ORIGINAL ARTICLE

High cholesterol dietary intake during pregnancy is associated with large for gestational age in a sample of low-income women of Rio de Janeiro, Brazil

Maria Beatriz Trindade de Castro¹ | Dayana Rodrigues Farias¹ | Jaqueline Lepsch¹ |
Roberta Hack Mendes² | Aline Alves Ferreira¹ | Gilberto Kac¹

¹Nutritional Epidemiology Observatory, Department of Social and Applied Nutrition, Institute of Nutrition Josué de Castro, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

²BRAIN Laboratory (Basic Research and Advanced Investigations in Neurosciences), Hospital de Clínicas de Porto Alegre, Porto Alegre, Brazil

Correspondence

Maria Beatriz Trindade de Castro, Nutritional Epidemiology Observatory, Department of Social and Applied Nutrition, Institute of Nutrition Josué de Castro, Federal University of Rio de Janeiro, Av. Carlos Chagas Filho 373, Bloco J-2 andar 21941-590-Ilha do Governador, Rio de Janeiro, Rio de Janeiro, Brazil.
Email: mbtcastro@gmail.com

Abstract

The association between the quality of maternal dietary fat intake during pregnancy and the infant's birthweight (BW) remains controversial. Our goal was to investigate the association between maternal dietary fat intake during pregnancy and the rate of large for gestational age (LGA) newborns. This study employed a cross-sectional analysis of 297 pairs of mothers/children attending a public maternity at Rio de Janeiro, Brazil. BW for gestational age according to the Intergrowth 21st was defined as follows: adequate for gestational age (AGA $\leq$ 90th percentile) and LGA (>90th percentile). The statistical analysis was a Poisson regression with robust estimations of the standard errors. Maternal dietary fat intake variables comprised lipids (% total energy); saturated (mg/1000 kcal), monounsaturated (mg/1000 kcal) and polyunsaturated (mg/1000 kcal) fats; and cholesterol (mg/1000 kcal), all of which were obtained with a Food Frequency Questionnaire. The mean BW was 3338 g (SD = 446.9), and the rate of LGA newborns was 13.1%. The mean maternal total energy intake was 2880 kcal (SD = 1074), cholesterol was 154.3 mg/1000 kcal (SD = 68.1) and monounsaturated fat was 6.9 mg/1000 kcal (SD = 2). Mothers of LGA newborns reported higher cholesterol dietary intake (195.8 vs. 148 mg/1000 kcal; $P < 0.001$), pre-pregnancy body mass index (25.1 vs. 23.5 kg/m²; $P = 0.026$) when compared with mothers of AGA newborns. Women with cholesterol intake within the fourth quartile were 2.48 (95% confidence interval: 1.31–4.66) times more likely to have an LGA infant compared with those in the 1–3 quartiles. Dietary intake of cholesterol during pregnancy influences LGA even after adjusting for other confounders.

KEYWORDS

assessment of nutritional status, birth, cholesterol, food and nutrient intake, pregnancy and nutrition, weight

1 | INTRODUCTION

Infants who are large for gestational age (LGA) experience short- and long-term adverse implications on their future health outcomes, such as obesity in adulthood, hypertension and metabolic disorders (Shankar et al., 2008; Yu et al., 2011; Poston, 2012; Barbour, 2014; Zhang, Wang, Liu, & Cai, 2014; Walsh, McGowan, Mahony, Foley, & McAuliffe, 2014). Independent of the macrosomia cutoff values employed, the literature suggests that a birth weight >4,000 g results in numerous associated perinatal and maternal complications (Ju, Chadha, Donovan, &

O'Rourke, 2009). Maternal obesity, excessive gestational weight gain, multiparity, gestational diabetes and a pre-pregnancy overweight nutritional status are some of the factors that may increase the risk of macrosomia (Institute of Medicine, 2009; Ju et al., 2009; Walsh et al., 2014). It is already known that maternal dietary intake may be associated with large birth weights and has deleterious consequences on gestational outcomes (Institute of Medicine, 2009).

The Institute of Medicine (IOM) guidelines recommend that pregestational nutritional status, age, stature and levels of physical activity should be considered in the calculation of the energy

expenditure and dietary intake (Institute of Medicine, 2009). It has been established that 20–35% of the amount of women's energy intake during pregnancy should consist of a mixture of saturated, polyunsaturated and monounsaturated fatty acids and should preferably range between 7% and 10% of the total fat intake. It is recommended that the cholesterol dietary intake be lower than 300 mg (US Department of Agriculture, Agricultural Research Service) or be as low as possible for a safe diet (Institute of Medicine, 2006).

Lipids components play an important role during the fetal intra-uterine nutrition and postnatal development. Lipids are responsible for human brain neural tube and cognitive development and also for cell membrane and hormone formation (Carlson, 2009; Nyaradi, Li, Hickling, Foster, & Oddy, 2013). However, the relationship between maternal dietary fat intake during pregnancy and birth weight is still contradictory and inconclusive. One reason could be the use of different study methodologies and measurement tools (Andreasyan et al., 2007). Another reason could be the mixed dietary factors that are involved with fetal fat accretion in utero and weight gain (Swensen, Harnack, & Ross, 2001; Yang, Cairns, & Beral, 2010; Zilko, Rehkopf, & Abrams, 2010; Vrijkotte et al., 2012; Borengasser et al., 2014).

Considering the importance of maternal dietary fat intake on birth weight and the negative implications of excess intake on a child's future health, the objective of the present study was to evaluate the association between dietary fat intake during pregnancy and the occurrence of LGA newborns among low-income women, who received prenatal care at a public maternity unit in Rio de Janeiro, Brazil.

2 | METHODS

2.1 | Study population and design

This cross-sectional analysis evaluated data from a prospective study conducted with postpartum women who gave birth between February 2009 and February 2011 in the public maternity ward of the Municipal Hospital Leonel de Moura Brizola, located at Mesquita county in Rio de Janeiro, Brazil. We evaluated mothers and their offsprings within the first week postpartum. We measured maternal anthropometric status and administered a structured sociodemographic and Food Frequency Questionnaire (FFQ) (Sichieri & Everhart, 1998).

The women who met the following criteria were eligible to participate in the study: between the ages of 18 and 45 years, had a

singleton pregnancy and did not present with preexisting chronic diseases, except obesity. From the 334 women who accepted to participate in the study, we excluded seven who had reported energy intakes higher than 6,000 kcal/day (Willett, 1998; Oken, Kleinman, Olsen, Rich-Edwards, & Gillman, 2004; Pedersen et al., 2013), 25 who lacked gestational age data and five who had a gestational age lower than 33 weeks. Thus, the final sample comprised 297 (88.9%) pairs of women and their infants.

2.2 | Outcome

The LGA birth was the study outcome and was classified using the International Fetal and Newborn Growth Consortium for the 21st Century (INTERGROWTH-21st) Project birth weight for gestational age and sex curves (Villar et al., 2014). We classified infants as small for gestational age (SGA) or adequate for gestational age (AGA) if their birth weights were ≤ 90 th percentile. Infants were classified as LGA if their birth weights were > 90 th percentile. The following newborn characteristics were obtained from obstetric records and were considered in the outcome classification: sex of the infant (male or female), birth weight (g) and the gestational age at delivery (weeks). Birth length (cm) was measured to describe the newborn characteristics.

2.3 | Independent variables

The following independent variables were obtained and analyzed using a structured questionnaire regarding sociodemographic and lifestyle conditions: education (years of schooling), total family income (US dollars), age (years), parity (1 or ≥ 2), marital status (married or stable union/single or others), self-reported skin color (black/brown or white), smoking habit (no/yes) and alcohol consumption during pregnancy (no/yes).

The maternal anthropometric variables included the following: pregestational weight (PGW), height (cm), pre-pregnancy body mass index (PPBMI), total gestational weight gain (GWG) and the adequacy of the GWG. To calculate the GWG and PPBMI, we used either the mothers' PGW prior to 13 gestational weeks as reported in the obstetric records or the self-reported PGW if the obstetric record was missing. Maternal height was measured at the maternity ward with a portable stadiometer (AlturaExata®, Brazil), with a precision of 0.1 cm. GWG (kg) was calculated based on the difference between the last measured weight before delivery (after 38 weeks) and the PGW. To classify the GWG as adequate, insufficient or excessive, we used the IOM guideline (Institute of Medicine, 2009) that included a

Key messages

- The association between maternal dietary fat intake during pregnancy and infant's birthweight remains controversial in the literature.
- The rate of large for gestational age (LGA) newborns was 13.1% in a sample of Brazilian low-income women.
- We observed a higher rate of LGA (22.7%) in women classified in the fourth quartile of the cholesterol dietary intake distribution compared with those in the 1–3 quartiles (9.9%).
- Women with cholesterol dietary intake during pregnancy within the fourth quartile were 2.48 times more likely to have an LGA infant than those in the 1–3 quartiles.

range of weight gain for each category of the PPBMI. PPBMI was calculated using the PGW and postpartum measured height [PPBMI = weight (kg)/height (m)²].

The daily energy and maternal dietary fat intake values were extrapolated from a validated FFQ that referenced the last 6 months of pregnancy until 7 days postpartum. The reported foods and frequencies were converted into estimated means of daily intake using a program (Sichieri, 1998) developed in the Statistical Analysis version 9.3 (SAS Institute Inc, 2004). To assess the foods' nutritional composition, we used the Brazilian Food Composition Table (NEPA, 2006). In the case of missing food items from this table, the U.S. Department of Agriculture Food Composition Table (US Department of Agriculture and US Department of Health and Human Services, 2010) was used.

The evaluation of maternal dietary fat intake included the following variables: lipids (% total energy); cholesterol (mg/1,000 kcal); and saturated (mg/1,000 kcal), monounsaturated (mg/1,000 kcal) and polyunsaturated (mg/1,000 kcal) fats. The densities of the maternal dietary fat intake were calculated using the proportion of 1.000 kcal [fat intake (g or mg)/ energy (kcal)].

2.4 | Statistical analysis

Data analyses were performed in three stages. First, the parametric assumptions fulfillment was evaluated. The presence of maternal characteristics differences among the 327 women that remained in the study and the 37 excluded subjects were tested. The characteristics of the 297 women were described using relative and absolute frequencies for categorical variables and means (standard deviation) for the continuous ones. We further evaluated the existence of differences in maternal sociodemographic, lifestyle and anthropometric variables and maternal dietary fat intake according to birth weight categories (SGA or AGA/LGA) using the chi-square or Fisher's exact test for proportions and Student's *t*-tests for means. We also analyzed the rate of LGA according to the categories of the selected variables.

We constructed univariate and multiple Poisson regressions with robust error variance models to test the association between maternal variables and the rate of LGA births, reporting prevalence ratios and 95% confidence intervals (CI). Variables displaying a univariate association ($p < 0.20$) with the outcome were included in the multiple regression model. In the multiple models, variables with p -values > 0.05 were removed one by one in decreasing order of significance. It has been demonstrated by Zou (2004) and others (Petersen and Deddens 2008) that the use of a logistic regression to estimate the odds ratio may lead to an overestimation of the relative risk and inadequate interpretation of the results in situations where the prevalence of the outcome is high (i.e., $>10\%$), as in our case. To avoid this overestimation, we chose to use a modified Poisson regression approach for binary outcomes with a robust estimation of the standard errors (Zou, 2004).

A sensitivity analysis was also performed excluding the cases of SGA from the AGA data, but the results did not change (data not shown).

The statistical analyses were performed in Stata: Data analysis and statistical software, version 12.0 (Stata Corp., College Station, Texas, USA), and a p -value ≤ 0.05 was regarded as significant.

2.5 | Ethics approval

The study was approved by the Ethics Committee of the Institute of Social Medicine of the State University of Rio de Janeiro (IMS/UERJ-0022.0.259.000-09 protocol). All ethical principles recommended by the National Health Council were met.

3 | RESULTS

We did not observe statistically significant differences in maternal characteristics, such as age, weight, height, PGW, PPBMI, parity and total family income, when we compared the 297 women included in the analysis to the 37 women who were excluded (data not shown in tables).

The mean (SD) birth weight was 3,338 kg (SD = 446.9), and the mean birth length was 50.2 cm (SD = 2.3). The women had a mean age of 24.8 years (SD = 5.5), 160.7 cm (SD = 6.4) of height, and 12.8 kg (SD = 6.3) of GWG. The mean energy intake during pregnancy was 2,880 kcal (SD = 1,074), and the mean cholesterol intake was 154.3 mg/1,000 kcal (SD = 68.1). Women who gave birth to infants classified as LGA were older (26.2 versus 24.6 years; $p = 0.047$) and had higher total family income (409.4 versus 327.0 dollars; $p = 0.027$), PPW (66.5 versus 60.6 kg; $p = 0.009$), GWG (15.1 versus 12.6 kg; $p = 0.016$) and cholesterol intake (195.8 versus 148.0 mg/1,000 kcal; $p < 0.001$) when compared with those women who gave birth to infants who were defined as SGA or AGA (Table 1).

We observed a higher rate of LGA in women with PPBMI ≥ 25 kg/m² (19.6 versus 10.4%; $p = 0.031$), who had excessive GWG (20.9 versus 9.2%; $p = 0.007$) and were classified in the fourth quartile of the cholesterol dietary intake distribution (22.7 versus 9.9%; $p = 0.005$) (Table 2).

In the multiple model, we observed a positive and significant association between dietary cholesterol intake density (PR = 2.48; 95% CI [1.31, 4.66]; $p = 0.005$), excessive GWG (PR = 2.26; 95% CI [1.21, 4.24]; $p = 0.011$) and total family income (PR = 1.001; 95% CI: 1.00–1.01; $p = 0.014$) and LGA births. We did not observe significant associations between maternal saturated, monounsaturated and polyunsaturated dietary fat intake and LGA births (Table 3).

4 | DISCUSSION

We observed that women with a dietary cholesterol intake within the fourth quartile of the distribution were 2.48 times more likely to have a newborn with an LGA classification than women whose intake belonged to the first to the third quartile. In contrast, we did not find a significant association between dietary total lipid and saturated and polyunsaturated fatty acids intake with LGA newborns. Other studies have found an association between cholesterol dietary intake (Campos, Pereira, Queiroz, & Saunders, 2013), maternal dietary fat intake (Horan, McGowan, Gibney, Donnelly, & McAuliffe, 2014) and a lipid-based nutritional supplement intake (Adu-Afarwuah et al.,

TABLE 1 Sociodemographic conditions, maternal anthropometric variables and newborn characteristics according to birth weight categories—Rio de Janeiro, Brazil, 2011

Variables	Birth weight categories*			p-value [†]
	All (n = 297)	SGA or AGA (n = 258) Mean (SD)	LGA (n = 39)	
Newborn				
Birth weight (g)	3,338 (446.9)	3,231 (361.2)	4,046 (288.7)	<0.001
Birth length (cm)	50.2 (2.3)	49.9 (2.2)	52.1 (2.1)	<0.001
Gestational age (weeks)	39.3 (1.7)	39.3 (1.4)	39.5 (1.1)	0.467
Sociodemographic				
Maternal age (years)	24.8 (5.5)	24.6 (5.5)	26.2 (5.6)	0.047
Total family income (US \$)	337.4 (202.8)	327.0 (184.5)	409.4 (294.3)	0.027
Maternal anthropometry				
Pre-pregnancy weight (kg)	61.1 (12.1)	60.6 (12.6)	66.5 (15.1)	0.009
Height (cm)	160.7 (6.4)	160.4 (6.2)	162.6 (7.0)	0.042
Pre-pregnancy BMI (kg/m ²)	23.6 (4.6)	23.5 (4.6)	25.1 (5.2)	0.026
Gestational weight gain (kg)	12.8 (6.3)	12.6 (6.3)	15.1 (6.7)	0.016
Maternal dietary intake				
Energy (kcal)	2,880 (1,074)	2,876 (1,085)	2,910.4 (1,011)	0.426
Lipid (% of energy intake)	23.2 (5.2)	23.1 (5.2)	23.9 (5.2)	0.383
Cholesterol (mg/1,000 kcal)	154.3 (68.1)	148.0 (62.3)	195.8 (88.6)	<0.001
Saturated fat (mg/1,000 kcal)	9.9 (2.4)	9.8 (2.4)	10.1 (2.6)	0.541
Monounsaturated fat (mg/1,000 kcal)	6.9 (2.0)	6.9 (2.0)	6.8 (6.8)	0.835
Polyunsaturated fat (mg/1,000 kcal)	3.7 (0.9)	3.7 (0.9)	3.8 (0.9)	0.336

BMI = body mass index; SGA = small for gestational age; AGA = adequate for gestational age; LGA = Large for gestational age; SD = standard deviation.

*SGA or AGA refers to ≤ 90 th percentile and LGA > 90 th percentile of the INTERGROWTH-21st birth weight curves for gestational age and sex.

[†]p-Value refers to Student's *t*-test.

2015) and a newborn's anthropometric measurements and fetal growth as measured by birth weight and BMI-for-age z-scores. According to Kulkarni *et al.* (2013), data from the Pune Maternal Nutrition Study revealed that the cholesterol concentrations at both 18 and 28 gestational weeks were positively associated with the newborn birth size.

Some methodological limitations could be identified in the present study, such as the lack of information regarding maternal serum concentrations of lipids. Yet, it is known that the amount and composition of dietary fat seem to be associated with serum concentrations of lipids (Hu, Manson, & Willett, 2001; Schwingshackl & Hoffmann, 2013). Furthermore, although we used a validated FFQ with high reliability, we cannot exclude the possibility of underestimation or overestimation of the dietary intake, as this is an inherent limitation of the dietary recall method (Willett, 1998). The dietary assessment is influenced by the ability of the individuals to recall the frequency and quantity of the food they consumed (Scagliusi *et al.*, 2008). However, it has been shown that the FFQ has acceptable validity and reproducibility to measure dietary intake in nutritional epidemiologic studies during pregnancy (Barbieri, Nishimura, Crivellenti, & Sartorelli, 2013; Vioque *et al.*, 2013).

In contrast, the study sample size and the evaluation of dietary intake of the entire sample in the last 6 months of pregnancy are the main significant strengths of the study. Because there are few studies and the results are contradictory, this new investigation of the association between maternal lipid intake during pregnancy and LGA

occurrence in a sample of adult Brazilian low-income women can contribute to new insights into prenatal nutritional dietary counseling.

Maternal dietary intake seems to be strongly associated with newborn birth weight (Campos *et al.*, 2013; Coelho, Cunha, Esteves, Lacerda, & Theme, 2015) and appears to be positively associated with maternal weight gain, which can be considered a proxy for birth size. The effect of the lipid profile on the fetal growth was also reported (Schaefer-Graf *et al.*, 2008; Ye *et al.*, 2015), and there is a positive association between triglycerides and LDL-cholesterol and LGA births, while HDL-cholesterol shows an inverse directional relationship. However, this information is still controversial (Kulkarni *et al.*, 2013). Campos *et al.* (2013) evaluated 139 Brazilian pregnant adolescents and found that cholesterol intake during the second trimester was positively associated with birth weight, even after adjusting for confounding factors. Another longitudinal Brazilian study showed a positive association between a dietary pattern named "snack" and birth weight among 1,298 pregnant women (Coelho *et al.*, 2015). Both studies are in agreement with our results. Rao *et al.* (2001) reported a positive association between a high dietary fat intake at the 18th week with birth weight and triceps skin fold within 72 hr of birth in rural Indian mothers with a lower energy intake.

The association between higher energy and fat intake during pregnancy with birth weight is not completely understood (Rao *et al.*, 2001; Lagiou *et al.*, 2004; Godhia, Nigudkar, & Desai, 2012), and further questions arise. Some studies (Kulkarni *et al.*, 2013; Horan *et al.*,

TABLE 2 Rate of large for gestational age (LGA) births according to newborn and maternal socioeconomic, demographic, life style, obstetric, anthropometric and dietary variables—Rio de Janeiro, Brazil, 2011

Variables	Total sample (n = 297) N (%)	LGA* (n = 39)		p-value [†]
		n	Prevalence (%)	
Newborn				
Sex				
Female	143 (48.2)	20	14.0	0.674
Male	154 (51.8)	19	12.3	
Sociodemographic				
Self-reported skin color				
Black/brown	247 (83.2)	34	13.8	0.646
White	50 (16.8)	5	10.0	
Marital status				
Married/stable union	234 (79.9)	32	13.7	0.714
Single or others	59 (20.1)	7	11.9	
Smoking habit				
No	255 (86.2)	35	13.7	0.322
Yes	41 (13.8)	3	7.3	
Alcohol consumption				
No	251 (84.5)	35	13.9	0.476
Yes	46 (15.5)	4	8.7	
Obstetric				
Parity				
1	97 (32.8)	10	10.3	0.309
≥2	199 (67.2)	29	14.6	
Maternal anthropometry				
Pre-pregnancy BMI (kg/m ²)				
< 25	192 (66.4)	20	10.4	0.031
≥ 25	97 (33.6)	19	19.6	
GWG adequacy [‡]				
Insufficient or adequate	184 (66.9)	17	9.2	0.007
Excessive	91 (33.1)	19	20.9	
Maternal dietary intake				
Cholesterol (mg/1,000 kcal, quartile)				
1st, 2nd or 3rd (48.0–182.6)	222 (74.8)	22	9.9	0.005
4th (183.5–466.7)	75 (25.2)	17	22.7	
Saturated fat (mg/1,000 kcal, quartile)				
1st, 2nd or 3rd (2.0–11.4)	223 (75.1)	27	12.1	0.365
4th (11.4–18.3)	74 (24.9)	12	16.2	
Monounsaturated fat (mg/1,000 kcal, quartile)				
1st, 2nd or 3rd (1.6–7.7)	223 (75.1)	27	12.1	0.365
4th (7.7–20.0)	74 (24.9)	12	16.2	
Polyunsaturated fat (mg/1,000 kcal, quartile)				
1st, 2nd or 3rd (2.0–4.2)	222 (74.8)	26	11.7	0.213
4th (4.2–6.8)	75 (25.2)	13	17.3	

GWG = gestational weight gain; BMI = body mass index.

*The >90th percentile of the INTERGROWTH-21st birth weight curves for gestational age and sex.

[†]p-value refers to chi-squared test or Fisher's exact test.

[‡]According to the Institute of Medicine cutoff points.

2014; Ye et al., 2015) suggest that dietary fat intake and maternal lipid profile levels could be linked to the newborn birth weight. Studies also reported a positive association between animal fat intake during the second trimester of pregnancy and newborn birth size (Weigel,

Nárváez, López, Félix, & López, 1991) as well as a positive association between the percentage of maternal energy intake from saturated fat in late pregnancy and neonatal central adiposity (Lagiou et al., 2004). However, Denguezli et al. (2009) evaluated the association between

TABLE 3 Crude and adjusted Poisson regression models for large for gestational age*—Rio de Janeiro, Brazil, 2011

	Crude		Adjusted	
	PR (95% CI)	p-value [†]	PR (95% CI)	p-value [†]
Maternal age (years)	1.04 (1.0–1.09)	0.073	—	—
Total family income (US \$)	1.00 (1.00–1.01)	0.025	1.01 (1.00–1.01)	0.014
Pre-pregnancy BMI (<25/≥25 kg/m ²)	1.88 (1.05–3.36)	0.033	—	—
GWG adequacy (insufficient or adequate/excessive) [‡]	2.26 (1.23–4.14)	0.008	2.26 (1.21–4.24)	0.011
Cholesterol (mg/1,000 kcal, 1st, 2nd or 3rd/4th quartile)	2.29 (1.28–4.07)	0.005	2.48 (1.31–4.66)	0.005
Energy (kcal)	1.00 (1.00–1.00)	0.842	—	—
Saturated fat (mg/1,000 kcal, 1st, 2nd or 3rd/4th quartile)	1.34 (0.71–2.51)	0.362	—	—
Monounsaturated fat (mg/1,000 kcal, 1st, 2nd or 3rd/4th quartile)	1.34 (0.71–2.51)	0.362	—	—
Polyunsaturated fat (mg/1,000 kcal, 1st, 2nd or 3rd/4th quartile)	1.48 (0.80–2.73)	0.210	—	—
Self-reported skin color (black or brown/white)	1.38 (0.56–3.35)	0.481	—	—
Marital status (married or stable union/single or others)	0.87 (0.40–1.87)	0.717	—	—
Smoking habit (no/yes)	0.53 (0.17–1.66)	0.277	—	—
Alcohol consumption (no/yes)	0.62 (0.23–1.167)	0.348	—	—
Parity (1/≥2 parturitions)	1.41 (0.72–2.78)	0.317	—	—

PR = prevalence ratio; CI = confidence interval; GWG = gestational weight gain; BMI = body mass index.

*The >90th percentile of the INTERGROWTH-21st birth weight curves for gestational age and sex.

[†]p-value refers to Poisson regression.

[‡]According to the Institute of Medicine cutoff points.

maternal fat intake during pregnancy in 350 Tunisian women and found no significant association with birth weight.

Our results indicated a positive association between dietary cholesterol intake and LGA births, independent of energy intake, GWG adequacy and total family income. The results observed in our study may reflect the association between the quality of fat intake during pregnancy and the occurrence of LGA newborns. According to Horan *et al.* (2014), the maternal diet and the dietary saturated fat percentage were associated with neonatal adiposity. Moreover, the retrospective descriptive study design employed by Godhia *et al.* (2012) showed a significant correlation between maternal energy, carbohydrate intake and birth weight and also between fat intake and head circumference among 100 full-term and preterm newborns from Mumbai, India.

The prior maternal nutritional status and conditions during pregnancy can affect the gestational outcome and the newborn birth weight. The literature suggests a strong association between excessive GWG in obese women and the risk of being macrosomic or LGA at birth (Poston, 2012; Santos *et al.*, 2012; Gante *et al.* 2015). A cross-sectional study conducted by Santos *et al.* (2012) with 542 pregnant adolescents in Rio de Janeiro showed that pregestational BMI was associated with birth weight. A historical cohort study performed in four Danish university centers with 481 obese glucose-tolerant women showed that increased weight gain in obese women was associated with newborn birth weight and pregnancy complications (Jensen *et al.*, 2005). The meta-analysis conducted by Yu *et al.* (2013) verified that pre-pregnancy overweight or obesity nutritional status increased the risk of several complications, including being macrosomic, LGA and high birth weight when compared with normal-weight mothers.

Finally, a positive association between excessive GWG during pregnancy and LGA is evident. According to Sparano *et al.* (2013), fetal macrosomia was associated with the development of excess body

weight during childhood, which also occurred in the absence of maternal gestational diabetes. Boney, Verma, Tucker, and Vohr (2005) reported a trend toward a higher prevalence of maternal obesity before pregnancy in the LGA offspring with or without gestational diabetes mellitus.

Thus, it is important to consider these conditions during prenatal appointments, especially in Brazil, which has many women in unequal social conditions (Buss & Pellegrini, 2006) and a high incidence of body weight excess among women in the reproductive age ranges from 27% to 52.5% of Brazilian capitals (Ministério da Saúde, 2015). These conditions are risk factors for the development of chronic diseases and have short- and long-term consequences, such as insulin resistance and metabolic syndrome in newborns. Some of these can be observed in the early years of life and have a higher economic impact on public health.

5 | CONCLUSION

In conclusion, we found that maternal dietary cholesterol density was positively associated with LGA status after adjusting for GWG adequacy and total family income. These results suggest that maternal animal fat intake during pregnancy plays a role in fetal development and emphasizes the importance of assessing food intake during pregnancy and nutritional counseling aimed at preventing adverse fetal outcomes. The evaluation of maternal food consumption during pregnancy is important, and studies conducted in Brazil and Latin America remain scarce.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

CONTRIBUTIONS

MBTC conceptualized the study and collected the data, performed the statistical analysis and the interpretation of the data, draft the manuscript and contributed to the discussion of the results. DRF conceptualized and drafted the manuscript, performed the statistical analysis and contributed to the interpretation of the results. JL, RMH and AFA drafted the manuscript and contributed to the interpretation of the results. GK reviewed and contributed to the discussion of the manuscript, performed the statistical analysis, contributed to the interpretation of the results. All authors have approved the final version of the manuscript.

REFERENCES

- Adu-Afarwuah, S., Lartey, A., Okronipa, H., Ashorn, P., Zeilani, M., Pearson, J. M., et al. (2015). Lipid-based nutrient supplement increases the birth size of infants of primiparous women in Ghana. *American Journal of Clinical Nutrition*, 101, 835–846.
- Andreasyan, K., Ponsonby, A. L., Dwyer, T., Morley, R., Riley, M., Dear, K., et al. (2007). Higher maternal dietary protein intake in late pregnancy is associated with a lower infant ponderal index at birth. *European Journal of Clinical Nutrition*, 61, 498–508.
- Barbieri, P., Nishimura, R. Y., Crivellenti, L. C., & Sartorelli, D. S. (2013). Relative validation of a quantitative FFQ for use in a Brazilian pregnant women. *Public Health Nutrition*, 16, 1419–1426.
- Barbour, L. A. (2014). Changing perspectives in pre-existing diabetes and obesity in pregnancy: Maternal and infant short- and long-term outcomes. *Current Opinion in Endocrinology, Diabetes, and Obesity*, 21, 257–263.
- Boney, C. M., Verma, A., Tucker, R., & Vohr, B. R. (2005). Metabolic syndrome in childhood: Association with birth weight, maternal obesity, and gestational diabetes mellitus. *Pediatrics*, 115, e290–e296.
- Borengasser, S. J., Kang, P., Faske, J., Gomez-Acevedo, H., Blackburn, M. L., Badger, T. M., et al. (2014). High fat diet and in utero exposure to maternal obesity disrupts circadian rhythm and leads to metabolic programming of liver in rat offspring. *PLoS One*, 9, e84209.
- Buss, P. M., & Pellegrini, F. A. (2006). Iniquidades em saúde no Brasil, nossa mais grave doença: comentários sobre o documento de referência e os trabalhos da Comissão Nacional sobre Determinantes Sociais da Saúde. *Cadernos de Saúde Pública*, 22, 2005–2008.
- Campos, A., Pereira, R., Queiroz, J., & Saunders, C. (2013). Ingestão de energia e nutrientes e baixo peso ao nascer: estudo de coorte com gestantes adolescentes. *Revista de Nutrição*, 26, 551–561.
- Carlson, E. (2009). Early determinants of development: A lipid perspective. *The American Journal of Clinical Nutrition*, 89, 1523S–1529S.
- Coelho, N. L. P., Cunha, D. B., Esteves, A. P. P., Lacerda, E. M. A., & Theme, M. M. (2015). Dietary patterns in pregnancy and birth weight. *Revista de Saúde Pública*, 49, 62–71.
- Denguezli, W., Faleh, R., Fessi, A., Yassine, A., Hajjaji, A., Laajili, H., et al. (2009). Risk factors of fetal macrosomia: Role of maternal nutrition. *La Tunisie Médicale*, 87, 564–568.
- Gante, I., Amaral, N., Dores, J., Almeida, M. C. Impact of gestational weight gain on obstetric and neonatal outcomes in obese diabetic women. *BMC Pregnancy Childbirth*, 15, 249.
- Godhia, M., Nigudkar, M., & Desai, R. (2012). Associations between maternal nutritional characteristics and the anthropometric indices of their full-term and pre-term newborns. Pakistan. *Journal of Nutrition*, 11, 343–349.
- Horan, M. K., McGowan, C. A., Gibney, E. R., Donnelly, J. M., & McAuliffe, F. M. (2014). Maternal low glycaemic index diet, fat intake and postprandial glucose influences neonatal adiposity—secondary analysis from the ROLO study. *Nutrition Journal*, 13, 78–89.
- Hu, F. B., Manson, J. E., & Willett, W. C. (2001). Types of dietary fat and risk of coronary heart disease: A critical review. *Journal of the American College of Nutrition*, 20, 05–19.
- Institute of Medicine (2009). *Weight gain during pregnancy: Reexamining the guidelines* Washington, DC: The National Academies Press.
- Institute of Medicine: Dietary reference intakes (DRIs) (2006). *The essential guide to nutrient requirements* Washington, DC: The National Academies Press.
- Jensen, D. M., Ovesen, P., Beck-Nielsen, H., Molsted-Pedersen, L., Sorensen, B., Vinter, C., et al. (2005). Gestational weight gain and pregnancy outcomes in 481 obese glucose-tolerant women. *Diabetes Care*, 28, 2118–2122.
- Ju, H., Chadha, Y., Donovan, T., & O'Rourke, P. (2009). Fetal macrosomia and pregnancy outcomes. *Australian and New Zealand Journal of Obstetrics and Gynaecology*, 49, 504–509.
- Kulkarni, S. R., Kumaran, K., Rao, S. R., Chougule, S. D., Deokar, T. M., Bhalerao, A. J., et al. (2013). Maternal lipids are as important as glucose for fetal growth. *Diabetes Care*, 36, 2706–2713.
- Lagiou, P., Tamimi, R. M., Mucci, L. A., Adami, H. O., Hsieh, C. C., & Trichopoulos, D. (2004). Diet during pregnancy in relation to maternal weight gain and birth size. *European Journal of Clinical Nutrition*, 58, 231–237.
- Ministério da Saúde (2015) Vigitel Brasil 2014: vigilância de fatores de risco e proteção para doenças crônicas por inquérito telefônico. Ministério da Saúde, Secretaria de Vigilância em Saúde, Departamento de Vigilância de Doenças e Agravos não Transmissíveis e Promoção da Saúde: Brasília.
- NEPA (2006) Tabela brasileira de composição de alimentos [Brazilian Food Composition Table] (2nd ed). NEPA-UNICAMP: Campinas. Available from http://www.unicamp.br/nepa/taco/contar/taco_versao2.pdf (accessed July 2010).
- Nyaradi, A., Li, J., Hickling, S., Foster, J., & Oddy, W. H. (2013). The role of nutrition in children's neurocognitive development, from pregnancy through childhood. *Frontiers in Human Neuroscience*, 7, 01–16.
- Oken, E., Kleinman, K. P., Olsen, S. F., Rich-Edwards, J. W., & Gillman, M. W. (2004). Associations of seafood and elongated n-3 fatty acid intake with fetal growth and length of gestation: Results from a US pregnancy cohort. *American Journal of Epidemiology*, 160, 774–783.
- Pedersen, M., Schoket, B., Godschalk, R. W., Wright, J., Stedingk, H., Törnqvist, M., et al. (2013). Bulky DNA adducts in cord blood, maternal fruit-and-vegetable consumption, and birth weight in a European Mother–Child Study (New Generis). *Environmental Health Perspectives*, 121, 1200–1206.
- Petersen, M. R. & Deddens, J. A. (2008). A comparison of two methods for estimating prevalence ratios. *BMC Med Res Methodol*, 28, 8–9.
- Poston, L. (2012). Maternal obesity, gestational weight gain and diet as determinants of offspring long term health. *Best Practice & Research Clinical Endocrinology & Metabolism*, 26, 627–639.
- Rao, S., Yajnik, C. S., Kanade, A., Fall, C. H. D., Margetts, B. M., Jackson, A. A., et al. (2001). Intake of micronutrient-rich foods in rural Indian mothers is associated with the size of their babies at birth: Pune maternal nutrition study. *Journal of Nutrition*, 131, 1217–1224.
- Santos, M. M. A. S., Baião, M. R., Barros, D. C., Pinto, A. A., Pedrosa, P. L. M., & Saundres, C. (2012). Estado nutricional pré-gestacional, ganho de peso materno, condições da assistência pré-natal e desfechos perinatais adversos entre puérperas adolescentes. *Revista Brasileira de Epidemiologia*, 15, 143–154.
- SAS Institute Inc (2004) SAS/STAT9.1 Users guide. SAS Institute Inc.: Cary, NC.

- Scagliusi, F. B., Ferriolli, E., Pfrimer, K., Laureano, C., Cunha, C. S., Gualano, B., et al. (2008). Underreporting of energy intake in Brazilian women varies according to dietary assessment: A cross-sectional study using doubly labeled water. *Journal of the American Dietetic Association*, 108, 2031–2040.
- Schaefer-Graf, U., Graf, K., Kulbacka, I., Kjos, S. L., Dudenhausen, J., Vetter, K., et al. (2008). Maternal lipids as strong determinants of fetal environment and growth in pregnancies with gestational diabetes mellitus. *Diabetes Care*, 31, 1858–1863.
- Schwingshackl, L., & Hoffmann, G. (2013). Comparison of effects of long-term low-fat vs high-fat diets on blood lipid levels in overweight or obese patients: A systematic review and meta-analysis. *Journal of the American Dietetic Association*, 113, 1640–1661.
- Shankar, K., Harrell, A., Liu, X., Gilchrist, J. M., Ronis, M. J. J., & Badger, T. M. (2008). Maternal obesity at conception programs obesity in the offspring. *The American Journal of Physiology—Regulatory, Integrative and Comparative Physiology*, 294, R528–R538.
- Sichieri, R. (1998). *Epidemiologia da Obesidade* Rio de Janeiro: EdUERJ.
- Sichieri, R., & Everhart, J. E. (1998). Validity of Brazilian food frequency questionnaire against dietary recalls and estimated energy intake. *Nutrition Research*, 18, 1649–1659.
- Sparano, S., Ahrens, W., Henauw, S., Marild, S., Molnarm, D., Moreno, L. A., et al. (2013). Being macrosomic at birth is an independent predictor of overweight in children: Results from the IDEFICS Study. *Maternal and Child Health Journal*, 17, 1373–1381.
- Swensen, A. R., Harnack, L. J., & Ross, J. A. (2001). Nutritional assessment of pregnant women enrolled in the special supplemental program for women, infants, and children (WIC). *Journal of the American Dietetic Association*, 101, 903–908.
- US Department of Agriculture and US Department of Health and Human Services (2010). *Dietary guidelines for Americans*, 2010 (7th ed.). Washington, DC: U.S. Government Printing Office.
- Villar, J., Papageorgiou, A. T., Pang, R., Ohuma, E. O., Cheikh-Ismail, L., Barros, F. C., et al. (2014). The likeness of fetal growth and newborn size across non-isolated populations in the INTERGROWTH-21 Project: The Fetal Growth Longitudinal Study and Newborn Cross-Sectional Study. *The Lancet Diabetes & Endocrinology*, 2, 781–792.
- Vioque, J., Navarrete-Munoz, E., Gimenez-Monzó, D., García-de-la-Hera, M., Granado, F., Young, I. S., et al. (2013). Reproducibility and validity of a food frequency questionnaire among pregnant women in a Mediterranean area. *Nutrition Journal*, 12, 26–35.
- Vrijkotte, T. G., Krukowski, N., Hutten, B. A., Vollebregt, K. C., Van Eijdsen, M., & Twickler, M. B. (2012). Maternal lipid profile during early pregnancy and pregnancy complications and outcomes: The ABCD study. *The Journal of Clinical Endocrinology & Metabolism*, 97, 3917–3925.
- Walsh, J. M., McGowan, C. A., Mahony, R. M., Foley, M. E., & McAuliffe, F. M. (2014). Obstetric and metabolic implications of excessive gestational weight gain in pregnancy. *Obesity*, 22, 1594–1600.
- Weigel, M. M., Návárez, W. M., López, A., Félix, C., & López, P. (1991). Prenatal diet, nutrient intake and pregnancy outcome in urban Ecuadorian primiparas. *Archivos Latinoamericanos de Nutrición*, 41, 21–37.
- Willett, W. (1998). *Nutritional epidemiology* New York: Oxford University Press.
- Yang, T. Y. O., Cairns, B. J., & Beral, V. (2010). Association between birth weight and obesity in adult females. *Journal of Epidemiology and Community Health*, 64, A18–A19.
- Ye, K., Bo, Q., Du, Q., Zhang, D., Shen, Y., Han, Y., et al. (2015). Maternal serum lipid levels during late pregnancy and neonatal body size. *Asia Pacific Journal of Clinical Nutrition*, 24, 138–143.
- Yu, Z., Han, S., Zhu, J., Sun, X., Ji, C., & Guo, X. (2013). Pre-pregnancy body mass index in relation to infant birth weight and offspring overweight/obesity: A systematic review and meta-analysis. *PloS One*, 8, e61627.
- Yu, Z. B., Han, S. P., Zhu, G. Z., Zhu, C., Wang, X. J., Cao, X. G., et al. (2011). Birth weight and subsequent risk of obesity: Systematic review and meta-analysis. *Obesity Reviews*, 12, 525–542.
- Zhang, Y., Wang, Z. L., Liu, B., & Cai, J. (2014). Pregnancy outcome of overweight and obese Chinese women with gestational diabetes. *Journal of Obstetrics and Gynaecology*, 9, 01–04.
- Zilko, C. E. M., Rehkopf, D., & Abrams, B. (2010). Association of maternal gestational weight gain with short and long-term maternal and child health outcomes. *American Journal of Obstetrics and Gynecology*, 202, 574–581.
- Zou, G. (2004). A modified Poisson regression approach to prospective studies with binary data. *American Journal of Epidemiology*, 159, 702–706.

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