 for Hadlock's.

For Shepard's model (depends on BPD and AC), it did better in twins' body weight estimation from singletons with improving ability to pick up those babies up to 10% of their actual birth weight, with ratios of 74.76% and 50.7% as in Shepard's et al. similar results for Shepard's were obtained by Stephen Ong et al, with percent of 65% [9] and 50.7% for twins and singletons consequently. But it is back withdrawal in twins is that, its action is significantly affected by birth weight groups.

In testing the ability of each model in diagnosing fetuses lie within 10% of actual birth weight in twin population, Femur 4 had the highest percent that was of 87.9% this compared well with Stephen Ong et al (71.4%).

The performance of Femur 4 was not affected significantly by birth weight groups, while the performance of singleton – derived formulae regressed in twins e g, for Campbell which has the ability to diagnose up to 74% as in Nahum et al study [15] within 10% of actual birth weight its action dropped to 66% in twins in this study and even further reduced in the study of Stephen Ong. et. al. to 57.6% (note that Campbell's model depends on AC alone).

For Hadlock's model (depends on AC, HC, and FL) yielded relatively comparable performance in twins and singleton population of 82% and 78% respectively, Nahum et al [15], with additional gain that it's not affected significantly by birth weight groups.

This may be explained as follows, formulae incorporate more than one body part such as BPD, HC, AC and FL, have the highest accuracy for in utero weight estimation Hadlock's et al [16].

In reverse to the results obtained by Ong et al in which Femur 4 gives over estimation for infants weighed > 3000 grams by + 4.54 (813) [9], in our study Femur 4 under estimated such birth weight group by – 6.16 (7.42), probably this can be explained by the small number of this group in the current study 17 compared to 45 babies for the former study.

Regarding deviation in fetal growth in twin pregnancy for those who were below 10th centile and growth discordant twins, Femur 4 has improved the overall accuracy of sonographic fetal biometry with sensitivity, specificity, PPV, and NPV of 74.2%, 93.7%. 67.6%, and 95.3% compared to 62%, 96%, 47% and 98% for each value in singleton – derived model, Nahum et al [15].

Other study shows that the accuracy of ultrasonographic estimated fetal weight seems to be lower for twin gestations than for singleton gestations, especially for second twins. These data should be considered by clinicians when making decisions based on ultrasonographic characteristics [17], while still 3D sonography allows superior fetal weight estimation by including soft tissue volume [18].

One matter to be discussed is whether those formulae derived from American population suit our population, similar to our results, Venkat et al[19] concluded that Campbell, Shepard, and Hadlock's formulae derived from American ethnicity were equally useful in South- East Asians.

Fetal biometry continues to have an important role in estimation of fetal weight which and when plotted on customized charts will give an indication of the growth status of the fetus. There is a need for improved screening and further investigation of those babies who are at risk including twin pregnancies and in conditions when accurate estimation of fetal weight in twins may affect management plan, time and mode of delivery, fetal biometry using the mathematical model of Femur 4 seems to be more reliable. While those formulae designed for American population are probably still applicable on our Iraqi population keeping in mind that we used them in twin pregnancies.

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