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Maternal Body Composition Near Term and Birth Weight

FRANCISCO MARDONES-SANTANDER, MD, MSc, GABRIELA SALAZAR, MPhil,
PEDRO ROSSO, MD, AND LUIS VILLARROEL, MSc

Objective: To assess the relative influence of maternal body composition at late gestation on birth weight.

***Methods*: Maternal body composition was estimated in 224 women near term using a deuterium dilution technique. Using a stepwise multiple linear regression analysis, we studied the association with birth weight of eight factors, including maternal fat-free mass and fat mass.**

***Results*: Maternal fat-free-mass was the most important variable influencing birth weight ($R^2 = .144$, $P < .001$), followed by maternal fat mass ($R^2 = .051$, $P < .001$). Gestational age at delivery was the third strongest influence on birth weight ($R^2 = .047$, $P < .001$).**

***Conclusion*: In late pregnancy, fat-free mass was the most important maternal body component associated with birth weight. The implementation of longitudinal studies could shed more light on the influence of maternal body composition on birth weight. (Obstet Gynecol 1998;91:873–7. © 1998 by The American College of Obstetricians and Gynecologists.)**

Estimates of energy and protein requirements during pregnancy are an approximation, because they do not take into account differences in maternal body composition.[1] Furthermore, in the development of standards for optimum weight gain during pregnancy or in using weight gain to identify suboptimal pregnancies, the variability in the components of weight gain must be recognized: Fetal growth may be influenced more by specific maternal tissue changes, for example, by accretion of fat-free mass, fat mass, or body water, than by total gestational weight gain.[2]

Data concerning the effect of changes in maternal body composition on fetal growth have been considered to be meager and inconclusive.[2] Most maternal body composition studies have neither correlated body compartments with birth weight nor used reference methods, such as isotope dilution.[3–5] Isotope dilution has been considered recently as giving one of the best estimates of body composition in late pregnancy.[4] A study of healthy women was designed to assess the

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From the Departments of Public Health and Pediatrics, and Center for Medical Research, School of Medicine, Catholic University of Chile, Santiago, Chile; and Institute of Nutrition and Food Technology, University of Chile, Santiago, Chile.

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relative influence on birth weight of maternal body composition—as estimated by using isotope dilution—at late gestation.

Materials and Methods

The study was conducted in a low-income urban population of women attending one public clinic from the Southeastern Health Service of Santiago, Chile, from June 1989 to June 1990. Two hundred twenty-four women met the following enrollment criteria: singleton pregnancy, 19 years of age or older, one previous live birth, nonsmoker, nondrinker, at least 34 weeks' gestation, free of medical and obstetric conditions known to affect fetal growth, and delivery at term (38–42 weeks' gestation) of newborns free from congenital infections and anomalies. Gestational age was established from the onset of the last menstrual period; cases with uncertain dates were not included in the study.

All maternal measurements were made at recruitment. Weight and height were measured in a standardized manner following international recommendations.[6] Women were weighed on balance-beam scales while wearing only underwear and a previously-weighed light robe. Elbow breadth measurements, an indicator of maternal frame size, were performed following Frisancho's guidelines.[7]

Total body water was measured using the deuterium dilution technique of Schoeller et al[8] as we described previously for pregnant women.[9] The estimation of total body water was used in the scope of a two-compartment model (fat and fat-free mass) for the determination of body composition. It is also assumed that the fat compartment is anhydrous and that the fat-free compartment is hydrated to a certain extent. Thus, if total body water is measured, fat-free mass can be calculated and hence fat mass by difference from body weight.[5] We used the equations developed by Van Raij et al[10] to account for maternal hydration of fat-free mass at different weeks of gestation. A basal saliva sample was collected before administration of the isotopic dose and another after equilibrium was reached (2.5 hours). Samples were frozen immediately for later determinations of deuterium concentration using mass spectrometry.

Shortly after delivery, the newborn anthropometric characteristics were recorded. The association of birth weight with the following eight factors was investigated: maternal height, elbow breadth, gestational age at delivery, fat-free mass, fat mass, maternal age, sex, and parity. Apart from the body composition variables, other factors were included in the study to control their possible effect on birth weight; this effect is well known for most of these factors (maternal height, gestational age at delivery, maternal age, sex, and parity)[11] and is not established for elbow breadth.

Statistical analysis to evaluate the univariate association of each factor with birth weight included use of Pearson correlation coefficients and Student t test; significant P values were those less than .05. The eight factors were entered into a stepwise multiple linear regression analysis to select those that predict birth weight independently[12]; $P < .05$ was considered for entry and removal of variables into the model. This analysis was done both with the whole study sample, ie, cases with gestational age at recruitment of 34 weeks' and more, and with a smaller sample that included only the cases with gestational age at recruitment of 37 weeks' and more; this allowed for the evaluation of eventual changes in the predictive capacity of the different factors. Maternal weight at recruitment and total body water were not included in these analyses because of redundancy with maternal fat-free mass and fat mass data.

For selected factors in the stepwise regression models, mean birth weight values were calculated either for quintile distributions of continuous variables or for each level of categoric variables. Analysis of variance and Duncan tests were used to ascertain significant differences ($P < .05$) between mean birth weight values. The SAS/STAT program package 1989 (SAS Institute Inc., Cary, NC) was used for all data processing.

The study protocol was approved by the Ethics Committee of the Institute of Nutrition and Food Technology, University of Chile. All procedures followed were in accordance with the Helsinki Declaration of 1975 as revised in 1983. The deuterium dose given to each mother was minimal, to double approximately the existing natural basal concentration of 150 mg/L. The resulting doubled concentration is about 100 times lower than a hazardous concentration.[13]

Results

General characteristics of mothers are presented in Table 1; maternal body composition and birth weight are shown in Table 2. The sex ratio (males:females) was 1.00. Mean birth weight (g) was 3392 ± 447 in males and 3345 ± 430 in females ($P = .42$).

Univariate analysis of the association of maternal variables with birth weight showed that all except maternal age and parity correlated significantly (Table 3). However, in the multiple regression model, only fat-free mass, fat mass, and gestational age at delivery showed independent associations ($P < .05$) with birth weight (Table 4). Fat-free mass appeared to have the highest explanatory value (R^2) for birth weight, fol-

Table 1. General Characteristics of Study Participants

Variable	Mean ± SD	%
Maternal age (y)	28.2 ± 4.9	
Parity	2.7 ± 0.9	
Maternal height (cm)	154.0 ± 5.5	
Maternal elbow breadth (cm)	6.66 ± 0.55	
Maternal weight at recruitment (kg)	67.6 ± 9.7	
Gestational age at recruitment (wk)	36.6 ± 1.3	
34		3.6
35		17.4
36		28.1
37		21.4
38		22.3
39		6.7
40		0.4
Gestational age at delivery (wk)	40.0 ± 1.2	
38		13.4
39		23.2
40		29.0
41		22.8
42		11.6
Difference between both gestational ages (wk)	3.3 ± 1.6	
0		4.0
1		11.6
2		16.1
3		17.9
4		27.7
5		13.4
6		8.0
7		1.3

SD = standard deviation.

lowed by fat mass with gestational age at delivery in the third place.

In cases with 37 weeks' or more gestational age at recruitment, the multiple regression model also indicated fat-free mass as having the highest explanatory value (R^2) for birth weight, followed by gestational age at delivery, fat mass, and sex (Table 5). R^2 values for fat-free mass and fat mass were almost identical to those of Table 4, and the value for gestational age at delivery was similar. In this group, mean birth weight (g) was 3457 ± 488 in males and 3338 ± 469 in females (P = .19).

Birth weight means in each quintile of maternal fat-free mass and fat mass values showed a tendency for a positive association in both cases and a wider range for the former than for the latter (Table 6). These observations also are reflected in the presence of statistically significant differences for two quintiles against the others regarding fat-free mass; meanwhile, just one quintile had a significant difference with the others in the case of fat-mass.

Table 2. Body Composition and Birth Weight

	Mean ± SD
Total body water (L)	39.43 ± 5.51
Maternal fat-free mass (kg)	52.80 ± 7.34
Maternal fat mass (kg)	14.78 ± 5.57
Birth weight (g)	3368 ± 438

SD = standard deviation.

Table 3. Pearson Coefficients of Maternal Variables in Relation to Birth Weight

	Birth weight (P)
Maternal height (cm)	.259 (.001)
Maternal age (y)	−.004 (.946)
Parity	.029 (.663)
Maternal elbow breadth (cm)	.260 (.001)
Maternal fat-free mass (kg)	.379 (.001)
Maternal fat mass (kg)	.272 (.001)
Gestational age at delivery (wk)	.251 (.001)

Mean birth weight tended to increase positively with gestational age in newborns delivered from 38 weeks on, with the exception of those delivered at 42 weeks (Table 7). Nevertheless, mean birth weight at 38 weeks was significantly lower than at 40, 41, and 42 weeks.

Discussion

The correlation we found between fat-free mass and fetal growth might be mediated by fluid retention, including plasma volume expansion. Under normal circumstances, total body water and plasma volume are closely related,[14–16] and human and animal data show that maternal plasma volume correlates significantly with birth weight.[17] In turn, plasma volume expansion would influence certain maternal hemodynamic adjustments such as cardiac output and, ultimately, uterine blood flow.[17]

Although there were no great differences between gestational age at recruitment and at delivery, there was a potential further accumulation of both fat-free mass and fat mass for some cases in the weeks following recruitment (Table 1). Nevertheless, comparison of values from the regression models obtained for the whole study group and for the smaller sample of women, with a lower difference between gestational age at recruit-

Table 4. Stepwise Linear Multiple Regression Model for Birth Weight

Term	Coefficient	SE	P	Partial R^2	Model R^2
Constant	−1090.692	857.333			
Fat-free mass	19.640	3.547	.001	.144	.144
Fat mass	18.103	4.655	.001	.051	.195
Gestational age at delivery	78.941	21.348	.001	.047	.242

SE = standard error.

Table 5. Stepwise Linear Multiple Regression Model for Birth Weight in Women at Least 37 Weeks at Recruitment

Term	Coefficient	SE	P	Partial R^2	Model R^2
Constant	−1968.601	1205.761			
Fat-free mass	18.048	5.222	.001	.140	.140
Gestational age at delivery	103.165	29.770	.001	.078	.218
Fat mass	23.007	7.049	.002	.057	.275
Sex	−181.332	76.817	.020	.035	.310

SE = standard error.

ment and at delivery, showed that selected variables were equally good predictors of birth weight at either gestational age.

An important finding of this study was that the effect of maternal height and elbow breadth on birth weight is expressed better by the maternal body composition compartments near term. Maternal age and parity were not associated significantly with birth weight in univariate analysis, probably because most of their effect was controlled when their full range of values was excluded by study design, ie, maternal age less than 20 years old and primiparous.

The tendency for a higher birth weight in male newborns was more apparent in the women at 37 and more weeks' gestational age at recruitment than in the whole sample. This fact probably influenced the presence of sex among the selected factors in the stepwise regression analysis for this group.

Longitudinal studies of body composition have shown a progressive increase in total body water and fat mass during pregnancy, but the studies disagree with respect to absolute values reflecting methodologic limitations.[3] As discussed below, those methodologic limitations also may have affected research done in Guatemalan and Swedish women.[18,19]

Table 6. Birth Weight Means in Each Quintile of Maternal Fat-Free Mass and Fat Mass Values

	n	Mean ± SD (g)*
Maternal fat-free mass (kg)		
≤46.2	44	3165 ± 438A
46.3–51.4	45	3288 ± 356A
51.4–54.0	45	3309 ± 432A
54.0–58.7	45	3502 ± 409B
≥58.8	45	3572 ± 438B
Maternal fat-mass (kg)		
≤10.3	46	3256 ± 420A
10.4–12.9	45	3294 ± 382A
12.9–14.8	44	3355 ± 500A
14.8–19.0	45	3378 ± 416A
≥19.1	44	3564 ± 418B

SD = standard deviation.

* Means with the same letter are not significantly different.

Table 7. Birth Weight Means According to Gestational Age at Delivery

Gestational age (wk)	n	Mean ± SD (g)*
38	30	3143 ± 425A
39	52	3268 ± 439AB
40	65	3406 ± 384BC
41	51	3527 ± 451C
42	26	3422 ± 431BC

SD = standard deviation.

* Means with the same letter are not significantly different.

Recent studies of maternal body composition and fetal growth have given opposite results. A study of Guatemalan women found that fat gain early in pregnancy was associated strongly with fetal growth.[18] In contrast, a study of body composition during pregnancy in Swedish women concluded that gain in fat was not correlated with birth weight, although a relationship was found between birth weight and the change of maternal lean body mass at the beginning of pregnancy.[19]

The study of Guatemalan women could have biased estimations of both fat-free mass and fat mass due to the application of fat-free mass density equations derived from nonpregnant women.[18] The study of Swedish women included measurements of total body water based on isotope dilution, but most probably, maternal body components were estimated wrongly because the equations to account for maternal hydration of fat-free mass[10] were not used.[19] Another partial explanation of the differences between our findings and the two studies[18,19] may be related to the fact that the present study was conducted near term. In Guatemalan women, fat deposition continued until the end of pregnancy, and fat gain before the 30th week of gestation was associated strongly with fetal growth.[18] In Swedish women, fat accretion was completed at gestational week 30, and 60% already was gained by gestational weeks 16–18; meanwhile, the fat-free mass association with birth weight was found at the beginning of pregnancy.[19] Another study, which used skinfold thickness to estimate fat stores, found that gain in upper arm fat late in pregnancy is a significant predictor of a reduced birth weight.[20]

Longitudinal studies of the whole gestational period to allow for the timing of the evaluation are still needed. As changes in maternal body composition are related closely to energy balance,[4] these longitudinal studies may consider measurement of this balance.

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Address reprint requests to:
Francisco Mardones-Santander, MD
Department of Public Health
School of Medicine
Catholic University of Chile
Casilla 114-D
Santiago
Chile
E-mail: mardones@med.puc.cl

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