Sex-specific effects of maternal anthropometrics on body composition at birth

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OBJECTIVE: The purpose of this study was to assess whether maternal factors that are associated with fetal lean and fat mass differ between sexes.

STUDY DESIGN: Secondary analysis of a prospective cohort that delivered by scheduled cesarean section from 2004-2013. Maternal blood was collected before surgery for metabolic parameters. Placental weight and neonatal anthropometrics were measured within 48 hours. Anthropometric differences between sexes were assessed with the Student *t* test. Multiple stepwise regression analysis assessed the relationship between independent maternal variables and neonatal lean body mass (LBM), fat mass (FM), or percentage of fat as dependent variables in male and female infants combined and separately.

RESULTS: We analyzed 360 women with normal glucose tolerance and a wide range of pregravid body mass index (16-64 kg/m^2) and their offspring (male, 194; female, 166). Male infants had more FM (mean difference, 40 $\pm$ 18 g; $P = .03$) and LBM (mean difference, 158 $\pm$ 34 g; $P < .0001$) than female infants. Percentage of body fat and measured maternal variables did not differ between sexes. In both sexes, placental weight had the strongest correlation with both neonatal LBM and FM, which accounted for 20-39% of the variance. In male infants, maternal height, body mass index, and weight gain were significant predictors of both lean and fat mass. In female infants, plasma interleukin-6 and C-reactive protein, respectively, were associated independently with percentage of body fat and LBM.

CONCLUSION: Our findings suggest that the body composition and inflammatory environment of the mother modulate the metabolic fitness of neonates, as predicted by fat and lean mass, in a sex-specific manner.

Key words: inflammation, maternal BMI, neonatal anthropometry, placenta

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It is well-established that infants who are born small- or large-for-gestational age are at a higher risk of the development of cardiovascular disease, obesity, and metabolic deficiencies in later life.[1,2] Understanding factors that influence fetal growth in utero are of clinical interest in the determination of a child's long-term health. Maternal nutrition (ie, diet and body composition) and placental transport capability are key influences on fetal growth and are associated strongly with birthweight.[3-5] However, increasingly, it is understood that birthweight is not the only marker of perturbations in fetal growth. It was reported previously that offspring of obese mothers have increased fat mass (FM), but not lean mass,[6] in addition to increased insulin resistance,[7] which suggests that fetal adiposity is sensitive to maternal nutrition and potentially underlies long-term metabolic fitness.

There is mounting evidence that the fetus responds to the maternal environment in a sex-specific manner. Male infants are born heavier and longer to well-nourished mothers,[8] which suggests that male growth may be more sensitive to nutrient supply during pregnancy. Indeed, when mothers are nourished poorly, male infants tend to be more affected than female infants, which shows greater degrees of growth restriction (or fat deposition)[9-11] and increases in cardiovascular disease risk in later life[12]; this sensitivity may be due to a mismatch in the supply and demand of nutrients. These findings suggest that the growth of male fetuses is more sensitive to maternal nutrition throughout pregnancy and that female fetuses may be more able to adapt to minor nutritional differences.

Maternal prepregnancy and early pregnancy body composition (fat and fat-free mass or, clinically, body mass index [BMI]) indicate long-term maternal nutrition and are thought to be better predictors of fetal outcome than weight gain, a marker of nutrition during pregnancy.[13-15] Lampl et al[8] showed that birthweights of male offspring were correlated more highly with maternal weight and height than female offspring birthweights. Although Lampl et al[8] used birthweight as the primary outcome, the sex-specific effects of maternal anthropometrics on the

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TABLE 1
Maternal and neonatal characteristics

Characteristic	Male			Female		
	n	Mean ± SD	Minimum—maximum	n	Mean ± SD	Minimum—maximum
Maternal						
Gestational age, wk	191	38.8 ± 0.7	36.0—41.0	164	38.8 ± 0.6	36.0—40.0
Parity, n	194	1.7 ± 1.0	0.0—6.0	166	1.7 ± 1.1	0.0—6.0
Age, y	194	28.1 ± 5.6	18.0—46.0	166	27.3 ± 5.9	18.0—42.0
Race (black/Hispanic/white), %	193	38/12/49		164	37/10/53	
Prepregnancy weight, kg	194	81.2 ± 23.3	42.3—156.8	165	82.6 ± 24.6	43.1—164.5
Height, m	194	1.6 ± 0.1	1.5—1.8	166	1.6 ± 0.1	1.4—1.9
Prepregnancy body mass index, kg/m^2	194	30.8 ± 8.4	16.0—55.2	165	31.3 ± 8.9	16.9—64.3
Late pregnancy body mass index, kg/m^2	194	36.8 ± 7.9	20.8—57.5	166	36.6 ± 8.4	21.2—69.2
Net weight gain, kg	188	11.7 ± 8.3	−5.3—42.9	153	10.5 ± 8.5	−14.9—37.1
Insulin, μU/mL	190	18.3 ± 8.9	4.1—63.3	157	17.7 ± 9.8	3.0—73.4
Glucose, mg/dL	189	77.9 ± 9.0	54.0—118.0	156	77.0 ± 9.5	54.0—107.0
Homeostasis model assessment-estimated insulin resistance	189	3.6 ± 2.1	0.7—16.0	156	3.5 ± 2.3	0.5—19.4
C-reactive protein, ng/mL	124	9345 ± 7221	435—28,482	86	9334 ± 6891	795—26,721
Iinterleukin-6, pg/mL	111	3.8 ± 3.0	0.7—18.8	92	3.3 ± 1.7	0.9—8.5
Triglycerides, mg/dL	85	184 ± 78	56—541	67	195 ± 75	72—425
Neonatal						
Birthweight, kg	194	3.4 ± 0.5	1.9—5.0	165	3.2 ± 0.4[a]	2.1—4.8
Length, cm	192	49.3 ± 2.1	39.8—54.4	164	48.5 ± 2.0[a]	42.4—57.1
Fat mass, kg	184	0.44 ± 0.19	0.02—1.12	156	0.40 ± 0.15[a]	0.07—0.87
Lean mass, kg	184	2.9 ± 0.3	1.9—3.9	156	2.8 ± 0.3[a]	2.1—3.9
Body fat, %	184	12.5 ± 3.7	1.1—23.8	156	12.2 ± 3.3	2.9—21.0
Placental weight, g	188	685.8 ± 172.7	294.3—1316.5	155	648.5 ± 148.9[a]	298.0—1189.5
Fetal:placental weight	188	5.1 ± 0.9	2.9—8.9	154	5.1 ± 1.0	3.1—11.4
Insulin, μU/mL	183	7.5 ± 4.4	1.9—30.2	155	7.8 ± 4.5	0.8—26.3
Glucose, mg/dL	184	66.6 ± 12.6	27.0—122.0	157	66.5 ± 11.5	33.0—111.0
Homeostasis model assessment—estimated insulin resistance	182	1.2 ± 0.8	0.3—6.6	154	1.3 ± 0.8	0.1—5.3

[a] $P < .05$ vs male infants by the Student *t* test.

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