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Dietary Patterns During Pregnancy and Their Association with Gestational Weight Gain and Anthropometric Measurements at Birth

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Abstract

Background Dietary patterns can influence maternal and child health outcomes. The study aims to characterize dietary patterns during pregnancy as well as to identify their associations with gestational weight gain (GWG) and anthropometric measurements at birth.

Methods A minimum sample size of 95 nursing mothers was estimated for this work. Socioeconomic, anthropometric, physical activity, obstetric and food consumption (food frequency questionnaire) data was collected from mothers and their newborns in immediate postpartum (n = 260) at the maternity hospital. Maternal pregestational weight and GWG were self-reported and the neonatal data was obtained from their records. The patterns were derived posteriori by Principal Component Analysis (PCA). Multinomial Logistic Regression and Poisson Regression with Robust Variance were applied.

Findings Four dietary patterns were derived: "pattern 1", characterized by the consumption of meat and eggs, processed meat, vegetables and olive oil; "pattern 2", consisting of sweets, snacks and cookies; "pattern 3", which includes cereals and breads, coffee and tea, and processed fats; and "pattern 4", characterized by soft drinks, tubers and instant noodles. Together, the dietary patterns account for 49.16% of the total variance for food intake. Higher adherence to "pattern 3" was associated with inadequate birth weight (low and excessive birth weight); while greater adherence to "pattern 2" was associated with lower chances of inadequate GWG.

Conclusion The dietary patterns presented mixed composition and predominance of ultra-processed foods. They were associated with the investigated outcomes, denoting the importance of strategies to promote healthy eating habits during pregnancy in order to avoid possible complications.

Keywords Dietary patterns · Gestational weight gain · Gestation · Newborn · Birth weight

Significance

What is known on this subject? Dietary patterns can be characterized as the food groups consumed by a given population, obtained from statistical methods of aggregation or reduction of components (Corrêa et al., 2017). They make it possible to evaluate food intake from a broader perspective when compared to nutrient-focused approaches (Carvalho et al., 2016). Studies demonstrate the associations between dietary patterns and maternal and child health outcomes e.g. macrosomia and GWG (Chen et al., 2016; Wei et al., 2019).

What does this study add? Understanding the associations between the Brazilian dietary patterns during pregnancy and outcomes, for both mother and child, will contribute to the

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development of strategies for promoting healthier eating habits, preventing unwanted outcomes.

Introduction

Among the different moments in the life cycle, the gestational stage stands out due to its greater demand for nutrition. The higher demand for dietary intake during pregnancy and the physiological changes experienced, may affect gestational weight gain (GWG) and neonatal health (Starling et al., 2017; Wei et al., 2019). GWG reflects in many pregnancy variables such as maternal fat accumulation, fluid retention and growth of fetus, uterus and placenta. This results in a direct association with the health outcomes of the mother and the newborn (Hawley et al., 2015; Voerman et al., 2019) and it is known that inadequate GWG is related to pregnancy complications (Von Ruesten et al., 2014). For example, inadequate GWG is associated with low birth weight and preterm birth, while excessive GWG is related to fetal macrosomia, gestational diabetes mellitus and childhood obesity. Researches also showed that weight gain from low-income food nutritional quality can have an impact on maternal and child's health outcomes. (Arora & Aeri, 2019; Gaillard et al., 2013; Kibret et al., 2019; Santos et al., 2019; Wei et al., 2019).

A systematic review showed an association between maternal food intake and GWG (Tielemans et al., 2016). Inadequate vegetable intake and the consumption of margarine, sugar and snacks were positively associated with excessive GWG (Shin et al., 2016; Tielemans et al., 2015). A study conducted in Spain showed that a "Mediterranean pattern" during pregnancy is related to lower GWG and better nutrient adequacy (Cano-Ibáñez et al., 2020). Little is known about the associations between the dietary patterns of pregnant Brazilian women and GWG. A Brazilian study (Alves-Santos et al., 2018) found no associations with maternal dietary patterns and GWG.

The scarcity of studies that address this subject in developing countries reveal a gap in the literature and the urge for more research on the subject.

Given the above considerations, the present study aims to explore the associations between the dietary patterns of pregnant Brazilian women, GWG as well as the anthropometric measurements of the newborn at birth.

Methods

This is a cross-sectional study, part of a larger cohort carried out in a referral centre for maternal and child health care in the city of Belo Horizonte, Minas Gerais—Brazil. It is a Public University Hospital, reference in medium and high complexity care for the concerned population, part of the Municipal and State Health System. In 2020, the Hospital had a demand for 190 monthly childbirths (Brazilian Ministry of Education 2020).

Data was collected between July 2018 and June 2019. Minimum sample size (n = 95) was estimated using a sample size formula in which the number of subjects in the study should be at least five times greater than the number of food item groups in the analysis when the FFQ has more than 15 items (Alves-Santos et al., 2018; Kac et al., 2007).

The mothers participating in this study were in good general health and at a maximum 48 h postpartum with alive full-term children (Quinn et al., 2016). Any individuals who had twin pregnancy, history of gestational diabetes mellitus (or other condition requiring change in food intake), preeclampsia, complications in their health or had children who required medical care during the study period were excluded. A structured questionnaire and a food frequency questionnaire (FFQ) were applied by previously trained researches to collect the data for the present study. Newborn information was obtained from medical records.

Maternal socioeconomic information, anthropometric measurements as well as physical activity status during pregnancy were collected. Socioeconomic information included maternal age (continuous), professional occupation (domestic, housewife, unemployed, administrative assistant, self-employed or others), education level (elementary school, high school or higher education), number of people living in the household (continuous), marital status (single, married or stable union, divorced or separated, widow) and family income (< 1, 1 to 3 or > 3). Data about the pregnancy and childbirth were also collected: parity (1 or > 1), number of pregnancies (continuous), number of abortions (continuous), number of children (continuous) and physical activity status during pregnancy (yes or no).

Food intake data was obtained through adapted, self-reported and validated FFQ for the Brazilian adult population (Ribeiro et al., 2006). The information obtained in the FFQ refers to the last six months of food intake and the questionnaire included foods from the following groups: milk and dairy products, meats and egg, oils, snacks and canned foods, cereals and legumes, vegetables and fruits, desserts and sweets, drinks, diet and light and processed products. The questionnaire consisted of 59 food items, distributed between the groups and a likert scale (Kac et al., 2007), with 7 consumption frequencies (once a day; 2 or more times a day; 5 to 6 times a week; 2 to 4 times a week; once a week; 1 to 3 times a month; rarely or never).

Maternal anthropometric measurements included pregestational weight, height and GWG. Pregestational weight and GWG was self-reported and maternal height was measured by an anthropometer coupled to a Welmy® scale. This data allowed the calculation of body mass index (BMI = kg/m^2)

analysed according to World Health Organization criteria (World Health Organization, 1995). It was considered insufficient or excessive GWG those who presented data below or above the IOM recommendations according to pregestational BMI, respectively (Institute of Medicine, 2009).

Data regarding prenatal care (number of consultations [< 6, 6 or more]), childbirth (gestational age, date of delivery, type of delivery [vaginal, caesarean, vaginal use of forceps]) and data of the newborn (birth gender, birth weight, length at birth and head circumference at birth) were obtained through the medical records.

This study was conducted according to the guidelines specified by the Declaration of Helsinki and all procedures involving the research's participants were approved by the Research Ethics Committee under the registration number 86818118.0.0000.5149. Written consent was read and signed by all participants in this research.

Statistical Analysis

The collected data was processed in the Epi Info version 3.4.5 program, through double typing, which allowed the proper consistency analysis. In addition, data was analysed using the Statistical Package for the Social Sciences (SPSS) version 19.0. The variables adherence to the normal distribution was evaluated using the Kolmogorov–Smirnov test. Descriptive analysis was then performed, with the calculation of frequencies and measures of central tendency and dispersion. To identify dietary patterns, Principal Components Analysis (PCA) was applied using orthogonal rotation (Varimax). The Kaiser–Meyer–Olkin measurement for sample adequacy (0.652) and Bartlett's sphericity test ($p < 0.001$) confirmed PCA as the appropriate reduction technique for sample application. Eigenvalues, as well as scree plot analysis and total variance explain (in percentage) were used to define the dietary patterns. Food items or food groups that had a greater or equal factor loading to 0.3 in the rotated matrix reflected a strong association with the components and, therefore, were used to compose the eating patterns. The scores of dietary patterns were categorized according to the cut-off point of the median distribution.

Chi-square and Mann–Whitney statistical tests were performed for categorical and quantitative variables respectively. Multinomial Logistic Regression was used to evaluate the association of patterns (explanatory variable) with GWG (dependent variable). Adjustments for confounding variables were carried out considering the possible variables that could influence maternal dietary patterns and child's anthropometric measurements at birth. The adjustments were made in two models, the first considered maternal age, education level, family income, marital status and parity, while the second model considered the first model data plus the maternal pregestational BMI.

Poisson Regression with Robust Variance was also performed with robust variance to identify the effect of each identified dietary pattern (explanatory variable), being a dependent variable the inadequacy of the child's birth weight. The models were adjusted for the following variables: maternal age, marital status, income, education and pregestational body mass index.

The prevalence ratio (PR) with a 95% confidence interval (95% CI) was used as an effect measure. Values of $p < 0.05$ were adopted as a level of statistical significance.

Results

Among the 260 participants, most were multiparous (64.1%) with high school education (65.6%) and had a median age of 28 (19–45) years. A high prevalence of GWG inadequacy (38.2%) was observed and most of them (85.7%) did not practice physical activities. Other socioeconomic and anthropometric data of the participants are presented in Table 1.

A total of 144 girls and 116 boys participated in this study, with the overall description of neonatal anthropometric measurements presented in Table 2. The only significant difference found between genders was weight at birth (5.7% and 0% for underweight among girls and boys, respectively, $p = 0.019$).

Four distinct dietary patterns were identified, representing 49.16% of the total variance (Table 3). "Pattern 1" was characterized by the presence of meats and egg, processed meat, vegetables and olive oil (19.22%). "Pattern 2" was composed of sweets, snacks and cookies (10.96%). "Pattern 3" was characterized by the presence of cereals and bread, coffee and tea and ultra-processed fats (10.03%). Finally, "Pattern 4" has in its composition soft drinks, tubers and instant noodles (8.95%).

Women with greater adherence to "Pattern 2" during pregnancy were less likely to have inadequate GWG (OR 0.14; 95% CI 0.03–0.60; $p = 0.008$ adjusted for maternal age, education level, family income, marital status, parity, and pregestational BMI). No associations between the other patterns and GWG were found (Table 4).

Newborns whose mothers had a higher adherence to "Pattern 3" were more likely to have inadequate weight (low-for-age or high-for-age) at birth in all models (crude model: RP 1.27; 95% CI 1.13–1.42/ adjusted model: RP 1.27; 95% CI 1.11–1.45), as shown in Table 5. Other dietary patterns showed no association with any other tested nutritional parameters ($p > 0.05$).

Table 1 Characterization of postpartum participants at a referral maternity hospital

Characteristics	Absolute frequency	Relative frequency
Education level		
Elementary school	43	16.6
High school	170	65.6
Higher education	46	17.8
Marital status		
Single	89	34.2
Married/Stable Union	162	62.3
Divorced/Separated	8	3.1
Widow	1	0.4
Professional occupation		
Domestic	5	1.9
Housewife	55	21.1
Unemployed	31	11.9
Self-employed	40	15.3
Administrative assistant	7	2.7
Others	110	42.1
Family income[a]		
< 1	43	16.5
1 to 3	146	56.2
> 3	71	27.3
Parity		
1	93	35.9
> 1	166	64.1
Pre-gestational BMI[b]		
Severely underweight	3	1.2
Moderate underweight	7	2.9
Underweight	11	4.5
Normal	107	43.9
Overweight	57	23.4
Obese Class I	29	11.9
Obese Class II	19	7.8
Obese Class III	11	4.5
Pre-natal consultations		
< 6 consultations	23	9.2
≥ 6 consultations	228	90.8
GWG adequacy[c]		
Inadequate	89	38.2
Adequate	78	33.5
Excessive	66	24.5
Physical activity during pregnancy		
Yes	37	14.3
No	222	85.7
Type of delivery		
Vaginal	185	71.4
Caesarian	70	27.0
Vaginal with forceps	4	1.5
Characteristics	Median (min–max)	IQR
Maternal age (years)	28 (19–45)	10.0

Table 1 (continued)

Characteristics	Median (min–max)	IQR
People living in the household	4 (3–15)	2.0
Family Income (reais)	1908.0 (0–6000)	1300.0
Gestational age (weeks)	39 (37–42)	2.0
Pre-natal consultations	9 (0–20)	5.0
Number of pregnancies	2 (1–14)	2.0
Number of children	2 (1–9)	2.0
Number of deliveries	2 (1–9)	1.0
Number of abortions	0 (0–5)	0.0

Women who, for some reason, did not answer any item of the questionnaire, were not included in the sample for that data

[a]Brazilian minimum wage: R$ 998 ≈ $238; CI: Confidence Interval; IQR: Interquartile range

[b]Severely underweight < 16 kg/m^2; Moderate underweight 16 to 16.9 kg/m^2; Underweight 17 to 18.4 kg/m^2; Normal 18.5 kg/m^2 to 24.9; Overweight 25 to 29.9 kg/m^2; Obese Class I 30 to 34.9 kg/m^2; Obese Class II 35.0 to 39.9 kg/m^2; Obese Class III ≥ 40 kg/m^2

[c]Those who presented data below or above the IOM recommendations according to pre-gestational BMI, respectively, were considered insufficient or excessive GWG

Table 2 Nutritional status of newborns in a referral maternity hospital (n = 260)

Characteristics	Frequency	Prevalence (%)
Weight at birth		
Low weight-for-age	8	3.1
Normal weight-for-age	247	96.5
High weight-for-age	1	0.4
Total (n)	256	
Height at birth		
Low height-for-age	30	11.8
Normal height-for-age	224	87.8
Total (n)	254	
Head circumference at birth		
Low head circumference-for-age	13	6.6
Normal head circumference-for-age	179	91.3
High head circumference-for-age	4	2.0
Total (n)	196	

Discussion

The results suggest that a dietary pattern predominantly characterized by sweets, snacks and cookies (Pattern 2) reduced the chances of mothers presenting inadequate (insufficient) GWG. In addition, a dietary pattern mostly characterized by ultra-processed fats (salad dressings, margarine and mayonnaise), coffee and tea (Pattern 3) increased the chances of birth weight inadequacy (low-for-age or high-for-age).

In this context, it is important to emphasize that literature demonstrates that a healthy dietary consumption during pregnancy contributes to prevent inadequate GWG (Cano-Ibáñez et al., 2020). Moreover, healthy dietary patterns composed primarily of vegetables, legumes, fruits, whole grains, low-fat dairy, lean protein, fish and seafood, along with physical activity during pregnancy could reduce the chance of inadequate GWG, premature births and reduce the risk of "small for gestational age" newborns (Cano-Ibáñez et al., 2020; Chia et al., 2019).

The dietary patterns derived in the study have mixed characteristics (healthy and unhealthy foods in the same group) and resemble patterns found in other studies with pregnant women and GWG (Maugeri et al., 2019; Shin et al., 2016; Tielemans et al., 2015; Wei et al., 2019).

The "Pattern 2", associated with lower chances of inadequate GWG in the study, has a characteristic of high caloric density, being the only which has sweets, snacks and cookies in its composition. For this reason, it may be responsible for greater weight gain during pregnancy, reducing the chances of insufficient GWG. Similarly, Uusitalo et al. (2009) found an association between greater adherence to a dietary pattern characterized by high consumption of sweets, snacks and fast food with a higher weekly GWG rate. In the study by Tielemans et al. (2015) greater adherence to the "margarine, sugar and snacks" pattern was also associated with higher prevalence of excessive GWG.

Despite this association, it should be noted that the mentioned pattern (richer in sweets, snacks and cookies) does not represent a healthy way to avoid inadequate GWG, given its nutritional characteristics and possible associations with negative gestational outcomes such as fetal macrosomia, gestational diabetes and pre-eclampsia. During pregnancy, the diet must be balanced and healthy, in order to optimally fulfill all nutritional and energy needs and achieve an adequate GWG. Given that, it is important to follow the recommendations of the Dietary Guidelines for the Brazilian

Table 3 Loads of the rotated matrix factors for dietary patterns of women attending a referral maternity hospital

Food items or food groups	Dietary Patterns			
	Pattern 1	Pattern 2	Pattern 3	Pattern 4
Meats and egg	0.641			
Vegetables	0.662			
Olive Oil	0.442			
Processed Meat	0.562			
Tubers				0.493
Cereals and breads			0.443	
Sweets		0.792		
Snacks and cookies		0.777		
Processed fats			0.722	
Coffee and tea			0.794	
Soft drinks				0.754
Instant noodles				0.797
Explained variance (%)	19.22	10.96	10.03	8.95
Cumulative explained variance (%)	19.22	30.18	40.21	49.16

The food items or food groups presented had factor loadings ≥ 0.3, therefore, they were used to describe each dietary pattern, with the items with the highest factor loading only remaining

Population, which advocates that a healthy diet must be mostly composed of *in natura* or minimally processed foods (Brazilian Ministry of Health, 2014). Although the approach is not specific to the gestational stage, pregnant women and women in reproductive age should be informed about the importance of these concepts in order to reach healthier outcomes. The World Health Organization also recommends prenatal care for healthier outcomes in pregnancy including dietary interventions to keep women healthy and prevent excessive weight gain (Kac et al., 2007).

The dietary pattern "Pattern 3", which was associated with inadequate birth weight, has in its composition the presence of ultra-processed fats and coffee and tea, these two often consumed with sugar. It can also be considered a high caloric density pattern. In addition, the predominant foods in "Pattern 3" are nutritionally poor—which can compromise the adequate intake of multiple nutrients. A study carried out by Alves-Santos et al. (2019) with 193 pregnant women in the city of Rio de Janeiro found that the "fast food and sweets" pattern—an analogous diet with ultra-processed fats and sugar—presented greater chances of increasing the high weight for age (OR 4.38; 95% CI 1.32–14.48). The consumption of high calorie and low nutritional dietary patterns may be associated with birth weight, due to the influence on the elevation of blood glucose levels in pregnant women as well as the lack of nutrients, favouring the increase in rates of fetal growth and on the risk of large-for-gestational-age babies and impaired child growth and development (Geurtsen et al., 2019).

Corroborating the findings regarding the dietary patterns identified in the current study, the results of the Brazilian Family Budget Survey (2017–2018) point out to increased consumption of ultra-processed products by the population. The intake of healthy food groups like cereals, vegetables and oilseeds has been decreasing over time—from 10.4% in 2002–2003 to 8.0% in 2008–2009 and 5% in 2017–2018. At the same time, unhealthy food groups had an increased consumption, the beverages and infusions group (includes soft drinks and alcoholic beverages) increased—from 8.5% in 2002–2003 to 9.7% in 2008–2009 and 10.6% in 2017–2018. The processed foods group (includes French fries, chips, chicken fingers, smoked meat and frozen food) increased—from 2.3% to 2.9% and reached 3.4% (Brazilian Institute of Geography & Statistics, 2020).

Despite these results, the present study still has a limitation regarding sample homogeneity in terms of socioeconomic characteristics. It should be noted, however, that this is the first study identifying associations between dietary patterns and GWG in Brazilian women, as well as conducting a joint evaluation of anthropometric measurements at birth.

Food intake during pregnancy was characterized in four dietary patterns, with mixed qualities and strong presence of ultra-processed foods. Higher adherence to "Pattern 3" (processed meat, cereals and bread, coffee and tea and ultra-processed fats) was associated with inadequate birth weight (low-for-age or high-for-age) in all models of adjustment. Greater adherence to "Pattern 2" (sweets, snacks and cookies) was associated with inadequate GWG when adjusted for socioeconomic factors and maternal pregestational BMI.

The results suggest that a diet characterized by high caloric density—through the consumption of ultra-processed foods and fats—may be associated with weight gain during pregnancy and with undesirable anthropometric

Table 4 Multinomial logistic regression model of association between gestational dietary patterns and inadequate or excessive weight gain

	Insufficient gestational weight gain[a]						Excessive gestational weight gain[a]					
	Crude model		Model 1		Model 2		Crude model		Model 1		Model 2	
	OR (CI 95%)	p-value	OR (CI 95%)	p-value	OR (CI 95%)	p-value	OR (CI 95%)	p-Value	OR (CI 95%)	p-value	OR (CI 95%)	p-value
Pattern 1												
< Median	1		1		1		1		1		1	
≥ Median	0.80 (0.43–1.49)	0.497	0.75 (0.29–1.92)	0.558	1.11 (0.37–3.33)	0.851	0.65 (0.34–1.27)	0.216	0.85 (0.31–2.34)	0.766	0.73 (0.22–2.35)	0.601
Pattern 2												
< Median	1		1		1		1		1		1	
≥ Median	0.76 (0.41–1.41)	0.391	0.42 (0.15–1.18)	0.101	0.14 (0.03–0.60)	**0.008**	1.79 (0.91–3.51)	0.087	2.11 (0.67–6.57)	0.197	1.67 (0.41–6.77)	0.471
Pattern 3												
< Median	1		1		1		1		1		1	
≥ Median	1.22 (0.66–2.26)	0.512	0.91 (0.34–2.38)	0.852	1.13 (0.36–3.50)	0.827	1.73 (0.89–3.37)	0.105	1.30 (0.44–3.83)	0.629	1.39 (0.38–5.04)	0.609
Pattern 4												
< Median	1		1		1		1		1		1	
≥ Median	0.99 (0.53–1.82)	0.973	0.77 (0.29–2.06)	0.615	1.29 (0.39–4.25)	0.670	0.81 (0.42–1.58)	0.553	0.80 (0.28–2.27)	0.688	0.73 (0.21–2.48)	0.616

[a]Dependent variable reference category: Adequate gestational weight gain

Note: CI = confidence interval; OR = odds ratio

Model 1: adjusted for maternal age, educational level, family income, marital status e parity

Model 2: adjusted for model 1 variables and pre-gestational body mass index

Table 5 *Poisson Regression with Robust Variance model* of association between gestational dietary patterns and inadequate child birth weight

	RP crude (CI 95%)	p-value	RP adjusted[a] (CI 95%)	p-value
Pattern 1				
< Median	1		1	
≥ Median	1.12 (0.92–1.35)	0.253	1.14 (0.91–1.43)	0.263
Pattern 2				
< Median	1		1	
≥ Median	1.12 (0.92–1.35)	0.253	1.07 (0.85–1.35)	0.550
Pattern 3				
< Median	1		1	
≥ Median	1.27 (1.13–1.42)	**< 0.001**	1.27 (1.11–1.45)	**0.001**
Pattern 4				
< Median	1		1	
≥ Median	1.04 (0.84–1.29)	0.719	0.97 (0.77–1.22)	0.810

CI confidence interval, *RP* prevalence ratio

[a]Adjusted for maternal age, educational level, family income, marital status, parity and pre-gestational body mass index

characteristics of the newborn. This corroborates the current discussions on excessive energy consumption associated with low nutritional quality that compromises the possibility of healthy child growth and development. New studies on the subject, which may involve more diverse populations and food cultures, are suggested. There is also an urgent need to establish specific Brazilian dietary guidelines for the gestational stage and to spread general dietary guidelines such as those proposed by the Food Guidelines for the Brazilian Population.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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