Prediction of Newborn Birth Weight Based on the Estimation at 20–24 Weeks of Gestation

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SUMMARY

Objective: The aim of this study was to develop a mathematical equation to predict the birth weight during the second trimester at 20–24 weeks of gestation.

Materials and Methods: In a university hospital, 110 healthy pregnant women were eligible for inclusion at 20–24 weeks of gestation. We recorded the maternal weight (pre-pregnancy, mid-pregnancy, and at delivery) and body mass index (BMI), newborn birth weight, time period from ultrasound examination to term delivery, and also the fetal biometrics sonographically at 20–24 weeks of gestation. Pearson's correlation was used to verify the extent of the relationship between all the above measurements and the newborn birth weight. Multiple regressions with the stepwise method were used to analyze maternal weight factors, fetal biometrical factors, and pregnancy interval. An equation for term birth weight estimation during the second trimester was determined.

Results: Maternal BMI at mid-pregnancy, time interval from mid-pregnancy to term, and abdominal circumference had the highest correlation with newborn birth weight ($r = 0.388$, 0.341, and 0.315, respectively, $p < 0.05$). Using the stepwise regression analysis, an optimal formula with variance of 0.303 was derived: estimated birth weight $= -700 + 49.766 \times$ (mid-pregnancy BMI [kg/m^2]) $+ 13.362 \times$ (time interval from mid-pregnancy to term delivery [days]) $+ 68.696 \times$ (abdominal circumference [cm]).

Conclusion: We propose an accurate, simple, and easy formula to better assess the newborn birth weight at mid-pregnancy for the Asian population. Mid-pregnancy BMI was a more significant factor for birth weight estimation than other maternal weight factors in this study. [*Taiwan J Obstet Gynecol* 2010;49(3):285–290]

Key Words: birth weight estimation, fetal biometrics, maternal body mass index, pregnancy interval, ultrasound

Introduction

Predictions of fetal weight during pregnancy are useful for making clinical decisions in obstetrics. Traditionally, clinically estimated fetal body weight has used the results of abdominal examinations, such as symphysis-fundus height measurement and gestational age. Over the past 30 years, a number of equations for estimating fetal weight have been proposed using measurements of fetal biometrics sonographically, including biparietal diameter (BPD), abdominal circumference (AC), and femur length (FL). The Aoki formula [1] is the most commonly used in Japan; the Hadlock formula [2] in the United States; and the Campbell and Wilkin [3] and the Shepard formulas [4] in the United Kingdom. Although estimation of fetal weight using ultrasound has its limitations, the mean absolute percentage of error of sonographically predicted birth weight ranges between 6–15% [5].

Diagnosis early during pregnancy may be useful when clinical decisions are based on accurate estimates because this may prevent premature delivery, leading to surgical delivery and the potential hazards of delivering

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possible macrosomic infants vaginally [6]. It is also crucial to consider maternal body mass index (BMI) during pregnancy because excessive weight gain is an independent risk factor for macrosomia and increased rate of cesarean birth [7].

Most estimations of fetal weight are carried out late during pregnancy and are used to determine current fetal weight and term birth weight. There have been a few reports that predict the birth weight at term as early as mid-pregnancy [8–10]. The aim of our study was to examine the relationship of term birth weight to maternal weight factors, pregnancy time interval and sonographic fetal biometrics, and to develop a simple and easy mathematical equation for term birth weight estimation at mid-pregnancy based on maternal factors, pregnancy intervals, and fetal biometric factors.

Materials and Methods

From January 2000 to December 2002, a total of 148 pregnant women were selected for this study from the Department of Obstetrics and Gynecology in the Chung Shan Medical University Hospital. The women in this study are healthy, primiparous or multiparous carrying with only one fetus when undergoing examination. Gestational age is based on LMP dating. The inclusion criteria for subjects included maternal normality were singleton pregnancy, accurate last menstrual period, regular menstrual cycles, no substance use, and no history of diabetes or hypertension. Exclusion criteria from our analysis were fetal congenital malformations, fetal death, gestational age less than 37 complete weeks, twin pregnancies, missing records, and unspecified pregnancy duration. A total of 110 women were eligible for inclusion in the analysis.

The maternal age, pre-pregnancy weight and height, BMI, and date of last menstrual period were recorded at the time of the first prenatal visit. At mid-pregnancy (between 20–24 weeks of gestation), the maternal weight, weight gain, BMI, BMI gain, and date for ultrasound examination were recorded. At admission to the hospital for delivery, the measurements of maternal weight as mentioned above, the date of delivery, and the time interval from ultrasound examination at mid-pregnancy to term delivery were recorded.

As reference standards, gestational ages were calculated from the first day of the last menstrual date. Maternal age was defined as age in completed years. Documented term birth weight was obtained at delivery.

All pregnant women at the time of mid-pregnancy underwent ultrasound measurements for fetal BPD, occipitofrontal distance (OFD), AC, FL, humerus length, tibia length (TL) and fibula length using an ultrasound machine (Hewlett Packard Image Point Hx, Andover, MA, USA) with a 3.5 mHz curvilinear array probe. All of the measurements for fetal biometrics were performed by one well-trained sonography technician.

The BPD and OFD were measured from the leading edge of the skull to the leading edge (BPD, the outer margin to the inner margin of the skull; OFD, the outer margin to the outer margin of the skull) at the standard level for intracranial landmarks, including the falx, cavum septum pellucidum, third ventricle, and thalamic nuclei. Head circumference was calculated using BPD and OFD $[(BPD + OFD) \times 3.14/2]$. AC was measured in a plane perpendicular to the fetal spine where the umbilical vein enters the fetal liver. FL was measured from the greater trochanter to the distal femur excluding the distal epiphysis.

All data were analyzed using SPSS version 10.0 (SPSS Inc., Chicago, IL, USA). Multiple regressions were used to determine the relationship of the newborn birth weight to three defined parameters: maternal weight factors such as weight, weight gain, BMI, and BMI gain; fetal biometric factors measured during mid-pregnancy; and pregnancy time interval from mid-pregnancy to term. The Pearson's correlation was used to verify the extent of the relationship in all of the above measurements to the term newborn birth weight. Statistical significance with a two-tailed test was defined as a p value of < 0.05. The stepwise method analysis was performed to yield a predictive model, which was used to estimate term newborn birth weight at the time of delivery.

Results

A total of 110 patients fulfilled our inclusion criteria and their clinical characteristics and measurements are shown in the Table. The mean maternal age for all patients was 29.6 years (range, 22–38). The mean maternal height and weight pre-pregnancy was 158.5 cm (range, 148.0–168.0 cm) and 51.7 kg (range, 40.0–69.8 kg). The mean maternal weight gain was 15.6 kg (range, 5–33 kg) throughout the pregnancy and 9.79 kg (range, 3–21 kg) from mid-pregnancy to term. The maternal BMI was 20.6 kg/m^2 (range, 16.7–28.7 kg/m^2) at pre-pregnancy, 22.9 kg/m^2 (range, 18.7–30.8 kg/m^2) at mid-pregnancy, and 26.8 kg/m^2 (range, 20.4–39.4 kg/m^2) at term. The mean term birth weight was 3,200.99 g (range, 2,210–4,100 g). Gestational age at term delivery was 274.7 days (range, 265–294 days) and the time interval from mid-pregnancy to term delivery was 119.3 days (range, 94–150 days).

Table. Clinical characteristics and measurements in this study and variables correlated to newborn birth weight ($n = 110$)

	Mean ± SD (range)	r
Maternal parameters		
Age (yr)	29.6 ± 3.8 (22–38)	NA
Height (cm)	158.5 ± 4.1 (148.0–168.0)	NA
Weight pre-pregnancy (kg)	51.7 ± 5.8 (40.0–69.8)	0.324*
Weight at mid-pregnancy (kg)	57.5 ± 6.5 (45–75)	0.358*
Weight at delivery (kg)	67.3 ± 7.8 (49–91)	0.317*
BMI before pregnancy (kg/m^2)	20.6 ± 2.1 (16.7–28.7)	0.355*
BMI at mid pregnancy (kg/m^2)	22.9 ± 2.5 (18.7–30.8)	0.388*
BMI at delivery (kg/m^2)	26.8 ± 3.00 (20.4–39.4)	0.342*
Weight gain from pre-pregnancy to term delivery (kg)	15.6 ± 4.8	0.109
Weight gain from pre- to mid-pregnancy (kg)	5.78 ± 3.22	0.137
Weight gain from mid-pregnancy to term delivery (kg)	9.8 ± 3.8	0.180*
BMI gain from pre-pregnancy to term delivery (kg/m^2)	6.21 ± 1.93	0.112
BMI gain from pre- to mid-pregnancy (kg/m^2)	3.9 ± 1.5	0.150
BMI gain from mid-pregnancy to term delivery (kg/m^2)	2.3 ± 1.3	0.180*
Fetal ultrasound biometrics at mid-pregnancy		
Biparietal diameter (cm)	5.42 ± 0.47 (4.3–6.5)	0.300*
Abdominal circumference (cm)	17.0 ± 1.62 (13.6–20.9)	0.315*
Femur length (cm)	3.61 ± 0.37 (2.7–4.3)	0.065
Head circumference (cm)	19.4 ± 1.52 (16.0–22.7)	0.167*
Fetal abdominal area (cm^2)	23.2 ± 4.42 (15.0–34.7)	0.211*
Humerus length (cm)	3.39 ± 0.35 (2.7–4.2)	0.134
Ulna length (cm)	3.09 ± 0.35 (2.1–4.1)	0.167*
Radius length (cm)	2.97 ± 0.32 (2.3–3.7)	0.163*
Tibia length (cm)	3.17 ± 0.35 (2.3–3.9)	0.139
Fibula length (cm)	3.12 ± 0.35 (2.2–3.8)	0.181*
Time interval		
Gestational age at term delivery (d)	274.7 ± 9.4 (265–294)	0.340*
Gestational age at mid-pregnancy (d)	155.3 ± 9.6 (140–172)	NA
Time interval from mid-pregnancy to term delivery (d)	119.3 ± 11.9 (94–150)	0.341*
Newborn birth weight (g)	3,200.9 ± 377.7 (2,210–4,100)	

*$p < 0.05$. BMI = body mass index; r = Pearson's correlation coefficient; SD = standard deviation.

The Pearson's correlation analysis of variables for newborn birth weight is shown in the Table. The equation for birth weight estimation at mid-pregnancy as a function was generated from the data in this study using regression analysis. The eight variables, including maternal weight; BMI at pre-pregnancy, mid-pregnancy, and at term delivery; maternal weight gain; and BMI gain from mid-pregnancy to term delivery, demonstrated a significant positive correlation ($p < 0.05$) (Table). Maternal BMI at mid-pregnancy presented the highest Pearson's correlation coefficient ($r = 0.388$). Fetal biometrics such as BPD, AC, fetal abdominal area, ulna length, head circumference, and fibula length showed a significant positive correlation to newborn birth weight ($p < 0.05$; Table). The highest correlation ($r = 0.315$) was associated with AC. Gestational age at term delivery and gestational age from mid-pregnancy to term also showed a significant positive correlation to the newborn birth weight ($r = 0.340$ and 0.341, respectively, $p < 0.05$). The three most important variables, (Pearson's correlation coefficient, $r = 0.388$, 0.314, and 0.315, $p < 0.05$) were maternal BMI at mid-pregnancy, time interval from mid-pregnancy to term, and AC (Figure), were selected to develop an appropriate equation for estimation of birth weight.

Stepwise regression analysis generated an equation for birth weight estimation (EBW) at mid-pregnancy using three variables. The equation was: EBW (g) = $-700 + 49.766 \times$ (mid-pregnancy BMI [kg/m^2]) $+ 13.362 \times$ (time interval from mid-pregnancy to term delivery [days]) $+ 68.696 \times$ (AC [cm]), with a significant positive correlation (Pearson's correlation coefficient, $r = 0.548$, $p < 0.05$) and highest coefficient of determination (adjusted $r^2 = 0.303$). This predictive model was used to estimate the newborn birth weight at term delivery (37–42 weeks) from mid-pregnancy (20–24 weeks).

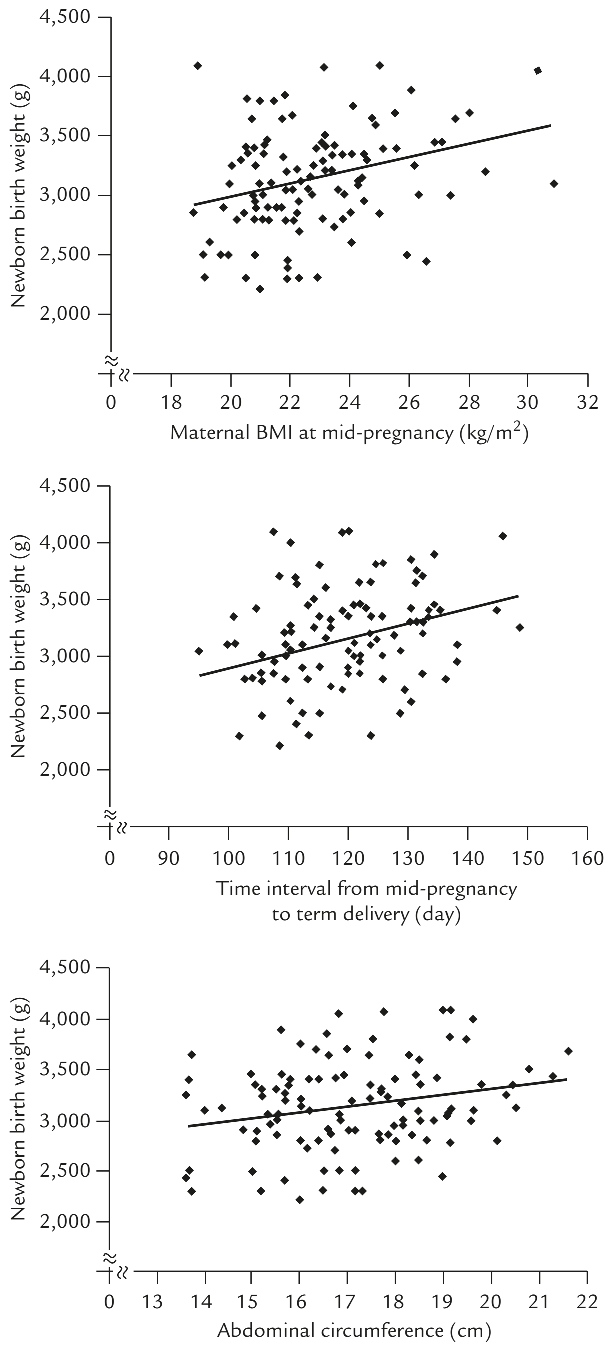

Figure. Equation generated from the three highest correlation parameters. BMI at mid-pregnancy ($r=0.388$, $p<0.05$), time interval from mid-pregnancy to term ($r=0.341$, $p<0.05$), and fetal abdominal circumference ($r=0.315$, $p<0.05$). BMI = Body mass index.

Discussion

We have been able to estimate the fetal weight indirectly from fetal or maternal anatomic characteristics during prenatal care, but actual birth weight can only be measured after childbirth. Many published formulas are used to estimate fetal weight and have been used in conjunction with ultrasound techniques to measure fetal biometrics [1–4].

These formulas have been proven to be highly accurate. Chien et al [11] performed ultrasound measurements of various fetal biometric parameters at term within a week of delivery using these formulas and they found that the validity of ultrasound estimations of fetal weight at term using four formulas was high. The intra-class correlation coefficients used to assess validity were 0.9 by the Aoki formula, 0.9 according Shepard, 0.85 by Campbell, and 0.84 by Hadlock's formula [11]. Kurmanavicius et al [5] estimated fetal weight within the last week prior to delivery from 500 g to 5,000 g. They reported that the Hadlock formula showed the most stable results out of all of the weight groups and both the Hadlock and Campbell formulas had the lowest percentages of errors [5]. Sherman et al [12] compared the clinical estimations of fetal weight that were obtained before rupture of the membranes and ultrasound estimations that were performed during the week preceding birth. They stated that the mean error and the rate of estimates were within 10% of the birth weight. Some researchers presented more accurate equations for estimation of fetal weight after the second trimester, such as Honarvar formula 1: EFW (kg) = 0.17(gestational age −20) [13], and Honarvar formula 2: EFW (kg) = 0.042FL(2) (cm) + 0.32FL − 1.36 [10]. Hotchin et al [14] presented an optimal equation to estimate fetal weight prior to 33 weeks using three fetal variables: Log_{10} birth weight = 0.714627 + 0.077362AC + 0.058758BPD + 0.287037FL − 0.011274AC × FL, where $r^2=0.91$) [14]. These formulas presented excellent accuracy and validity, and facilitated many obstetricians to make appropriate decisions when they estimated the weights of smaller or larger fetuses. However, the formulas were used mostly to estimate the fetal weight right before delivery either at term or preterm.

We have constructed a predictive model that could be used during mid-pregnancy in order to prevent pregnant women from carrying a macrosomic or small fetus. Our equation is: EBW = −700 + 49.766 × (mid-pregnancy BMI) + 13.362 × (time interval from mid-pregnancy to term delivery [days]) + 68.696 × (AC). The formula can be used to test the possibility of predicting small or large babies at 20 and 24 weeks of gestation. This formula would be valuable for obstetricians to provide appropriate prenatal care and to prevent the birth of very small or very large babies.

In this study, we tried to include many contributory factors related to birth weight such as gestational age, maternal characteristics, and fetal ultrasound biometrics. Maternal weight variables during pregnancy are significant factors that affect the newborn birth weight.

In this study, maternal weight gain and BMI gain had a significant correlation ($r = 0.18$, $p < 0.05$); however, maternal BMI and weight at 20–24 weeks of gestation showed the highest correlation coefficient ($r = 0.388$ and 0.358, respectively, $p < 0.05$). Many researchers have reported that excessive weight gain during pregnancy has been associated with multiple adverse perinatal outcomes including macrosomia, slower labor progression, shoulder dystocia, increased cesarean delivery, and future obesity [7,15–18]. According to the Institute of Medicine (IOM) guidelines, gestational weight gain has been categorized into different initial pre-pregnancy BMI: low (< 19.8), normal (19.8–26.0), high (26.1–29.0), and obese (> 29.0) [19]. Stotland et al [7] estimated approximately 288,000 primary cesarean deliveries in nulliparas in the United States 64,000 of these would have been prevented if the women had not gained weight above the IOM recommendations. The IOM recommendations for controlling weight gain during pregnancy have been the most popular guidelines used worldwide and pre-pregnancy BMI has been shown to be an important modifier in the relationship between gestational weight gain and a variety of perinatal outcomes [20–23]. Our findings were different from the published results, since our study revealed that mid-pregnancy BMI showed the highest correlation with birth weight at term delivery, not pre-pregnancy BMI nor maternal weight/BMI gain. In our predictive model, the mean BMI at mid-pregnancy was 22.9 kg/m^2 (range, 18–30 kg/m^2) and the birth weight was 3,200.99 g (range, 2,210–4,100 g). In other words, when pregnant women controlled their mid-pregnancy BMI at 22.9 kg/m^2, their newborns had a mean weight of 3,200 g at term gestation. Mid-pregnancy BMI was a more independent factor to newborn birth weight in this study. The results in our study may be limited due to the number of cases; however, most women were within the normal BMI, which resulted in few cases of high BMI or obesity, and had few larger newborns.

Our formula demonstrated variance as high as 0.303. However, predicting term birth weight at mid-pregnancy has some limitations. There are many unpredictable factors that affect birth weight during the period from mid-pregnancy to term delivery and some factors not analyzed in our study included maternal behaviors, nutrition, and exercise. As much as 30% of the factors for preventing larger and smaller infants at delivery can be practiced as early as 20–24 weeks of gestation, therefore it would be worthwhile to provide advice for maternal weight control.

Pregnancy can be an opportunity for clinicians to teach patients about healthy balanced diets that can continue for a lifetime [7]. Our findings may be useful for clinicians to provide prenatal care and to discuss weight throughout gestation, especially for women at risk of low-birth weight infants or macrosomia. Pregnant women may be persuaded to control their weight at prenatal visits during mid-pregnancy rather than before pregnancy because they feel the kicking fetus at 20–24 weeks of gestation. In conclusion, our formula was accurate, simple, and easy to assess the newborn birth weight at 20–24 weeks of gestation and may approximate the actual weight better in an Asian population.

References

1. Aoki M. Fetal weight calculation; Osaka University Method. In: Yoshihide C, ed. *Ultrasound in obstetrics and gynaecology*, 2nd edition. Kyoto: Kinpodo, 1990:95–107 [In Japanese].
2. Hadlock FP, Harrist RB, Sharman RS, Deter RL, Park SK. Estimation of fetal weight with the use of head, body and femur measurements—A prospective study. *Am J Obstet Gynecol* 1985;151:333–7.
3. Campbell S, Wilkin D. Ultrasonic measurement of fetal abdomen circumference in the estimation of fetal weight. *Br J Obstet Gynaecol* 1975;82:688–97.
4. Shepard MJ, Richard VA, Berkowitz RL, Warsof SL, Hobbins JC. An evaluation of two equations for predicting fetal weight by ultrasound. *Am J Obstet Gynecol* 1982;142:47–54.
5. Kurmanavicius J, Burkhardt T, Wisser J, Huch R. Ultrasonographic fetal weight estimation: accuracy of formulas and accuracy of examiners by birth weight from 500 to 5000 g. *J Perinat Med* 2004;32:155–61.
6. Predanic M, Cho A, Ingrid F, Pellettieri J. Ultrasonographic estimation of fetal weight: acquiring accuracy in residency. *J Ultrasound Med* 2002;21:495–500.
7. Stotland NE, Hopkins LM, Caughey AB. Gestational weight gain, macrosomia, and risk of cesarean birth in nondiabetic nulliparas. *Obstet Gynecol* 2004;104:671–7.
8. Ben-Haroush A, Yogev Y, Hod M. Predictive value of a single early fetal weight estimate in normal pregnancies. *Eur J Obstet Gynecol Reprod Biol* 2007;130:187–92.
9. Yoshida SH, Unno N, Kagawa H, Shinozuka N, Kozuma S, Taketani Y. Sonographic determination of fetal size from 20 weeks of gestation onward correlates wit birth weight. *J Obstet Gynecol Res* 2001;27:205–11.
10. Honarvar M, Allahhyari M, Dehbashi S. Assessment of fetal weight based on ultrasonic femur length after the second trimester. *Int J Gynaecol Obstet* 2001;73:15–20.
11. Chien PF, Owen P, Khan KS. Validity of ultrasound estimation of fetal weight. *Obstet Gynecol* 2000;95:856–60.
12. Sherman DJ, Arieli S, Tovbin J, Siegel G, Caspi E, Bukovsky I. A comparison of clinical and ultrasound estimation of fetal weight. *Obstet Gynecol* 1998;91:212–7.
13. Honarvar M, Allahyari M, Dehbashi S. A simple estimated fetal weight equation for fetuses between 24 and 34 weeks of gestation. *Int J Gynaecol Obstet* 1999;67:67–74.
14. Hotchin A, Bell R, Umstad MP, Robinson HP, Doyle LW. Estimation of fetal weight by ultrasound prior to 33 weeks of gestation. *Aust N Z J Obstet Gynaecol* 2000;40:180–4.

15. Thorsdottir I, Torfadottir JE, Birgisdottir BE, Geirsson RT. Weight gain in women of normal weight before pregnancy: complications in pregnancy or delivery and birth outcome. *Obstet Gynecol* 2002;99:799–806.
16. Vahratian A, Zhang J, Troendle JF, Savitz DA, Siega-Riz AM. Maternal prepregnancy overweight and obesity and the pattern of labor progression in term nulliparous women. *Obstet Gynecol* 2004;104:943–51.
17. Young TK, Woodmansee B. Factors that are associated with cesarean delivery in a large private practice: the importance of prepregnancy body mass index and weight gain. *Am J Obstet Gynecol* 2002;187:312–8.
18. Gunderson EP, Abrams B, Selvin S. The relative importance of gestational gain and maternal characteristics associated with the risk of becoming overweight after pregnancy. *Int J Obes Relat Metab Disord* 2000;24:1660–8.
19. Institute of Medicine (U.S.). Subcommittee on Nutritional Status and Weight Gain during Pregnancy, Institute of Medicine (U.S.). Subcommittee on Dietary Intake and Nutrient Supplements during Pregnancy. Nutrition during pregnancy: part I, weight gain; part II, nutrient supplements. Washington (DC): National Academy Press;1990.
20. Nuthalapaty FS, Rouse DJ, Owen J. The association of maternal weight with cesarean risk, labor duration, and cervical dilation rate during labor induction. *Obstet Gynecol* 2004; 103:452–6.
21. Bianco AT, Smilen SW, Davis Y, Lopez S, Lapinski R, Lockwood CJ. Pregnancy outcome and weight gain recommendations for the morbidity obese woman. *Obstet Gynecol* 1998;91:97–102.
22. Kirchengast S, Hartmann B. Maternal prepregnancy weight status and pregnancy weight gain as major determinants for newborn weight and size. *Ann Hum Biol* 1998;25: 17–28.
23. Ogunyemi D, Hullett S, Leeper J, Risk A. Prepregnancy body mass index, weight gain during pregnancy, and perinatal outcome in a rural black population. *J Matern Fetal Med* 1998;7:190–3.