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Increasing maternal parity predicts neonatal adiposity: Pune Maternal Nutrition Study

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KEY WORDS
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Objective: This study was undertaken to study the effect of parity on maternal and neonatal characteristics.

Study design: Maternal anthropometry, diet, micronutrient status, biochemistry, and physical activity were measured during pregnancy and detailed neonatal size recorded in 770 pregnancies in rural Maharashtra, India.

Results: Increasing parity was associated with larger offspring birth weight, skinfold thicknesses, and abdominal circumference, but not head circumference and length. Compared with primiparous women, multiparous women were older, less adipose, and more physically active but had similar education, socioeconomic status, nutritional intake, and weight gain during pregnancy. They had lower circulating concentrations of hemoglobin, albumin, ferritin, glucose, and insulin and lower total leucocyte counts at 18 and 28 weeks' gestation. There was no difference in their husbands' body size. The relationship between maternal parity and neonatal weight and adiposity was significant independent of the difference in maternal characteristics.

Conclusion: Increasing maternal parity predicts increasing adiposity in the newborn infant. This may result from maternal nutritional, cardiovascular, or immunologic factors.

Increasing maternal parity is associated with increasing birth weight in the infant. This has been shown in both cross-sectional studies and serial studies of the same women across more than one pregnancy.[1-3] Only a few studies have measured birth size other than weight. The Pune Maternal Nutrition Study (PMNS) is a population-based study of maternal nutrition and fetal outcome in 6 villages near the city of Pune, Maharashtra, India.[4-6] Maternal nutritional and metabolic status was measured before and during pregnancy, and detailed anthropometric measurements of the babies were made at birth. We have used data from this study to examine the relationship of parity to different neonatal measurements of the offspring.

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Material and methods

The PMNS methodology has been described previously.[4-6] In brief, 2675 married women of child-bearing age (excluding sterilized couples), living in 6 villages (total population 35,000) were identified by a house-to-house survey. Of these, 2466 women agreed to take part in the study. The majority were illiterate, belonged to subsistence farming families, and worked on the farm as well as doing household work. Field workers visited the women monthly to record their menstrual dates, and every 3 months to record anthropometry (weight, height, head circumference, and triceps, biceps, subscapular, and suprailiac skinfold thicknesses). Maternal prepregnant fat mass was calculated by using the 4 skinfolds.[7] Women who missed 2 successive periods were examined by ultrasound at 15 to18 weeks to confirm pregnancy and assess gestational age.[8] Gestational age was derived from the last menstrual period unless it differed from the sonographic estimate by more than 2 weeks, in which case the latter was used. Women entered the study if a singleton pregnancy of less than 21 weeks' gestation was confirmed. Enrollment of pregnant women ($n = 814$) began in June 1994 and ended in April 1996. Their socioeconomic status was assessed with a standardized questionnaire, which derives a composite score based on occupation and education of the head of the household, caste, type of housing, and family ownership of animals, land, and material possession.[9] Ethical permission for the study was granted by the KEM Hospital Ethical Committee, and by the local village leaders. All participants gave signed informed consent.

For all pregnant women, additional data were collected in a standardized manner at 18 ± 2 weeks' and 28 ± 2 weeks' gestation. These included the anthropometry of the women themselves (same measurements as prepregnancy) and their husbands (weight and height, waist and hip circumferences). A total of 21 trained observers made the measurements over the period of the study, with an average of 11 observers at any given time. A total of 9 interobserver variation (IOV) studies were performed during the study. The median (IQR) coefficient of variation (CV) for triceps skinfold was 8.4% (7.2-11) and for subscapular skinfold 2.7% (1.8-12.1).

Maternal dietary intakes were measured with a semi-weighed 24-hour recall method and a food frequency questionnaire.[4] Physical activity was assessed with a structured questionnaire that recorded the time spent in a range of activities and derived a total daily score, based on the relative energy expenditure of the different activities.[6] Fasting blood samples were taken at both time points in pregnancy; in addition, at 28 weeks' gestation an oral glucose tolerance test was carried out, with blood samples taken fasting and 120 minutes after a standard 75-g oral glucose load. Hemogram, glucose, lipids, and albumin were measured at Diabetes Research Laboratory at KEM Hospital, Pune. Assays for insulin, vitamin C, red cell folate, and ferritin were performed in Southampton and Cambridge, UK. Maternal hemoglobin concentrations and total leucocyte, red blood cell, and platelet counts were measured with a Coulter T540 analyser (Beckman Coulter UK Ltd, Buckinghamshire, UK). Serum albumin and plasma glucose and triglyceride concentrations were measured with Randox kits (Randox Laboratories Ltd, Crumlin, Northern Ireland) on an Abbott Spectrum autoanalyzer (Abbott Laboratories, Abbott Park, Ill). Erythrocyte folate and serum ferritin concentrations were measured with radioimmunoassays (Beckton Dickinson UK Ltd, Oxford, UK).[4] Serum vitamin C concentrations were measured with an ascorbate oxidase-orthophenylene diamine assay on a Roche Cobas Bio Centrifugal analyzer with fluorescence attachment.[4] Plasma insulin concentrations were measured on the Access Immunoassay System (Sanofi Pasteur Diagnostics, Chaska, Minn) with the use of a 1-step chemiluminescent immunoenzymatic assay. Insulin resistance was calculated from fasting glucose and insulin concentrations by using the homeostasis model assessment equation (HOMA).[10]

The babies were measured by 1 of 3 trained field workers within 72 hours of birth. IOV studies revealed a CV of 9.5% (range 7.5-10.8) for triceps and 7.5% (range 4.0-8.8) for subscapular skinfold. At the time of these measurements, all babies were exclusively breast fed. Birth weight was measured to the nearest 25 g by using a Salter spring balance and crown-heel length to the nearest 0.1 cm using a portable stadiometer (Pedobaby, ETS, JMB, Brussels, Belgium). Triceps and subscapular skinfold thicknesses were measured to the nearest 0.2 mm, on the left side of the body, with Harpenden skinfold calipers (CMS Instruments, London, UK). Occipito-frontal head circumference and midupperarm circumference (MUAC) were measured to the nearest 0.1 cm with fiberglass tapes (CMS Instruments). Abdominal circumference was measured at the level of umbilicus in expiration. Placental weight was recorded to the nearest 5 g with the use of Ishida scales, after trimming off the umbilical cord and membranes.

Effect of seasonality was investigated for maternal and neonatal measurements in a standardized manner: summer (April-July), rainy season (August-November), and winter (December-March).

Statistical methods

Mothers were divided into 3 parity groups, which we define as follows: women who were pregnant for the first (primipara), second (para 2), and third or more times (multipara). Data represented as mean $\pm$ SD unless otherwise specified. Variables with skewed distributions (subscapular and triceps skinfold thicknesses, and maternal ferritin and insulin concentrations) were

Table I Mean (SD) maternal characteristics according to parity

Characteristics	Primipara	Para 2	Multipara	*P*	*P**
N	245	268	257		
Age (y)	18.9 (2.2)	21.0 (2.7)	24.0 (3.4)	< .001	—
Illiterate (%), College educated (%)	17.7, 10.7	18.0, 13.0	19.0, 6.6	.13	—
Socioeconomic score	27.1 (6.7)	27.0 (6.6)	26.4 (7.2)	.19	—
Before pregnancy					
Height (cm)	152.5 (4.7)	151.8 (5.2)	151.3 (4.9)	< .01	.04
Weight (kg)	42.3 (4.9)	41.6 (5.1)	41.1 (5.0)	< .01	.04
BMI (kg/m^2)	18.2 (1.9)	18.0 (1.9)	17.9 (1.9)	.09	.06
Head circumference (cm)	52.1 (1.4)	52.3 (1.5)	52.3 (1.5)	0.21	.81
Subscapular skin fold (mm)[†]	11.3 (8.9-14.1)	9.9 (7.7-12.3)	9.3 (7.5-11.6)	< .001	< .001
Fat mass (kg)	9.6 (2.6)	8.8 (2.7)	8.4 (2.6)	< .001	< .001
At 28 wks' gestation					
Physical activity score	62.1 (25.9)	64.9 (26.5)	69.8 (25.4)	< .001	< .001
Weight gain (kg)	3.2 (2.0)	3.7 (2.4)	3.5 (2.1)	.09	.06
Energy intake (kcal)	1678 (485)	1672 (499)	1671 (506)	.89	.71
Hemoglobin (g/L)	113.0 (16.0)	112.0 (14.0)	108.0 (15.0)	< .001	< .001
Total leucocyte count ($\times 10^9$/L)	9.6 (2.1)	9.1 (2.0)	8.7 (1.8)	< .001	< .001
Red blood cell count ($\times 10^{12}$/L)	3.9 (0.4)	3.9 (0.5)	3.8 (0.4)	.47	.22
Serum albumin (g/L)	37.0 (3.0)	36.0 (3.0)	36.0 (3.0)	< .001	< .001
Plasma ferritin (pmol/L)[†]	29.2 (15.7-53.9)	22.5 (15.7-40.0)	22.5 (15.7-43.1)	.84	< .01
Erythrocyte folate (nmol/L)	1062.8 (407.9)	1049.2 (396.6)	1026.5 (407.9)	.389	.09
120-min plasma glucose (mmol/L)	4.6 (1.2)	4.4 (1.1)	4.2 (0.9)	< .01	< .01
120-min plasma insulin (pmol/L)[†]	95.0 (38.0-148.0)	77.0 (36.8-143.5)	60.5 (25.8-107.3)	< .01	< .001
Insulin resistance (HOMA-R)	0.59 (0.37-0.87)	0.55 (0.37-0.88)	0.50 (0.34-0.75)	.45	.83
Plasma triglycerides (mmol/L)	1.5 (0.5)	1.5 (0.6)	1.5 (0.4)	.25	.05
Systolic blood pressure (mm Hg)	115.3 (9.4)	112.3 (9.2)	110.4 (9.0)	< .001	< .001
At birth					
Gestational age (wk)	38.9 (2.1)	38.8 (1.9)	38.8 (1.8)	.67	.64
Preterm (%)	13.5	9.7	12.1	.40	—

P values indicate the significance of linear trend using analysis of variance.

* *P* after adjusting for maternal age and socioeconomic status.

† Median and interquartile range for log transformed variables.

log transformed to satisfy assumptions of normality. The significance of the mean difference between groups was analyzed by analysis of variance. We also tested for linearity of trend for maternal and offspring characteristics against parity. Multiple linear regression was used to determine the effects of maternal and paternal characteristics on the size of the newborn infants. Analyses were carried out with SPSS for Windows (version 10.0) (SPSS, Chicago, Ill).

Results

Of 814 women with confirmed pregnancies, 10 did not have prepregnant anthropometry recorded, 4 were beyond 21 weeks' gestation at recruitment, and 3 had major fetal anomalies detected on early ultrasound scan and subsequently terminated the pregnancy. Of the remaining 797 women, 12 spontaneously aborted, 14 underwent a medical termination of pregnancy, and 1 died from pregnancy-induced hypertension. Percentages of women who had spontaneous abortions were similar in all 3 parity groups, but a higher percentage of multiparous women underwent medical termination of pregnancy (n = 10; 3.8%) than primipara (0%) or para 2 (n = 4; 1.5%).

Of the 770 mothers who completed pregnancy, 245 (32%) were primipara, 268 (35%) were para 2, and 257 (33%) were multipara (Table I). Of the 257 multiparous mothers, 167 were para 3, 59 were para 4, 19 were para 5, 8 were para 6, 2 were para 7, and 1 each of parity 8 and 9. Mothers of higher parity were older, but the mean age in the multiparous group was still only 24 years. There were no associations between parity and education level or socioeconomic status. Before pregnancy, women of higher parity were shorter and lighter and had thinner skinfolds and lower fat mass. These associations remained significant after adjusting for maternal age, socioeconomic status, and observer. Maternal head circumference was similar in all parity groups. Paternal weight, height, and body mass index did not vary with maternal parity (data not shown). At 28 weeks' gestation, women of higher parity had higher physical activity scores. Though physical activity was

Table II Mean (SD) neonatal measurements according to maternal parity

Characteristics	Boys (338) Maternal parity Primipara	Para 2	Multipara	*P*	*P**	Girls (293) Maternal parity Primipara	Para 2	Multipara	*P*	*P**
N	111	117	110			84	109	100		
Weight (g)	2625 (334)	2757 (360)	2778 (353)	< .001	< .001	2518 (319)	2638 (358)	2639 (343)	.02	< .001
Length (cm)	47.8 (2.3)	48.2 (1.9)	48.3 (1.7)	.09	.06	47.3 (2.0)	47.3 (2.0)	47.4 (1.8)	.09	.43
Ponderal index (kg/m^3)	24 (2.0)	25 (2.0)	25 (2.0)	< .01	.02	24 (2.0)	25 (3.0)	25 (3.0)	.02	< .01
Skinfolds										
Subscapular (mm)[†]	3.6 (3.4 - 4.2)	4.2 (3.6-4.8)	4.2 (3.8-4.8)	< .001	< .001	4.0 (3.5-4.4)	4.3 (3.8-4.8)	4.4 (3.8-5.0)	< .001	< .001
Triceps (mm)[†]	3.8 (3.2-4.4)	4.2 (3.6-4.8)	4.2 (3.5-4.6)	< .001	< .001	4.1 (3.6-4.6)	4.2 (3.8-4.8)	4.3 (3.7-4.8)	.04	.03
Circumferences										
Head (cm)	33.3 (1.3)	33.4 (1.3)	33.4 (1.1)	.75	.45	32.7 (1.3)	32.8 (1.2)	32.8 (1.2)	.49	.17
Abdomen (cm)	28.3 (2.0)	28.8 (1.9)	28.9 (1.8)	.03	.03	28.2 (1.9)	28.8 (1.9)	28.8 (1.9)	.06	< .01
MUAC (mm)	9.6 (0.9)	9.7 (0.9)	9.8 (0.8)	.08	.09	9.5 (0.9)	9.8 (0.9)	9.7 (0.9)	.47	.04
Placental weight (g)	350.0 (67.0)	371.1 (76.6)	375.4 (84.0)	.02	.02	346.0 (66)	361.0 (79)	354 (80)	.51	.22

P values indicate the significance of linear trend using analysis of variance.
* *P* after adjusting for gestational age at delivery.
† Median and interquartile range for log transformed variables.

related to season (highest in winter, least in summer), the parity and physical activity association was unaffected by seasonality. Weight gain during pregnancy, dietary intakes (energy, protein, carbohydrate and fat intakes, and intakes of green leafy vegetables and dairy products) and erythrocyte folate and plasma vitamin C concentrations were similar in all parity groups (even after adjustment for seasonality). Women of higher parity had lower hemoglobin concentrations, total leucocyte counts, serum albumin concentrations, plasma ferritin, 120-minute glucose and insulin concentrations, and systolic blood pressure. Red blood cell and platelet counts, fasting glucose and insulin, plasma triglyceride concentrations, insulin resistance, and diastolic blood pressure did not vary with parity. Findings were similar for all these maternal measurements recorded at 18 weeks' gestation (data not shown). Average gestation at delivery and the percentage of preterm deliveries (<37 weeks' gestation) and stillbirths were similar in all 3 parity groups.

Of 770 babies delivered, we excluded 8 who were stillborn, 9 with major congenital anomalies, 51 who were not measured within 72 hours of birth, 69 who were born preterm, 1 born to the mother who developed gestational diabetes, and 1 whose mother had pregnancy-induced hypertension. The babies lost to evaluation were similarly distributed in the 3 parity groups: primipara, 50 (20.4%), para 2, 40 (14.9%), and multipara, 47 (18.3%) ($P = .261$). Our analysis is limited to the remaining 631 term live born babies (Table II). Birth weight rose with increasing parity; the mean was higher by 150 g for boys and 120 g for girls in the multipara group compared with the primipara group. Birth weight was not related to season at birth ($P = .296$) and the birth weight difference among the 3 parity groups was unaffected by adjusting for seasonality. Ponderal index and abdominal circumference were also larger in babies born to mothers of higher parity, and subscapular and triceps skinfolds increased strongly with increasing parity. A substantial component of this relationship was due to smaller skinfold thickness in babies of primipara women compared with those of multipara women, but there was also a continuous relationship between maternal parity and offspring adiposity. Offspring size, including skinfold thicknesses, were related to gestational age at delivery. However, the relationship between maternal parity and offspring size was unaffected by adjusting for gestation at delivery and observer. Season at birth was not a significant predictor of offspring adiposity, and the adjustment for seasonality did not alter the relationship between maternal parity and offspring adiposity. In contrast, neonatal length, head circumference, and MUAC were similar in all parity groups. These findings were similar for boys and girls, except that MUAC rose with increasing parity in girls, and placental weight was higher in boys but not girls born to mothers of higher parity. These results were unaffected by adjustment for seasonality of delivery and in para 2 and multiparous women for the interpregnancy interval.

Table III shows the relationships of parity, the infant's sex and gestational age at delivery, and parity-related maternal nutritional and biochemical characteristics to

Table III Multiple linear regression analysis of maternal parity and other maternal characteristics, fetal sex and gestational age, and paternal size, as predictors of birth weight, neonatal subscapular skinfold thickness, and head circumference

	Birth weight (G)				Sum of neonatal subscapular and triceps skinfolds (mm)				Neonatal head circumference (cm)			
	Univariate		Multivariate		Univariate		Multivariate		Univariate		Multivariate	
	β	*P*	β	*P*	β	*P*	β	*P*	β	*P*	β	*P*
Parity (3 groups)	47.42	< .001	48.68	.02	0.27	< .001	0.32	< .01	0.025	.54	0.0027	.97
Gestation (wk)	109.42	< .001	100.05	< .01	0.19	< .01	0.17	< .01	0.44	< .001	0.430	< .001
Sex (1: male, 2: female)	−116.94	< .001	−103.25	< .01	0.17	.19	0.09	.53	−0.61	< .001	−0.507	< .001
Socioeconomic score	1.15	.58	3.92	.14	0.004	.67	0.007	.59	−0.002	.79	0.0093	.32
Age (y)	12.19	< .01	6.34	.33	0.07	< .001	0.01	.66	0.01	.41	0.032	.17
Mother's height (cm)	11.81	< .001	8.88	< .01	−0.005	.97	0.005	.75	0.02	.03	0.020	.11
Prepregnant fat mass (kg)	26.43	< .001	15.19	.03	0.06	< .01	0.03	.29	0.07	< .001	0.027	.26
Activity score	−1.10	.04	−1.75	.02	0.002	.40	0.002	.58	−0.005	< .01	−0.0066	< .01
Hemoglobin (g/L)	−24.49	.02	−31.94	< .01	−0.02	.11	−0.04	.48	−0.01	.78	0.017	.08
Leucocyte count ($\times 10^9$/L)	−13.83	.09	1.27	.89	−0.02	.67	0.02	.69	−0.03	.39	0.0029	.92
Serum albumin (g/L)	−147.04	< .01	−96.97	.10	−0.78	< .01	−0.63	.02	−0.47	< .01	−0.396	.05
Plasma ferritin (pmol/L)	−2.15	.12	−1.18	.48	−0.01	.08	−0.008	.34	−0.002	.97	−0.0044	.45
120 min glucose (mmol/L)	1.00	.22	0.33	.72	0.007	.04	0.01	< .01	0.005	.11	0.0020	.52
120 min insulin (pmol/L)	0.15	.29	0.06	.67	−0.004	.48	−0.001	.32	0.0002	.72	−0.0055	.72
Systolic blood pressure (mm Hg)	1.03	.51	0.09	.96	−0.009	.16	0.002	.83	0.005	.35	0.0041	.52
Husband's height (cm)	4.79	.04	1.87	.51	−0.006	.55	−0.005	.73	0.02	< .01	0.017	.09
Husband's BMI (kg/m^2)	16.73	.01	7.56	.25	0.03	.18	0.03	.37	0.03	.11	−0.0010	.97

BMI, Body mass index.

newborn weight, sum of skinfold thicknesses, and head circumference. Neonatal measurements were strongly related to gestational age at delivery and fetal sex (boys were heavier and had larger head circumferences than girls). As already described, birthweight and neonatal skinfold thickness, but not head circumference, were larger in babies born to mothers of higher parity. Several of the other maternal variables were also related to newborn size. Increased maternal height, larger prepregnant fat mass, and lower hemoglobin and serum albumin concentrations during pregnancy were all associated with a larger newborn size. In a multivariate analysis, which included all maternal variables and which differed in the 3 parity groups and paternal size (height and body mass index), the effects of maternal parity on birthweight and neonatal adiposity were little changed and remained statistically significant.

Comment

In a large population-based study of rural Indian pregnant women, we have shown that increasing maternal parity is associated with increasing offspring adiposity, there was increased neonatal soft tissue but not increased skeletal size (length and head circumference). Multiparous mothers in our study were lighter, thinner, and more physically active than primiparous mothers. They also had lower hemoglobin, serum albumin and plasma glucose, insulin and ferritin concentrations, and lower systolic blood pressure. However, the effect of maternal parity on neonatal adiposity remained significant after adjusting for these characteristics.

Our population was rural and younger than in most other studies; the mean age of the multiparous group was only 24 years compared with 28 or more years elsewhere.[11] The lower adiposity of multiparous mothers in Pune contrasts with other published studies, all of which report higher body mass index and fat mass in multiparous women.[11,12] Dietary intakes were similar in all parity groups, but multiparous women were more physically active. Their lower adiposity may be a result of a high physical workload associated with both caring for the family and working on the farm, combined with repeated childbearing at a young age. The parity association was independent of socioeconomic status which itself was quite homogeneous for this rural farming population and also independent of seasonality of birth. In contrast to findings in other populations, in which maternal insulin resistance and the risk of diabetes tend to increase with rising parity,[13,14] multiparous mothers in our study had lower postload plasma glucose and insulin concentrations.[15] This is likely to be because of their lower adiposity and higher levels of physical activity. Women of higher parity had lower blood hemoglobin, plasma albumin, and ferritin concentrations, which may result from greater plasma volume expansion described in multiparous women.[16] Against this, however, was the lack of association between parity and other hematologic parameters that would be expected to fall with plasma volume expansion, such as red blood cell and platelet counts. Alternatively, lower hemoglobin, albumin, and ferritin concentrations could indicate poorer nutritional status in the multiparous group, perhaps as a result of successive pregnancies. Finally, this may be a result of reverse causality, larger fetuses extracting more nutrients from the mother. The lower leucocyte count in mothers of higher parity has not, to our knowledge, been reported elsewhere. This could, again, be attributed to greater plasma volume expansion or poorer nutritional status in multiparous women, or possibly a reduced immune response to pregnancy as a result of higher parity.[17,18] We favor the latter explanation especially because there was no association of parity with red cell and platelet counts.

As reported consistently in many different populations, the babies born to multiparous women in the PMNS were heavier.[1-3,19-21] There was no demonstrable effect of parity on neonatal length and head circumference, but the offspring of multiparous women had thicker triceps and subscapular skinfolds, and were thus both peripherally and centrally more adipose. The relationship between maternal parity and offspring adiposity was continuous across parity though the difference between babies of primiparous women and the rest was the most striking. Offspring of multiparous women also had larger abdominal circumferences, indicating either greater abdominal adiposity or larger visceral size. Few other studies have examined neonatal size other than birthweight in relation to parity, but the findings appear similar to ours. Among 4206 consecutive live births in Ethiopia, increasing parity predicted larger birth weight but not length and head circumference.[3] Only a few studies have measured neonatal skinfold thicknesses: both showed, like us, that increasing parity was associated with larger skinfold thickness or fat mass in newborn infants.[22,23] In the whole population of PMNS mothers, neonatal weight, skinfold thicknesses, and abdominal circumference were strongly positively related to maternal fat mass.[24] However, maternal fat mass decreased with increasing parity in rural Indian mothers in contrast with other population.[11,12] Thus, more adipose offspring born to (less adipose) multiparous mothers presents a paradox.

We can only speculate as to the reasons for this increased neonatal adiposity, and as to whether it is an advantage or disadvantage. We have already reported that as a population, the PMNS babies were considerably smaller at birth than white babies born in the United Kingdom, but were relatively adipose.[5] We suggested that this may have survival advantages in the neonatal period, but could lead to increased obesity in later life,[25] and thus partly explain the South Asian propensity for high percentage body fat, insulin resistance,[26-28] and type 2 diabetes.[29] The increased body fat of babies born to mothers of higher parity could indicate "better" fetal nutrition, perhaps as a result of "better" maternal physiologic adaptations to pregnancy (vasodilatation, plasma volume expansion, and immunologic changes) or to more effective placental transfer of nutrients. Equally, it could indicate fetal "malnutrition," for example, the fetuses of mothers who are undernourished as a result of successive pregnancies may receive inadequate substrate for skeletal and/or lean mass growth, and thus incorporate more energy into fat stores. The maternal metabolic variables that we measured could be considered proxies for maternal adaptations: vasodilatation (blood pressure), plasma volume expansion (hemoglobin, serum albumin, and plasma ferritin) and immune status (leucocyte count and plasma ferritin), and/or markers of maternal nutritional status: (hemoglobin, serum albumin, and plasma ferritin). The vascular adaptation and nutritional deficiency interpretations would provide opposing explanations of our findings. These measurements, however, did not explain the relationship of parity to birth size, which may be due to the relative crudeness of our measures, or point to some other aspect of parity as the mechanism mediating larger newborn size.

The strengths of our study were that it was population based, monitored mothers from before conception and throughout pregnancy, recorded gestational age accurately, measured maternal nutritional and metabolic status, and recorded detailed neonatal anthropometry. The main limitation was that the data were cross sectional, and hence some unmeasured maternal factors may vary between parity groups. Even in longitudinal studies in the same mothers, it is difficult to separate the effects of parity from other confounders such as advancing maternal age and secular changes in lifestyle and diet.

In summary, the PMNS mothers were multiparous at a younger age than in most other populations. They were lighter, less adipose, and more physically active than primiparous mothers, but did not differ in their dietary intakes or circulating nutrient levels. Their babies were heavier and more centrally and peripherally adipose, independent of maternal and paternal body size, and measures of maternal nutritional and metabolic status. This appears to be therefore a direct effect of parity. More research is required into maternal physiologic changes associated with increasing parity.[30] Future epidemiologic studies of long-term outcomes should examine the relationship of birth order to adult health outcomes, especially those related to adiposity such as insulin resistance and type 2 diabetes.

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