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Energy intake during pregnancy in relation to offspring gender by maternal height

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Abstract Male newborns are somewhat heavier than female ones and it has been reported, in a Caucasian population, that mothers carrying boys have higher energy intake during pregnancy compared to those carrying girls. In the context of a prospective study comprising 150 Caucasian women in Boston, USA and 243 Asian women in Shanghai China, energy intake at the second trimester of pregnancy was estimated based on center-specific food frequency questionnaires. There was a significant interaction ($P = 0.01$) of maternal height with offspring gender with respect to maternal daily energy intake. Among taller women, male gender of the offspring was associated with higher maternal energy intake (difference 341 kcal/day, 95% Confidence Interval 77–604; $P = 0.01$), whereas among shorter women, no significant association existed between offspring gender and maternal daily energy intake (difference −213 kcal/day, 95% Confidence Interval −479 to 54; $P = 0.12$). Our findings indicate that the higher somatic growth potential of boys in intrauterine life is realized only when there are no constrains imposed by maternal anthropometry and it is, then, associated with higher maternal energy intake during pregnancy.

Keywords Birth weight · Energy intake · Maternal height · Offspring gender · Pregnancy

Introduction

It is established and appears consistent across populations that male newborns are somewhat heavier than female ones [1]. In order to examine whether the difference is

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accounted for by higher energy intake, or more efficient energy utilization by a pregnant woman carrying a male rather than a female embryo, a study among Caucasian women in Boston, USA was undertaken. In that study, the only one on this topic in the literature, we found that pregnant women carrying a boy have an approximately 10% higher energy intake compared to those carrying a girl [2]. That study relied on an international prospective study on pregnancy hormones and outcomes among women in Boston, USA and Shanghai, China [3]. Because in earlier studies relying on this cohort the database for the Chinese diet was not available, only data on dietary intakes for the US women were reported [3, 4]. With procession of the dietary analyses on the Shanghai China data, we report now results based on data from both cohorts. We were particularly interested to examine the role of maternal height, which is different between Chinese and Caucasian women and is a crucial determinant of birth weight [5, 6], in the association of gender offspring with maternal energy intake.

Materials and methods

Subjects

Between March 1994 and October 1995, authorized health professionals met all pregnant women coming for their first routine prenatal visit to the collaborating maternity clinics of the Beth Israel hospital in Boston, USA and the Shanghai Medical University in China [3]. They ascertained the woman's eligibility to participate, explained to her the objectives of the study and obtained informed consent. A total of 402 Caucasian women in Boston, USA and 424 Asian women in Shanghai, China were identified. Eligibility criteria included age less than 40 years (to minimize selection bias generated by the unusual occurrence of pregnancies beyond that age and the higher proportion of assisted reproduction in that age group), a maximum parity of two, absence of a prior diagnosis of diabetes mellitus or thyroid disease, no hormonal medication during the index pregnancy and no known fetal abnormality. The maximum parity of two criterion was imposed by the one-child policy implemented in China.

Of the 402 eligible women in Boston, USA, 77 refused to participate in one or more aspects of the study, 9 were subsequently excluded because of a spontaneous or induced abortion in the index pregnancy, 2 were excluded because of twin birth, whereas 10 were lost to follow-up after the initial meeting. Of the remaining 304 women, we excluded 35 women with gestational age below 37 or above 42 weeks, 16 additional women with pregnancy toxemia and another 38 women with missing information on essential (e.g., age) or multiple covariates. We have considered imputations for these women but we have eventually opted for an assumption-free approach rather for a marginal increase in the statistical power of the study. For the present analyses we excluded 65 women with daily energy intake below 1,600 or above 6,000 kcal, which correspond to the lower 5% and upper 90% of energy intake among Chinese women. Eventually, 150 Caucasian women were considered in this study.

Of the 424 eligible women in Shanghai, China, 15 refused to participate in one or more aspects of the study, 2 women were excluded owing to induced abortion in the index pregnancy and another 2 because of twin birth, 7 women were lost to follow-up and 44 women were excluded because they had gestation duration outside the range of 37–42 weeks inclusive. There were no Asian women with preeclampsia. Another 59 women were excluded because of missing information on essential (e.g., age) or multiple covariates. For the present analyses we excluded 52 women with daily energy intake below 1,600 or above 6,000 kcal (which, as indicated, correspond to the lower 5% and upper 90% of energy intakes among Chinese women). Eventually, 243 Asian women were considered in this study.

The study was approved by the Institutional Review Boards of the Beth Israel Hospital, Shanghai Medical University and Harvard School of Public Health.

Baseline data and measurements

Baseline socio-demographic and lifestyle information was recorded in interviews at the 16th and the 27th gestational week visit of the women to the clinic. Information about medical conditions, maternal anthropometry and weight gain by the 16th and the 27th gestational week was abstracted from the women's medical records. At delivery, additional information concerning the newborn, including duration of gestation and birth size parameters, was recorded, as previously reported [3].

Dietary intakes during the second trimester were assessed through an extensive semi-quantitative food frequency questionnaire (FFQ) filled in by the women and checked for accuracy and completeness by trained interviewers during the 2nd visit at the maternity clinic around the 27th gestational week. For baseline socio-demographic and lifestyle variables, the information on both visits were taken into account. In the dietary questionnaires there were very few instances (<1%) where consumption information was not reported and we have assumed that the corresponding food item was not consumed. For women in Boston, USA, the FFQ was identical to the one used and validated in the Nurses' Health Study [7]. Intake of energy and energy-generating nutrients were calculated from the dietary data using the standard software used in the Nurses'

Health Study [8]. For women in Shanghai, China, the FFQ was reformulated so as to be compatible with the local dietary patterns and covered approximately 135 food and beverage items, but it was not formally validated. Intake of energy was calculated from the dietary data using the food composition tables developed by the Chinese Institute of Nutrition and Food Safety [9, 10].

Information concerning the study protocol and implementation has been published [3].

Statistical analyses

Statistical analyses were conducted using the SPSS statistical package (Statistical Package for Social Sciences v. 16.0, Chicago, Illinois, USA). We distributed

Caucasian and Chinese women by maternal–offspring characteristics and, for quantitative variables, we estimated the mean values and standard deviations. Missing pre-pregnancy maternal weight values (2 in each center) were replaced by the respective center-specific age and height-adjusted mean values, whereas missing maternal weight gain values (12 in Boston, USA and 5 in Shanghai, China) were replaced by the respective center-specific mean values for body mass index (BMI) values above or below 22, as appropriate.

Initially, in each center, we applied multiple regression models to estimate the effect of the gender of the fetus (male vs female) on maternal daily energy intake, controlling for maternal age (categorically; less than 30 years of age, 30–34 and 35+ years), educational level (categorically; high school graduate, college graduate, higher, unspecified), parity (only in the models applied for Boston, USA, women since almost all Chinese women had parity 1), duration of gestation (continuously; in weeks), maternal height (continuously, in centimeters), pre-pregnancy weight (continuously, in kg) and weight gain during pregnancy (continuously, in kg). We then ran regression models per center separately, as well as overall controlling for center, adding to the covariates indicated above an interaction term between gender of offspring and maternal height. Finally, we applied multiple regression models per center separately, as well as overall controlling for center, for women of short and tall stature according to the center-specific median cut off, i.e., 165 cm for Caucasian women and 160 cm for Chinese women.

Results

Table 1 shows characteristics of women in the two centers. Women in Shanghai, China in comparison to women in Boston, USA, were younger, mostly primiparae, of lower education, with lower stature and pre-pregnancy body weight and gained less weight during pregnancy ($P < 0.001$ in all these comparisons). Daily energy intake during the second trimester of pregnancy, estimated on the basis of reported food consumption, was substantially higher among women in Shanghai, China ($P < 0.001$); it is noted, however, that the FFQ used in Shanghai, China collected more detailed information and, hence, was more likely to lead to overestimation [11, 12], than the questionnaire used in Boston, USA. The sex ratio was also significantly different between the two centers ($P = 0.02$). All indicated variables were adjusted for in the analyses.

We regressed—separately for women in Boston, USA and Shanghai, China—daily energy intake on maternal age, parity (only in Boston, USA), education, pre-pregnancy body weight, maternal height, weight gain until the 27th gestational week, exact duration of gestation and offspring gender. In Boston, USA, only gender of the offspring was a marginally significant predictor of maternal energy intake, male vs female gender being associated with a daily energy intake higher by 173 kcal (95% confidence interval (CI): −1 to 347, $P = 0.05$). In Shanghai, China, gender of the offspring was unrelated to energy intake (regression coefficient of boys vs girls -54 kcal/day (95%CI: −351 to 244), $P = 0.72$), and only maternal height was a marginally significant predictor of maternal energy intake, with an increase of 364 kcal/day per 10 cm increment in maternal height (95%CI: 4–724, $P = 0.05$). We repeated the model for both centers combined, controlling for center. Maternal height remained a significant predictor ($P = 0.04$) of maternal energy intake, with an increase of 209 kcal/day per 10 cm increment in maternal height (95%CI: 13–406), whereas the association with offspring gender was non-significant (regression coefficient of boys vs girls 41 kcal/day (95%CI: −147 to 229), $P = 0.67$).

Because gender was a significant predictor of maternal energy intake only in Boston, USA, whereas maternal height was a significant predictor of maternal energy intake only in Shanghai, China, and because both maternal height and offspring gender were significantly different between the two centers, we ran models regressing maternal daily energy intake on the predictor variables previously indicated, but also including an interaction term for offspring gender by maternal height (continuous), separately in the two centers, as well as in both centers combined, controlling for center. The results are presented in Table 2. For maternal height and gender of offspring with respect to daily energy intake, there was a significant interaction over both centers and in Boston, USA and a suggestive one in the same direction in Shanghai, China. These results indicate that, among taller women, male gender of the offspring is associated with higher maternal energy intake, whereas among shorter women, no

Table 1 Distribution of pregnant women and offspring gender in Boston, USA and Shanghai, China by demographic and somatometric characteristics

	Boston, USA ($n = 150$)		Shanghai, China ($n = 243$)	
Maternal age (in years)	*n*	%	*N*	%
<30	38	25.3	213	87.7
30–34	97	64.7	22	9.1
35–39	15	10.0	8	3.3
Parity				
1	85	56.7	239	98.4
2+	65	43.3	4	1.6
Education				
High school graduate	11	7.3	110	45.3
College graduate	69	46.0	82	33.7
Higher	70	46.7	30	12.4
Unspecified	0	0	21	8.6
Maternal height (in meters)				
−1.54	14	9.4	29	11.9
1.55–1.59	16	10.7	74	30.5
1.60–1.64	34	22.7	97	39.9
1.65–1.69	42	28.0	37	15.2
1.70–1.74	29	19.3	6	2.5
1.75+	15	10.0	0	0.0
Maternal pre-pregnancy weight (in kg)				
−49	25	16.7	97	39.9
50–59	68	45.3	125	51.5
60–69	39	26.0	19	7.8
70+	18	12.0	2	0.8
Maternal weight gain until the 27th gestational week (in kg)	11.4	4.1	8.6	4.3
Duration of gestation (in weeks)	40.1	1.2	40.0	1.1
Daily energy intake (in kcal)	2,328	541	3,321	1,105
Gender of offspring				
Male	73	48.7	147	60.5
Female	77	51.3	96	39.5

For continuous variables mean (SD) for categorical *n* (%)

Women with gestational age between 37 and 42 weeks, no eclampsia and daily energy intake between 1,600 and 6,000 kcal

significant association exists between offspring gender and maternal daily energy intake. We repeated the analysis in the Boston, USA, cohort taking into account only women with parity 1 and the critical statistic, the regression coefficient among women with high stature in Boston, USA, had, if anything, slightly increased from 348 to 365 kcal/day.

Since women in Shanghai, China, were generally shorter than women in Boston, USA (Table 1), one would expect, on the basis of the results in Table 2, that the association of maternal daily energy intake with offspring gender would be more pronounced among Caucasian women in Boston, USA than among Chinese women in Shanghai, China, as indeed they were. In line with these results, birth weight and birth length of offspring were substantially different by offspring gender in Boston, USA but not so in Shanghai, China (Table 3).

Discussion

In a prospective study of pregnant women in Boston, USA and Shanghai, China, we found that among women of shorter stature, offspring gender was not significantly associated with maternal daily energy intake. In contrast, among taller women, carrying a male, rather than a female, offspring was significantly associated with higher maternal daily energy intake.

To our knowledge, there has been only one previous study examining gender of offspring in relation to maternal energy intake, and this relied on the Boston, USA sub-sample of the present investigation [2]. In that study, among the generally tall Caucasian women in Boston, USA, a significantly higher maternal energy intake was found among women carrying a boy rather than a girl, but no attempt was made to study interaction of offspring

Table 2 Regression-derived mean difference (b) in daily energy intake of pregnant women carrying a boy rather than a girl (baseline), by maternal height and study center

Maternal stature	b (kcal)	95% CI	*P*-value	*P* for interaction[a]
Boston, USA (boys vs girls)				
≤165 cm ($n = 64$)	−6.2	−235 to 222	0.96	0.03
>165 cm ($n = 86$)	348	82 to 614	0.01	
Shanghai, China (boys vs girls)				
≤160 cm ($n = 148$)	−332	−716 to 52	0.09	0.16
>160 cm ($n = 95$)	275	−216 to 766	0.27	
Both centers (boys vs girls)				
Shorter stature ($n = 212$)[b]	−213	−479 to 54	0.12	0.01
Taller stature ($n = 181$)[b]	341	77 to 604	0.01	

Controlling for maternal age (categorically), educational level (categorically), parity (for Boston, USA only), duration of gestation (continuously), pre-pregnancy weight (continuously), weight gain during pregnancy (continuously) and maternal height (continuously)

[a] *P* for interaction of offspring gender by maternal height (continuous) with respect to maternal daily energy intake

[b] Definition of taller versus shorter is center-specific as indicated. Controlling for center, maternal age (categorically), educational level (categorically), parity, duration of gestation (continuously), pre-pregnancy weight (continuously), weight gain during pregnancy (continuously) and maternal height (continuously)

Table 3 Mean values of somatometric characteristics of the offspring and energy intake among pregnant women by gender of the offspring in Boston, USA and Shanghai, China

	Boys	Girls	*P*-value[a]
Boston, USA			
Birth weight (gr)	3,653	3,520	0.03
Birth length (cm)	51.2	50.0	0.002
Energy intake (kcal/day)	2,422	2,239	0.05
Shanghai, China			
Birth weight (gr)	3,436	3,414	0.71
Birth length (cm)	49.8	50.2	0.15
Energy intake (kcal/day)	3,311	3,336	0.76

[a] Comparing boys vs girls through the non-parametric Mann–Whitney test

gender and maternal height with regard to maternal energy intake.

Energy requirements from infancy to adulthood are higher for males compared to females [13]. Our findings indicate that this pattern prevails in intrauterine life also, but in order to be manifested there should be minimal or no constrains imposed by maternal anthropometry on the fetal growth potential. Thus, among mothers of taller stature, birth size is generally bigger [3, 5, 14, 15], and differences in energy intakes during pregnancy between mothers carrying a boy compared to a girl, as well as differences in birth size between male and female offspring are pronounced. In contrast, among mothers of shorter stature, not only is birth size smaller, but differences in energy intake during pregnancy between mothers carrying a boy compared to a girl, as well as differences in birth size between male and female offspring are also minimized.

Strengths of our study are its prospective design, reliance of a uniform protocol in both centers and a reasonably large sample size. A weakness of the study was the use of different FFQs in the two centers which was imposed by the need to accommodate the characteristics of local diets. Indeed, the Chinese FFQ recorded detailed information, which could lead to overestimation of total energy intake [11, 12]. Although we excluded unreasonable high values of energy intake and even though many Chinese women were from rural areas, the level of energy intake in the Shanghai, China cohort was still unusually high. However, overestimation of energy intake is unlikely to be associated with measurement of maternal height or gender of the offspring and the systematic difference in reported energy intake between Boston, USA, and Shanghai, China, does not affect the reported results, which were either studied within center, or after controlling for center. Several exclusions were necessary, but these were generally undertaken for technical reasons, which are unlikely to have introduced bias. In some instances exclusions were made because of missing values (38 women in Boston, USA, that is 9.5% of the total, and 52 in Shanghai, China that is 12.3% of the total), but we have decided not to undertake imputation, opting for more conservative findings rather for marginal increase of statistical power. The Chinese FFQ was modeled according to the American FFQ, but it was not independently validated. This would be compatible with increased misclassification and effect attenuation, but it could not bias the results away from the null, since any errors in exposure ascertainment are not associated with possible errors in the later recorded outcome variables.

In conclusion, we have found evidence that among women of taller stature, but not among women of shorter stature, offspring gender is significantly associated with maternal daily energy intake. These findings need to be replicated, but we interpret the existing evidence as indicating that the higher somatic growth potential of boys in intrauterine life may be realized only when there are no constrains imposed by maternal anthropometry and is, then, associated with higher maternal energy intake during pregnancy.

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