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Ultra-Processed food consumption during pregnancy and its association with gestational weight gain and high birth weight in women with gestational diabetes: a prospective cohort study

Maria Elionês de Oliveira Araújo
Universidade Federal do Rio Grande do Norte
Amanda Gabriela Araújo da Silva
Universidade Federal do Rio Grande do Norte
Pollyana Carvalho de Souza
Universidade Federal do Rio Grande do Norte
Byanca Rodrigues Carneiro
Universidade Federal do Rio Grande do Norte
Amanda Maria Lira de Lucena
Universidade Federal do Rio Grande do Norte
Andriely Isa Melo dos Santos
Universidade Federal do Rio Grande do Norte
Camila Néri Campos Garcia
Universidade Federal do Rio Grande do Norte
Lara Virginia Pessoa de Lima
Universidade Federal do Rio Grande do Norte
Cristina Maria de Araújo Medeiros Santos
Universidade Federal do Rio Grande do Norte
Karla Danielly da Silva Ribeiro
karla.danielly@ufrn.br

Universidade Federal do Rio Grande do Norte

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Abstract

Background

Gestational diabetes mellitus (GDM) is associated with adverse maternal and neonatal outcomes, while dietary factors may influence gestational weight gain and fetal growth. Ultra-processed food (UPF) consumption has been associated with poorer diet quality and may contribute to excessive gestational weight gain and altered birthweight. This study aims to analyse the association between maternal ultra-processed food (UPF) intake, gestational weight gain (GWG) trajectory, and birthweight in women with gestational diabetes (GDM).

Methods

This prospective cohort study was conducted with women with GDM who had live singleton births. The study assessed the intake of UPFs, GWG trajectories, and neonatal outcomes. UPF intake (g/day) was evaluated according to the Nova classification. GWG (kg, Z-score) was calculated as the difference between pregestational and measured weights at the first (T1), second (T2), and third (T3) trimesters, and categorised as inadequate, adequate, or excessive based on Brazilian reference charts. Neonatal outcomes included birthweight-for-gestational-age and weight-for-length (Z-score, nutritional status). Associations between UPF intake (in tertiles) and study outcomes were assessed using multivariate linear and Poisson regression models, adjusted for potential covariates.

Results

Median UPF intake was 131.43 g/day (IQR 90.50–200.11), accounting for 17.95% (95% CI 16.24–19.66) of total daily energy intake. Excessive gestational weight gain was observed in 57.1% (T1), 47.6% (T2), and 50.7% (T3). High birthweight occurred in 8.8% of neonates. Each additional gram of UPF was associated with 0.014 kg higher GWG at T1 (β 0.014; p = 0.002) and 0.015 kg at T3 (β 0.015; p = 0.023). Higher maternal UPF intake increased the risk of neonatal high birthweight (adjusted RR 3.42; 95% CI 1.07–10.97; p = 0.038).

Conclusions

UPF intake during pregnancy was associated with excessive GWG and an increased risk of high birthweight in women with GDM, highlighting the importance of prenatal counselling.

Background

Gestational Diabetes Mellitus (GDM) is the most common metabolic disorder during pregnancy, with a worldwide prevalence of 16.7% [1, 2]. Approximately 18% of Brazilian pregnant women attended within

the Unified Health System (SUS) are affected by GDM.3 These pregnancies are classified as high-risk due to the potential for adverse perinatal and obstetric outcomes [1, 3].

Inappropriate gestational weight gain (GWG) may be one of the consequences of GDM. Excessive GWG is associated with an increased risk of caesarean section, macrosomia, large-for-gestational-age (LGA) neonates, and neonatal hypoglycaemia. Conversely, insufficient GWG may lead to preterm birth [4, 5]. Diet is a key determinant of both GWG and birthweight [6].

Maternal diets high in ultra-processed foods (UPF) have been associated with lower intake of legumes, vegetables, fruits, and protein, and with higher caloric and lipid intake compared with diets lower in UPF [7]. These dietary patterns have been linked to greater GWG and increased neonatal adiposity [8].

Poor diet quality has consistently been associated with the development and progression of GDM. Our findings indicate that a higher proportion of energy from UPF in the maternal diet increased the risk of neonatal hypoglycaemia in women with GDM, although no association was observed with glycaemic self-monitoring [9]. Additionally, among Brazilian women with pre-existing diabetes mellitus (DM), UPF intake was associated with alterations in glycaemic control [10].

Interest in UPF has increased considerably in recent years. These products are manufactured from food components to which additives are added, primarily to enhance sensory and aesthetic qualities. However, they are of low nutritional value [11] and have been linked to various adverse health outcomes, including a higher incidence of DM [12, 13].

In recent years, the incidence of GDM and its related complications has risen significantly [1–2]. GWG has been shown to influence both perinatal and obstetric outcomes [4, 5]. Moreover, UPF intake has been associated with adverse effects during pregnancy [7–10, 14, 15]. These findings highlight the urgent need to better understand the factors contributing to excessive GWG and elevated birthweight. Despite this, there remains no consensus on effective nutritional strategies for managing GWG in women with GDM [16]. In this context, it is essential to develop dietary counselling approaches that account for the impact of UPF intake on GDM management.

Using a prospective cohort design, we evaluated the association between UPF intake and GWG trajectory in women with GDM, as well as the birthweight of their neonates.

Methods

We conducted a prospective cohort study with 140 women diagnosed with GDM up to 20 weeks of gestation. All participants had singleton pregnancies and were followed in high-risk prenatal care until delivery at the public Januario Cicco Maternity School (MEJC), a SUS reference centre in Natal/RN. This study was approved by the Research Ethics Committee of Onofre Lopes University Hospital, under protocol number 5.167.567 and followed the STROBE-Statement checklist for reports observational

studies. All eligible pregnant women provided written informed consent to participate, along with consent for their neonates.

GDM was diagnosed based on fasting glucose (≥ 92 and ≤ 126 mg/dL) at any gestational age [1]. We excluded multiple pregnancies, pre-existing DM, comorbidities (cardiopathy, nephropathy, hepatopathy, thrombophilia, systemic lupus erythematosus, pancreatic disease), intellectual disability compromising interviews, withdrawal requests, and women without postpartum or dietary data.

Participants were recruited and assessed between February 2022 and June 2024. The mean follow-up duration was 25 weeks. Data were collected in the second trimester (T1 – Time 1), third trimester (T2 – Time 2), and immediate postpartum (T3 – Time 3) using structured interviews (face-to-face or online) and participants' electronic health records at each time point (Fig. 1). Collected information included sociodemographic characteristics, clinical and obstetric data. Neonatal outcomes collected were estimated fetal weight (EFW), mode of delivery, sex, gestational age at delivery, and anthropometric measures (weight and length).

The sample size was calculated using G*Power software (atest version 3.1.9.7; http://www.gpower.hhu.de/). We considered the difference in GWG (kg) between UPF intake tertiles as reported by Rohatgi et al. [17] With a power of 80% and a 95% confidence interval (CI), a minimum of 91 participants was required. Accounting for a 20% follow-up loss, the final sample size was set at 110 participants.

GWG was assessed at T1, T2, and T3 by calculating the difference between weight at each time point and pre-pregnancy weight. GWG was evaluated according to Brazilian reference curves for gestational age and pre-pregnancy body mass index (ppBMI) [18, 19]. GWG was analysed in two dimensions: cumulative weight gain by gestational age (T1 and T2) and total gestational weight gain (T3 weight measured prior to delivery). GWG was classified as inadequate, adequate, or excessive [19].

We also assessed estimated fetal weight for gestational age (EFW, Z-score) [20] at T2, birthweight categorised by intrauterine growth (centiles) [21], size at birth (grams) [18, 22], weight-for-age (WAZ), and weight-for-length (WLZ) [23] (Supplementary Information, Additional file 1). FWA, WAZ, and WLZ were analysed using INTERGROWTH-21st charts and categorised as low FWA (< 10th centile) and high WAZ (> + 2 Z-score) [23]; underweight (<-2 Z-score) and overweight (≥ + 1 Z-score) [23] Birthweight was categorised by intrauterine growth according to gestational age (small for gestational age, SGA, WA < 10th centile; and large for gestational age, LGA, WA > 90th centile) [23] and macrosomia (birthweight > 4,500g) [22] (Supplementary Information, Table S1).. EFW in grams was obtained via ultrasound, and birthweight from electronic health records. WAZ and WLZ were calculated using WHO Anthro Survey Analyser for term neonates and INTERGROWTH-21st for preterm neonates.

Dietary intake was assessed using three 24-hour food recalls adapted to the Nova classification (RecNOVA24h) [24], following the USDA Automated Multiple-Pass Method [25]. The mother was the primary respondent, either face-to-face or online. Portion sizes were estimated using a photographic

atlas [26]. Data collected included portion size, preparation method, ingredients (for homemade recipes), brand (for industrialised foods), food origin, and local consumption. Portions were converted into grams (g) or millilitres (mL) [26–28]. Homemade recipes were disaggregated into individual ingredients based on standardised technical sheets [27, 28] and quantified.

Nutritional analysis was performed using Virtual Nutri Plus software (http://www.virtualnutriplus.com.br) and Brazilian food composition tables. Caloric intake (kcal), protein (g), carbohydrates (g), lipids (g), and fibre (g) were calculated.

UPFs were defined according to the NOVA classification [11, 29] and expressed as % of energy, grams/day, and number of UPFs/day. Identification was based on food description, category, packaging, brand, and flavour where available (Supplementary Information, Additional file 1). Classification was double-checked, and discrepancies were resolved by a third specialised evaluator (KDSR).

A UPF ranking was created using the sum of grams of each UPF to identify the largest contributors to the diet. UPFs were clustered by similarity to facilitate classification and ranked by decreasing energy contribution (Supplementary Information, Additional file 3).

Usual UPF intake was estimated using the Multiple Source Method (https://nugo.dife.de/msm/) [30], which models the probability of consumption and usual intake, allowing adjustment for covariates such as energy intake. Only participants with more than two 24-hour recalls were included. UPF intake was expressed in grams per participant. Although many studies use energy contribution (%), we chose grams to capture low- or non-caloric UPFs such as artificially sweetened beverages and packaged bakery products.

Covariates collected included income (< USD 113.50 per capita), education (< high school), residence (rural/urban), race (non-white/white), maternal age, glycaemic control via self-monitoring (inadequate if fasting < 65 or > 95 mg/dL, 1-h post-meal > 140 mg/dL, 2-h post-meal > 120 mg/dL) [31], blood pressure (inadequate if SBP ≥ 140 mmHg and/or DBP ≥ 90 mmHg) [32], ppBMI (underweight, overweight, obesity), pregnancy complications, and GDM treatment (diet alone or diet plus insulin).

Diet was prescribed by the maternity nutritionist according to ppBMI and GWG-adjusted energy requirements. Participants received a list of food substitutes to improve dietary variety. Insulin therapy was initiated if ≥ 2 glycaemia measurements exceeded targets after 7–14 days of dietary intervention [33]. Doses and timing of regular and/or NPH insulin were adjusted according to glycaemic profile. Neonatal data included sex, gestational age at birth (preterm < 37 weeks), length, and delivery mode.

Statistical analyses were conducted using Statistical Package for Social Sciences (SPSS) version 23.0. Descriptive statistics included n (%) for categorical variables, mean ± SD for continuous variables, and median (IQR 25th–75th percentile) for non-parametric variables.

Usual dietary intake was energy-adjusted using the residual method, generating standardised residuals from regression of energy over UPF, macronutrients, and fibre to reduce measurement error.

Pearson's chi-square, ANOVA, or Kruskal–Wallis tests assessed categorical and continuous variables, respectively. Multiple linear regression analysed associations between UPF intake (g/day) and GWG (kg, Z-score at T1, T2, T3) and birthweight (g, WAZ, WLZ, FWZ) using stepwise selection. Significant models are presented with β coefficients, 95% CIs, and p-values.

Generalised linear models with Poisson adjustment assessed the impact of UPF tertiles on rapid GWG development (T1, T2), excessive GWG (T3), high WAZ (> + 2), overweight (≥ + 1 WLZ), and LGA (WA > 90th centile), estimating RR, 95% CI, and p-values. All models were adjusted for race, education, income, hypertensive disorders, glycaemic control, GDM treatment, ppBMI, and GWG T3 classification (for neonatal outcomes). Variables were entered stepwise, with significance set at $p < 0.05$.

Results

A total of 140 women with GDM and their neonates were included in the study (Fig. 2), with a mean age of 31.1 ± 6.1 years. Most participants were Black, Brown, or Indigenous and had low income. GDM was diagnosed at a median of 11 weeks' gestation (IQR 8–19); 33.4% received insulin, and around one-third exhibited inadequate glycaemic control by self-monitoring. Participants were also categorised according to tertiles of UPF intake (Table 1). Most deliveries were by caesarean section, and although the highest UPF tertile had more preterm births, there were no significant differences between groups in sociodemographic, clinical, obstetric, or delivery characteristics ($p > 0.05$) (Table 1).

Table 1

Sociodemographic, clinical, obstetrical and delivery characterization of Gestational Diabetes Mellitus pregnant women and their neonates clustered by ultra-processed food consumed in grams tertiles. Januario Cicco Maternity School, Natal/RN, 2022–2024 (n = 140).

Population Characteristics	Total (n = 140)	UPF grams Tertiles			P value
		Tertile 1 (0g–105.27g) (n = 46)	Tertile 2 (105.28g–167.47g) (n = 47)	Tertile 3 (> 167.47g) (n = 47)	
Maternal Data					
Age, years, mean (SD)	31.12 (6.10)	30.76 (6.39)	32.02 (5.88)	30.57 (6.07)	0.467[b]
Housing area, rural, n (%)	22 (15.70)	6 (27.30)	6 (27.30)	10 (45.50)	0.437[a]
Race, no-white, n, (%)	105 (75)	32 (30.50)	38 (36.20)	35 (33.30)	0.452[a]
Educational level					
Until elementary school, n (%)	51 (36.40)	17 (33.30)	18 (35.30)	16 (31.40)	
Until high school, n (%)	79 (56.40)	27 (34.20)	26 (32.90)	26 (32.90)	0.821[a]
Per capita income, Australian dollar (AUD), median (IQR)	60.42 (37.98–151.90)	76,71 (35,52–132.70)	148.52 (54.03–233.95)	54.25 (29.87–90.86)	0.953[c]
Low income, n (%)	79 (64.20)	26 (32,90)	25 (31.60)	28 (35.40)	0.962[a]
Social benefit, n (%)	66 (52.40)	27 (40.90)	16 (24.20)	23 (34.80)	0.052[a]
Number of pregnancies, median (IQR)	3 (2–3)	3 (2–4)	2 (1–2.5)	1 (1–3)	0.406[c]
Gestational age in GDM diagnosis, weeks, median (IQR)	11 (8–19)	9 (7.25–17)	8.50 (7.75–14.75)	13.50 (9–24.25)	0.939[c]
Glycaemia in GDM diagnosis, mg/dL, median (IQR)	98 (94–105.25)	98.50 (95.25–110.50)	103.35 (96.50–109.50)	102 (94.25–110.75)	0.584[c]
GDM treatment					
Diet control, n (%)	92 (65.70)	32 (34.80)	28 (30.40)	32 (34.80)	

Abbreviations: GDM: gestational diabetes mellitus; UPF: ultra-processed food; g: gramas; [a]Pearson's chi-square Test; [b]ANOVA Test; [c]Kruskal-Wallis Test. *Values indicate statistical significance ($p < 0.05$).

Population Characteristics	Total (n = 140)	UPF grams Tertiles			P value
		Tertile 1 (0g–105.27g) (n = 46)	Tertile 2 (105.28g–167.47g) (n = 47)	Tertile 3 (> 167.47g) (n = 47)	
Maternal Data					
Diet control and insulin therapy, n (%)	48 (34.30)	14 (29.20)	19 (39.60)	15 (31.30)	0.547[a]
Self-monitored glycaemia (capillary glycaemia)					
Fasting glycaemia, mg/dL, mean (SD)	86.02 (11.69)	84 (12.41)	85.75 (9.73)	88.16 (12.658)	0.259[b]
After breakfast, mg/dL, mean (SD)	116,49 (23.89)	115.45 (20.65)	118.51 (27.14)	115.50 (23.974)	0.804[b]
After lunch, mg/dL, median (IQR)	110 (99–125)	105.50 (93.25–123.25)	109.50 (85.5–136.5)	118 (98–127.75)	0.909[b]
After dinner, mg/dL, mean (SD)	117.07 (22.40)	118.55 (19.64)	121.68 (26.86)	112.03 (20.12)	0.185[b]
Glycaemic control, inadequate (n, %)	46 (34.33)	15 (32.60)	16 (34.80)	15 (32.60)	0.985[a]
Hospitalization for Glycaemic Control (n, %)	15 (10.80)	2 (13.30)	7 (46.70)	6 (40.00)	0.211[a]
Days of hospitalization, mean (SD)	6.60 (4.79)	2 (0.00)	8.57 (5.71)	5.83 (3.25)	0.163[b]
Systolic Blood Pressure, mmHg, median (IQR)	119 (110–129.25)	118 (108–128.75)	117 (110–130)	118 (106–123)	0.802[c]
Diastolic Blood Pressure, mmHg, median (IQR)	70 (66–80)	70.5 (65.75–79)	70 (66–74)	67.5 (63–74)	0.546[c]
Blood Pressure Control, inadequate, n (%)	14 (10)	5 (35.70)	5 (35.70)	4 (28.60)	0.916[a]
Hypertensive Diseases, n (%)	42 (30)	14 (33.30)	13 (31.00)	15 (35.70)	0.901[a]

Abbreviations: GDM: gestational diabetes mellitus; UPF: ultra-processed food; g: gramas; [a]Pearson's chi-square Test; [b]ANOVA Test; [c]Kruskal-Wallis Test. *Values indicate statistical significance ($p < 0.05$).

Population Characteristics	Total (n = 140)	UPF grams Tertiles			P value
		Tertile 1 (0g–105.27g) (n = 46)	Tertile 2 (105.28g–167.47g) (n = 47)	Tertile 3 (> 167.47g) (n = 47)	
Maternal Data					
Chronic Hypertension, n (%)	35 (83.30)	12 (85.70)	12 (92.30)	11 (73.30)	
Gestational Hypertension, n (%)	7 (16.70)	2 (14.30)	1 (7.70)	4 (26.70)	0.388[a]
Neonatal Data					
Sex, female, n (%)	55 (40.40)	22 (40.00)	18 (32.70)	15 (27.30)	0.285[a]
Mode of delivery, caesarean, n (%)	94 (68.60)	35 (37.20)	25 (26.60)	34 (36.20)	0.035[a*]
Gestational age at birth, weeks, median (IQR)	38 (37–38)	37.5 (37–38.75)	38 (37–39)	38 (37–38.25)	0.739[c]
Preterm, n (%)	14 (10.30)	2 (14.30)	5 (35.70)	7 (50.00)	0.234[a]

Abbreviations: GDM: gestational diabetes mellitus; UPF: ultra-processed food; g: gramas; [a]Pearson's chi-square Test; [b]ANOVA Test; [c]Kruskal-Wallis Test. *Values indicate statistical significance ($p < 0.05$).

UPF intake accounted for 17.95% of total dietary energy, corresponding to 131.43 grams of consumption (IQR 90.50–200.11) and a mean intake frequency of 3 (IQR 2–4) UPF items per day. Participants in the highest UPF tertile also exhibited the highest total energy intake (Table 2). The main UPFs consumed were cereals and biscuits (4.02%), followed by dairy products (3.60%) and sweetened beverages (3.23%) (Fig. 3).

Table 2

Food consumption of pregnant women with Gestational Diabetes *Mellitus* clustered by ultra-processed food consumed in grams tertiles. Januario Cicco Maternity School, Natal/RN, 2022–2024 (n = 140).

Food Consumption	**Total (n = 140)**	**UPF grams Tertiles**			**P value**
		Tertile 1 (0g–105.27g) (n = 46)	**Tertile 2 (105.28g–167.47g) (n = 47)**	**Tertile 3 (> 167.47g) (n = 47)**	
Total calorie, kJ, mean (DP)	8203.65 (1927.69)	7447.52 (1954.39)	8154.62 (1661.42)	8992.75 (1876.65)	< 0.001[a*]
Nova Classification					
Unprocessed or minimally processed Food, kJ, median (IQR)	5089.50 (4312.53–5993.54)	5501.96 (5000.46–7755.50)	5205.77 (3782.46–6699.55)	5334.26 (4199.06–5917.76)	0.513[b]
Cooking Ingredients, kJ, median (IQR)	734.75 (495.47–1060.56)	655.38 (506.22–1075.54)	721.32 (351.87–829.10)	829.27 (421.87–1503.35)	0.513[b]
Processed Food, kJ, median (IQR)	570.91 (289.82–831.99)	743.75 (540.99–1029.09)	332.33 (210.37–483.25)	402.24 (214.01–1076.92)	0.756[b]
Ultra-processed Food, kJ, median (IQR)	1322.73 (933.57–1851.42)	794.96 (472.16–990.02)	1351.01 (1133.40–1487.58)	2434.50 (1479.84–2809.39)	< 0.001[b*]
UPF gramma, g, median (IQR)	131.43 (90.50–200.11)	72.38 (45.59–89.13)	117.04 (112.25–135.02)	232.94 (200.11–273.35)	< 0.001[b*]
Frequency of UPF/day, n, median (IQR)	3 (2–4)	2 (1–2)	4 (2–5.25)	3 (2–6.5)	< 0.001[b*]
Macronutrients					
Carbohydrates, g, median (IQR)	256.96 (231.57–274.54)	269.22 (255.49–294.60)	263.04 (253.33–288.52)	256.15 (224.25–272.94)	0.240[b]

Abbreviations: UPF: ultra-processed food; kJ: quilojoules; g: grams; n: quantity; [a]ANOVA Test; [b]Kruskal-Wallis Test. *Values indicate statistical significance (p < 0.05).

Food Consumption	Total (n = 140)	UPF grams Tertiles			P value
		Tertile 1 (0g–105.27g) (n = 46)	Tertile 2 (105.28g–167.47g) (n = 47)	Tertile 3 (> 167.47g) (n = 47)	
Fibres, g, median (IQR)	28.35 (23.61–32.65)	28.2 (25.49–29.49)	31.05 (28.10–33.28)	23.75 (20.15–29.53)	0.397[b]
Proteins, g, median (IQR)	89.63 (81.10–99.93)	95.01 (85.46–103.83)	84.13 (78.35–89.96)	88.97 (79.55–101.16)	0.979[b]
Lipids, g, mean (SD)	62.03 (11.63)	60.17 (12.19)	62.36 (9.00)	63.51 (13.28)	0.374[a]

Abbreviations: UPF: ultra-processed food; kJ: quilojoules; g: grams; n: quantity; [a]ANOVA Test; [b]Kruskal-Wallis Test. *Values indicate statistical significance ($p < 0.05$).

Most women commenced pregnancy overweight (> 80%). The weight gain trajectory was rapid in both T1 (57.10%) and T2 (47.60%) (Table 3). Half of the women experienced excessive gestational weight gain (T3). The mean GWG was 6.86 (± 6.78) kg, with no significant differences between the UPF tertile groups (Fig. 4A and B) (Supplementary Information, Additional file 4).

Table 3

Anthropometric indicators of pregnant with gestational diabetes and neonates by tertiles of ultra-processed food intake in grams. Januario Cicco Maternity School, Natal/RN, 2022–2024 (n = 140).

Anthropometric Indicators	**Total (n = 140)**	**UPF grams Tertiles**			
		Tertile 1 (0g–105.27g) (n = 46)	**Tertile 2 (105.28g–167.47g) (n = 47)**	**Tertile 3 (> 167.47g) (n = 47)**	**P value**
ppBMI, kg/m², mean (SD)	31.32 (6.22)	30.15 (5.13)	31.82 (4.93)	31.97 (8.05)	0.296[b]
ppBMI Classification					
Overweight, n (%)	41 (29.30)	15 (36.60)	11 (26.80)	15 (36.60)	
Obesity, n (%)	80 (57.10)	24 (30.00)	32 (40.00)	24 (30.00)	0.446[a]
Classification of GWG of Time 1					
Slow, n (%)	40 (28.60)	15 (37.50)	12 (30.00)	13 (32.50)	
Fast, n (%)	80 (57.10)	26 (32.50)	27 (33.80)	27 (33.80)	0.899[a]
Classification of GWG of Time 2					
Slow, n (%)	30 (36.60)	11 (36.70)	9 (30.00)	10 (33.30)	
Fast, n (%)	39 (47.60)	16 (41.00)	14 (35.90)	9 (23.10)	0.789[a]
Classification of final GWG					
Low, n (%)	40 (28.60)	11 (27.50)	16 (40.00)	13 (32.50)	
High, n (%)	71 (50.70)	25 (35.20)	19 (26.80)	27 (38.00)	0.449[a]
EFW, g, median (IQR)	1618 (654–2314)	1515 (782.25–2136.75)	1945.5 (1547.38–2913.75)	2018 (862.5–2610.5)	0.970[c]
EFW Z-Score, median (IQR)	0,5 (-0.1–1.1)	0.25 (-0.22–0.85)	0.5 (0.2–0.73)	0.4 (0.08–1.35)	0.293[c]

Abbreviations: ppBMI: pre-pregnancy body mass index; GWG: gestational weight gain; T1 (Time 1) – First data collection (≥ 9 weeks); T2 (Time 2) – Third trimester (29–40 weeks); EFW: estimated foetal weight; SGA: small for gestational age; LGA: large for gestational age; [a]Pearson's chi-square Test; [b]ANOVA Test. [c]Kruskal-Wallis

Anthropometric Indicators	Total (n = 140)	UPF grams Tertiles			
		Tertile 1 (0g–105.27g) (n = 46)	Tertile 2 (105.28g–167.47g) (n = 47)	Tertile 3 (> 167.47g) (n = 47)	P value
EFW Classification					
Small, n (%)	12 (9.30)	4 (33.30)	4 (33.30)	4 (33.30)	
Large, n (%)	27 (20.90)	6 (22.20)	8 (29.60)	13 (48.10)	0.402[a]
Birthweight, g, mean (SD)	3133.17 (466.29)	3120.73 (445.34)	3139.24 (438.12)	3139.53 (521.20)	0.977[b]
Birth length, cm, median (IQR)	48 (47–50)	48 (47–49)	49.5 (47.75–51.25)	47 (46.75–49)	0.567[c]
Birthweight for gestational age Classification					
SGA, n (%)	7 (5.20)	4 (57.10)	1 (14.30)	2 (28.60)	
LGA, n (%)	11 (8.10)	3 (27.27)	5 (45.46)	3 (27.27)	0.596[a]
Birthweight Classification					
Low birthweight, n (%)	11 (8.20)	4 (36.40)	3 (27.30)	4 (36.40)	
Macrosomia, n (%)	1 (0.70)	–	–	1 (100.00)	0.693[a]
Z-Score weight for age, mean (SD)	-0.23(0.87)	-0.35 (0.89)	-0.12 (0.72)	-0.21 (1.00)	0.471[b]
Weight for age Classification					
Underweight, n (%)	3 (2.20)	2 (66.70)	–	1 (33.30)	
High weight, n (%)	1 (0.80)	–	–	1 (100.00)	0.398[a]
Z-Score of weight for length, mean (SD)	0.45 (1.19)	0.57 (1.27)	0.32 (1.10)	0.46 (1.20)	0.627[b]

Abbreviations: ppBMI: pre-pregnancy body mass index; GWG: gestational weight gain; T1 (Time 1) – First data collection (≥ 9 weeks); T2 (Time 2) – Third trimester (29–40 weeks); EFW: estimated foetal weight; SGA: small for gestational age; LGA: large for gestational age; [a]Pearson's chi-square Test; [b]ANOVA Test. [c]Kruskal-Wallis

Anthropometric Indicators	Total (n = 140)	UPF grams Tertiles			
		Tertile 1 (0g–105.27g) (n = 46)	Tertile 2 (105.28g–167.47g) (n = 47)	Tertile 3 (> 167.47g) (n = 47)	P value
Weight for length Classification					
Wasting, n (%)	14 (11.90)	4 (28.60)	6 (42.90)	4 (28.60)	
Overweight, n (%)	104 (88.10)	38 (36.50)	33 (31.70)	33 (31.70)	0.697[a]
Z-Score of length for age, median (IQR)	-0.62 (-1.52–0.06)	-0.75 (-1.43–-0.47)	0.19 (-1.04–1.13)	-1.15 (-1.56–-0.37)	0.399[c]
Length for age classification					
Stunting, n (%)	16 (11.90)	8 (50.00)	4 (25.00)	4 (25.00)	0.322[a]

Abbreviations: ppBMI: pre-pregnancy body mass index; GWG: gestational weight gain; T1 (Time 1) – First data collection (≥ 9 weeks); T2 (Time 2) – Third trimester (29–40 weeks); EFW: estimated foetal weight; SGA: small for gestational age; LGA: large for gestational age; [a]Pearson's chi-square Test; [b]ANOVA Test. [c]Kruskal-Wallis

The mean birthweight was 3133.17 (± 466.29) grams; 8% of neonates were classified as LGA, and the majority of these (88.10%) were categorised as overweight according to the WLZ anthropometric index (Table 3).

Multiple linear regression models (Table 4) demonstrated a positive association between increased UPF intake (g) in the maternal diet and GWG at T1 as well as final GWG (T3), both expressed in kilograms and their respective Z-scores (β = 0.014; p = 0.002 and β = 0.015; p = 0.023, respectively). Only pre-pregnancy BMI (ppBMI) showed an inverse association with GWG at T2. No significant associations were observed between UPF consumption in grams and neonatal weight outcomes.

Table 4
Association of maternal ultra-processed foods consumption (tertiles of g/day) and adverse maternal and neonatal outcomes. Januario Cicco Maternity School, Natal/RN, 2022–2024 (n = 140).

Maternal weight outcomes	β-adjusted	CI 95%	P valour
GWG in T1, kg[a]			
Model 1			
ppBMI (classification)	**-2.426**	-3.796 to -1.057	0.010*
Model 2			
ppBMI (classification)	-2.440	-3.783 to -1.098	< 0.001*
UPF (g)	0.014	0.003 to 0.025	0.002*
GWG Z-score in T1[b]			
Model 1			
UPF (g)	0.002	0.000 to 0.004	0.039*
GWG in T2, kg[a]			
Model 1			
ppBMI (classification)	-3.750	-5.937 to -1.563	0.001*
GWG Z-score in T2[a]			
Model 1			
ppBMI (classification)	-0.331	-0.646 to -0.016	0.040*
Total GWG, kg[b]			
Model 1			
ppBMI (classification)	-2.493	-4.105 a -0.880	0.003*
Model 2			

Abbreviations: UPF: ultra-processed foods; ppBMI: pre-pregnancy body mass index; GWG: gestational weight gain; WAZ: weight-for-age; WLZ: weight-for-length; LGA: large for gestational age; RR: relative risk; T1 (Time 1): First data collection (≥ 9 weeks); T2 (Time 2) – Third trimester (29–40 weeks); CI95%: confidence interval of 95%.

[a]Adjustment by confounding variables: income classification, educational level, race and GDM treatment. [b]Adjustment by confounding variables: pre-pregnancy body mass index classification, income classification, educational level, race and GDM treatment. [c]Adjusted by GDM treatment, race, educational level, income, ppBMI classification, glycaemic control e presence of hypertensive disease. For the neonates we included the final GWG classification; [d]Significative model adjusted by race and ppBMI. *Values indicate statistical significance (p < 0.05).

Maternal weight outcomes	β-adjusted	CI 95%	P valour
GWG in T1, kg[a]			
ppBMI (classification)	-2.509	-4.093 a -0.924	0.002*
UPF (g)	0.015	0.002 a 0.029	0.023*
Total GWG Z-score[b]			
Model 1			
UPF (g)	0.003	0.001 a 0.005	0.001*
Maternal and neonatal weight outcomes	**Tertiles of g/day of AUP**		
	RR	**IC 95%**	**P valour**
Maternal outcomes			
Fast GWG in T1[c]	0.982	0.939–1.027	0.425
Fast GWG in T2[c]	1.015	0.954–1.080	0.633
Elevated final GWG[c]	1.008	0.961–1.058	0.743
Neonatal outcomes			
High weight for age (> + 2 WAZ)[d]	3.424	1.068–10.974	0.038*
Overweight (>=+1 WLZ)[c]	1.000	1.000–1.000	0.947
LGA (weight for gestational age > 90th)[c]	1.007	0.979–1.036	0.629

Abbreviations: UPF: ultra-processed foods; ppBMI: pre-pregnancy body mass index; GWG: gestational weight gain; WAZ: weight-for-age; WLZ: weight-for-length; LGA: large for gestational age; RR: relative risk; T1 (Time 1): First data collection (≥ 9 weeks); T2 (Time 2) – Third trimester (29–40 weeks); CI95%: confidence interval of 95%.

[a]Adjustment by confounding variables: income classification, educational level, race and GDM treatment. [b]Adjustment by confounding variables: pre-pregnancy body mass index classification, income classification, educational level, race and GDM treatment. [c]Adjusted by GDM treatment, race, educational level, income, ppBMI classification, glycaemic control e presence of hypertensive disease. For the neonates we included the final GWG classification; [d]Significative model adjusted by race and ppBMI. *Values indicate statistical significance (p < 0.05).

Generalised linear models with Poisson adjustment indicated that a higher contribution of UPFs (g) in the maternal diet was associated with a 3.424-fold increased risk of high birthweight for gestational age (RR = 3.424; 95% CI 1.068–10.974; p = 0.038). However, as only one case was observed (Table 4), no conclusion can be drawn regarding the association between UPF consumption and other neonatal outcomes.

Discussion

In this prospective cohort, pregnant women with GDM had a mean UPF intake corresponding to 17.95% of their total diet, averaging 131.43 grams per day. We observed that UPF consumption was associated with adverse outcomes for GWG and high birthweight, both per 1 gram/day increase and in those with the highest dietary UPF contribution (tertile 3, >167.47 g/day).

The use of samples from a single maternity hospital is a limitation of our study. In addition, we relied on 24-hour dietary recalls to assess food intake, which may be limited by participants' memory. Therefore, the findings should be interpreted with caution. Furthermore, only one case of LGA was observed, which fell within the highest UPF tertile. Although this shows a significant association, it is important that the study be replicated in a more heterogeneous sample.

Nevertheless, it is worth emphasising that this is the first study to examine the impact of UPF on weight outcomes in women with GDM, highlighting the innovative approach employed. Although conducted in a single centre, our findings are consistent with literature reports on UPF consumption in low-risk pregnancies. They also reinforce that even a small amount of UPF intake can influence weight gain during pregnancy and at its conclusion.

Another important aspect of our research was the development of a prospective cohort study in a GDM population. This allowed us to evaluate participants throughout pregnancy regarding UPF consumption and to establish a causal relationship with its impact on GWG and birthweight. In addition, we analysed habitual dietary intake using the Multiple Source Method (MSM), providing greater reliability for total energy and macronutrient intake as well as UPF consumption in grams and calories. The use of dietary recalls adapted to the NOVA classification was also valuable for facilitating the identification of UPFs in the diet.

Despite the established literature on the importance of diet during pregnancy [34] and the adverse effects of UPF consumption in the general population [12, 35] research on the impact of UPF intake during pregnancy [8] and its outcomes in the context of GDM remains scarce [9]. Our group was among the first to investigate this, showing in a previous publication that higher UPF intake in the diet of women with GDM increased the risk of neonatal hypoglycaemia (OR = 1.144, 95% CI = 1.037–1.262; p = 0.007) [9].

Compared with other studies, UPF consumption in our cohort was lower than in low-risk pregnancies (20.9% and 35.3% of energy from UPFs) [14,36]. Our UPF consumption profile may reflect the nutritional support provided during prenatal care. Evidence suggests that women with GDM consume fewer UPFs and more unprocessed or minimally processed foods [37]. Other research found a lower likelihood of consuming unprocessed and minimally processed foods in the absence of nutritional counselling during prenatal care (OR = 0.459, 95% CI = 0.307–0.687; p < 0.001) [38]. This same study also showed that higher maternal age (>35 years) reduced the likelihood of UPF consumption (OR = 0.265, 95% CI =

0.105–0.666; p = 0.005) compared with pregnant women aged ≤19 years, who were 2.9 times more likely to consume UPFs (OR = 2.950, 95% CI = 1.683–5.168; p < 0.001) [38].

Most women with GDM exhibited a rapid or excessive GWG trajectory from early pregnancy. Shi et al. [39] conducted a retrospective cohort study in women with GDM and observed that GWG above the Institute of Medicine recommendations in the second and third trimesters was associated with an increased risk of gestational hypertensive disorders, LGA, and macrosomia. Conversely, they found a reduced likelihood of macrosomia when GWG was below the recommendations.

It is worth emphasising that, despite the recognised importance of nutrition in GDM management, the optimal dietary pattern to reduce adverse maternal and neonatal outcomes remains unclear [16,40]. In our study, the sample showed considerable consumption of cereals and biscuits, sweetened beverages, and packaged bakery products. Their high sugar and low fibre content may have contributed to increased GWG.

Conflicting evidence exists regarding the relationship between GWG and UPF consumption in studies of women without GDM [7]. Some studies reported no association, while others suggested a positive correlation [7, 17, 41]. Rohatgi et al. [17] conducted research in American pregnant women and found that each 1% increase in UPF caloric contribution was associated with a 1.33 kg increase in total GWG (95% CI = 0.3–2.4; p = 0.016). Similarly, a study in Brazilian pregnant women demonstrated that each 1% increase in UPF caloric contribution was associated with a 4g increase in weekly GWG through the third trimester (95% CI = 0.55–7.79; p = 0.024) [17]. This indicates an association between GWG and increased total caloric intake from UPFs, which typically have high energy density and low nutrient content. Considering that excessive GWG is associated with caesarean delivery, LGA, and macrosomia, strategies to reduce UPF consumption may be beneficial for controlling GWG [7].

Only one study has evaluated the impact of UPF consumption on neonatal body composition outcomes [17]. That study observed an association between higher UPF intake and increased neonatal adiposity. For each 1% increase in UPF caloric contribution, they reported an increase of 0.22 mm in thigh skinfold thickness (95% CI = 0.005–0.4; p = 0.045), 0.14 mm in subscapular skinfold thickness (95% CI = 0.02–0.3; p = 0.026), and 0.62% in total body adiposity (95% CI = 0.04–1.2; p = 0.037) [17]. In our study, it was not possible to assess the association between UPF consumption and neonatal excessive weight, as the majority of neonates did not present this condition.

Additionally, other factors may contribute, including foods and nutrients with recognised effects on weight control, such as excessive calories, added sugar, saturated fat, and low content of fibre, protein, and micronutrients [42]. Nevertheless, the poor nutrient profile of UPFs alone does not appear sufficient to fully explain the observed effects. Other studies have shown that the association between UPF consumption and health outcomes persists even after adjusting for overall dietary quality [43, 44]. The production of UPFs involves processed and refined ingredients that lack the natural food matrix, impairing satiety and increasing the glycaemic response [45]. Furthermore, the total and added sugars in UPFs may provoke glycaemic fluctuations, with potential adverse effects on maternal and neonatal

metabolism [15, 46]. In addition, UPFs tend to have higher energy density and low water content, facilitating overconsumption [47, 48].

Although we observed only one neonatal case of macrosomia and high birthweight for gestational age, it is important to emphasise its occurrence in women with GDM, particularly those with elevated pre-pregnancy BMI, gestational weight gain, and glycaemic levels [49]. Wahabi et al. [50] reported that GDM combined with maternal obesity significantly increased the risk of macrosomia (OR = 3.45; 95% CI = 2.05–5.81; $p < 0.001$), macrosomia percentiles ($p < 0.001$), and high birthweight ($p < 0.001$).

Conclusions

UPF intake during pregnancy was associated with excessive gestational weight gain and an increased risk of high birthweight among women with GDM, highlighting the importance of prenatal nutritional counselling focused on improving diet quality. These findings provide important evidence to support future research and the development of nutritional strategies aimed at reducing UPF consumption and improving maternal and neonatal outcomes in pregnancies complicated by gestational diabetes.

Abbreviations

DM: Diabetes Mellitus

EFW: Estimated Fetal Weight

GDM: Gestational Diabetes Mellitus

GWG: Gestational Weight Gain

LGA: Large-for-Gestational-Age

MSM: Multiple Source Method

ppBMI: Pre-pregnancy Body Mass Index

SGA: Small for Gestational Age

SUS: Unified Health System

RecNOVA24h: 24-hour Food Recalls

SPSS: Statistical Package for Social Sciences

T1: Time 1

T2: Time 2

T3: Time 3

UPF: Ultra-Processed Food

WAZ: Weight-for-Age

WLZ: Weight-for-Length

Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Health Research Ethics Committee of the Ethics Committee of the Onofre Lopes University Hospital (Approval No. 5.167.567), Natal, Brazil. Written informed consent was obtained from all participants prior to enrolment in the study. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Written informed consent for publication was obtained from all participants prior to enrolment in the study. All data were anonymized, and no identifying information is included in this article.

Availability of data and materials

All data generated or analysed during this study are included in this published article and its supplementary information files.

Competing interests

The authors declare no competing interests.

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Authors' contributions

MEAO, AGAS, PCS, CMAMS, and KDSR: Conceptualisation. MEAO, AGAS, BRC, PCS, CMAMS, and KDSR: Methodology and Investigation. MEAO, AGAS, BRC, LVPL, AMLL, AIMS, and CNCG: Data Curation. MEOA: Writing – Original Draft. KDSR: Supervision, Formal Analysis, Writing – Review & Editing, and Project Administration. All authors reviewed and approved the final version of the article, collectively accepting responsibility for the published content.

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Figures

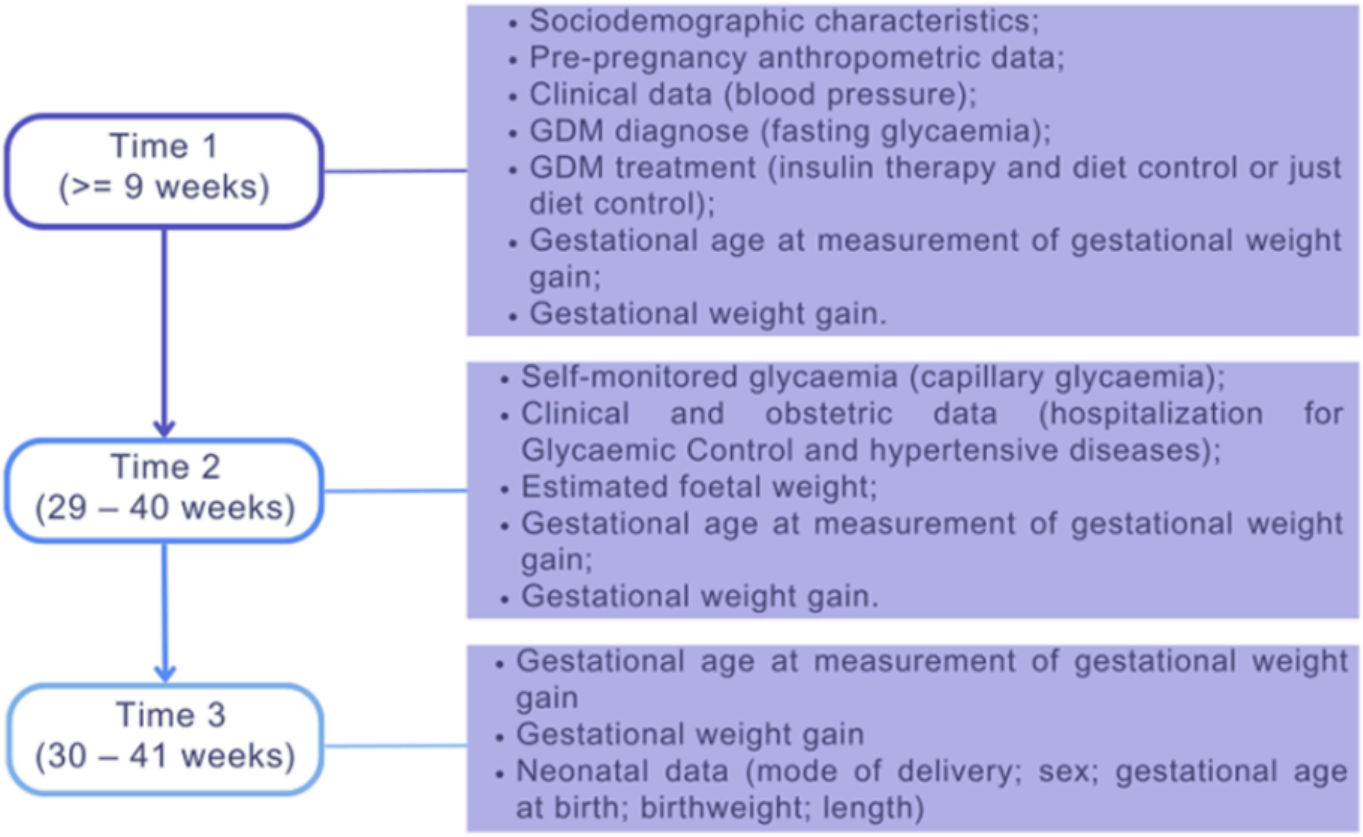
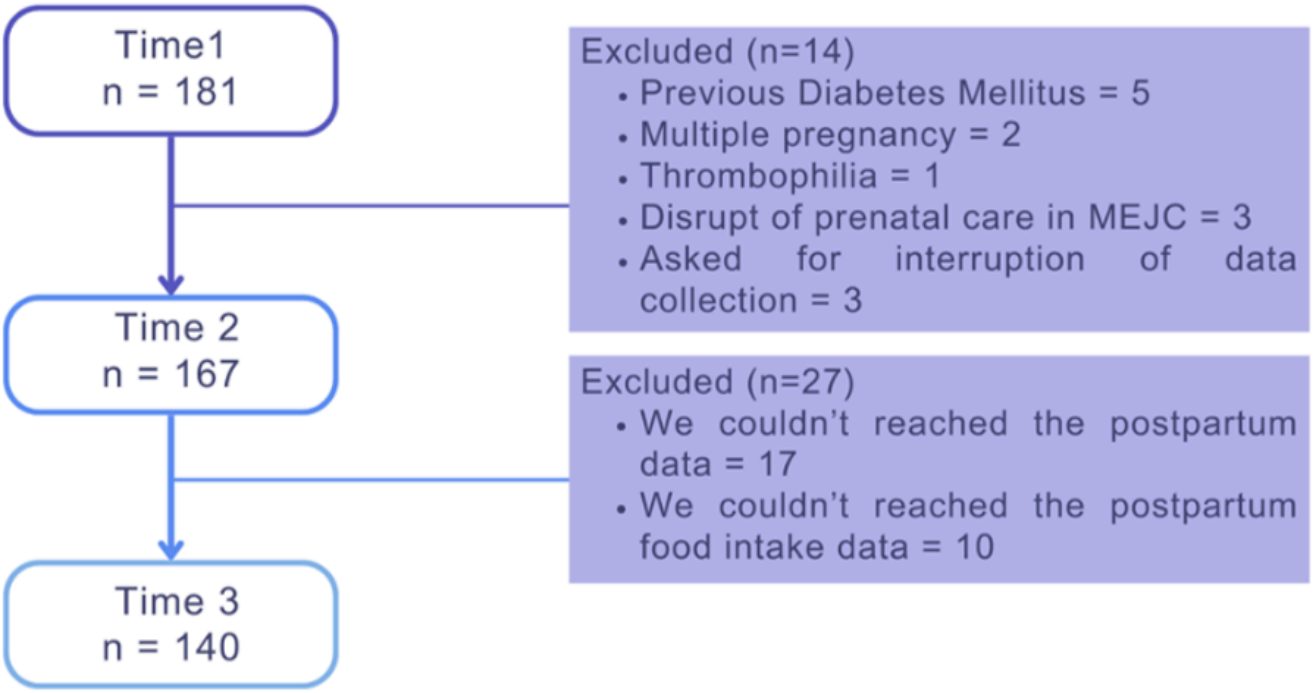


Figure 1

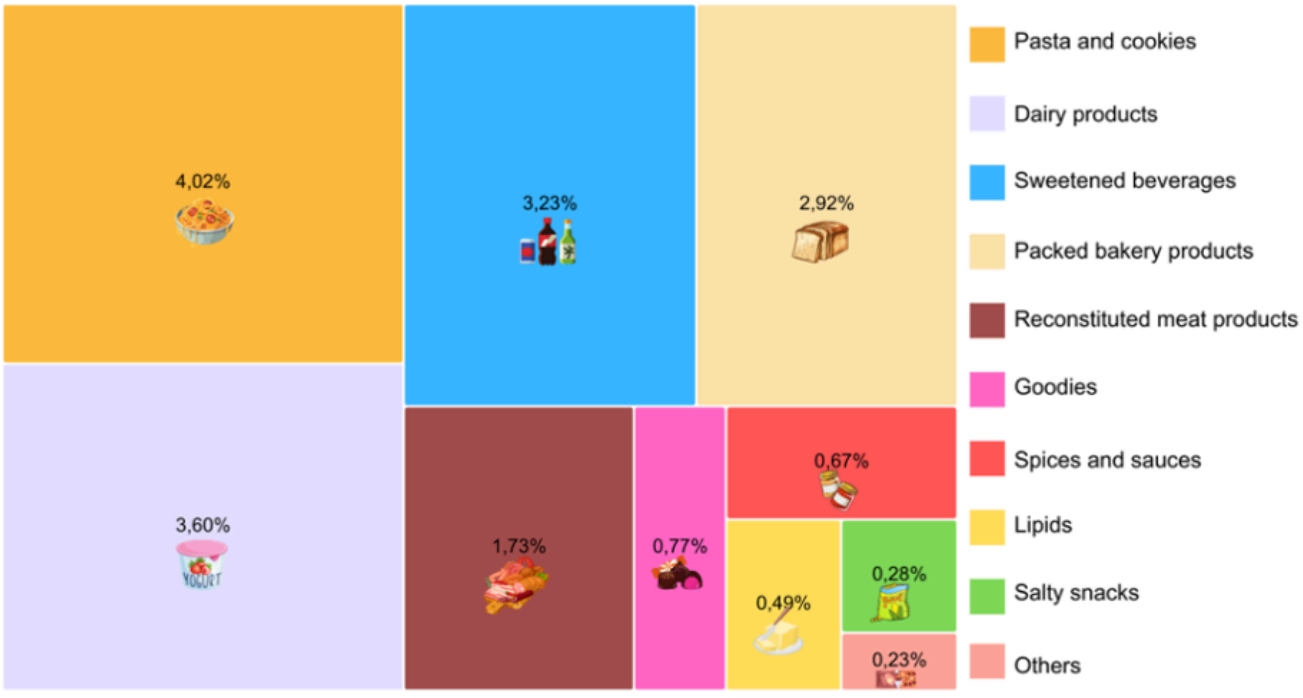
Times of data collection and respective data collected.



Abbreviation: MEJC: Januario Cicco Maternity School.

Figure 2

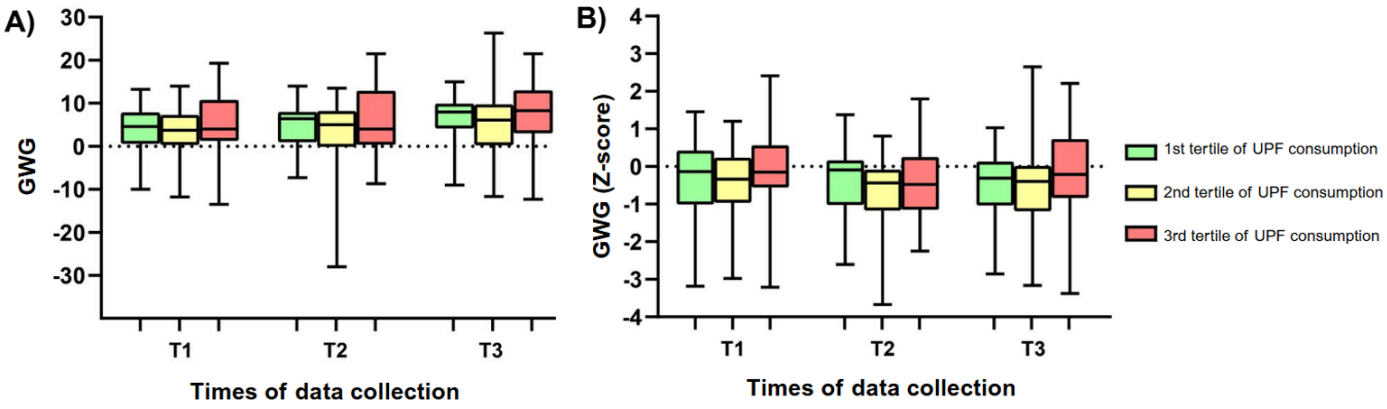
Study flowchart.



Legend: Percentages concerning 17.95% UPF consumed by pregnant women.

Figure 3

Gestational Diabetes Mellitus pregnant women ultra-processed food ranking consumption clustered by their similarities.



Abbreviation: GWG: Gestational Weight Gain; UPF: Ultra-Processed Food; T1 (Time 1): First data collection (≥ 9 weeks); T2 (Time 2): Third trimester (29 - 40 weeks); T3 (Time 3): Immediate postpartum (30 - 41 weeks). **Legend: A)** GWG in the three times of data collection in kg; **B)** GWG Z-score in the three times of data collection. There wasn't any statistical difference between the pregnant groups clustered in tertiles by UPF consumed in grams ($p > 0.05$).

Figure 4

Gestational weight gain among women with gestational diabetes according to tertiles of ultra-processed food intake.

Supplementary Files

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- supplementaryinformation.docx