ORIGINAL ARTICLE

Consumption of ultra-processed food and blood pressure in the first trimester of overweight pregnant women: a cross-sectional analysis of a randomized clinical trial

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Abstract

Objectives: to investigate the association between ultra-processed food (UPF) consumption and blood pressure (BP) in overweight pregnant women.

Methods: secondary analysis of the baseline of a randomized controlled trial including 311 overweight pregnant women. Blood pressure was obtained as the mean of three measurements using an automatic monitor. Dietary intake was assessed using two 24-hour recalls, and food was classified according to the processing degree (NOVA), with UPF identification based on ingredient lists and homemade recipe composition. The association between the percentage of energy (%E) consumption of UPF and BP was evaluated using linear regression, adjusted for confounding factors defined by a directed acyclic graph (DAG).

Results: younger, single, nulliparous, and former smoker pregnant women had higher %E of UPF. The subgroups that contributed the most to energy intake of UPF were sugar-sweetened beverages (16.53%), processed meats (14.48%), and cookies and crackers (10.95%). No association was observed between %E of UPF and systolic BP (β=0.04; 95%CI= -0.085, 0.167; p=0.52) or diastolic BP (β=0.05; 95%CI= -0.045, 0.153; p=0.28) after adjustment for confounding factors.

Conclusion: no association was observed between %E of UPF and BP in early pregnancy among overweight women.

Key words *Ultra-processed food, Pregnant women, Overweight, Blood pressure*

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Introduction

In Brazil, approximately 55.2% of women of reproductive age are overweight.[1] Prepregnancy overweight is associated with an increased risk of high blood pressure (BP) and adverse maternal and fetal outcomes.[2] The mechanisms involved in this association include changes in the metabolic status of pregnant women, such as insulin resistance, altered lipid profile, and increased levels of pro-inflammatory cytokines and antiangiogenic factors, which may contribute to endothelial dysfunction and placental ischemia, classic conditions associated with hypertensive disorders of pregnancy.[3]

In addition to excess weight, an inadequate diet is another risk factor for elevated blood pressure in pregnant women. According to NOVA classification, ultra-processed food (UPF), such as soft drinks and packaged salty snacks, are industrially manufactured products made primarily from food-derived substances, as well as additives such as preservatives and flavorings.[4] UPF is associated with dietary nutrient profiles—such as simple sugar, saturated fat, and sodium, related to increased risk of overweight, obesity, and high blood pressure. Furthermore, as the energy percentage (%E) of UPF intake increases, there is a lower intake of protective nutrients, such as potassium and fiber.[4]

In recent years, excessive consumption of UPF has been observed among various population groups, including pregnant women. In this group, a high %E of UPF appears to be associated with poorer maternal diet quality.[5–8] A study of 229 Brazilian pregnant women showed that those with higher UPF intake also consumed more calories, trans fat, and sodium.[9] Another study of 206 Israeli pregnant women related to higher consumption of UPF reduced potassium intake.[10] Since the new *Guia Alimentar para a População Brasileira* (Dietary Guidelines for the Brazilian Population) recommend avoiding the consumption of UPF, it is understood that such intake should be discouraged, especially during critical stages of the life cycle, such as pregnancy.[11]

Therefore, considering that being overweight and an inadequate diet are risk factors for elevated blood pressure, and that maintaining normal blood pressure is essential for reducing adverse maternal and fetal outcomes, the present study aimed to investigate the association between the %E of the usual UPF intake and blood pressure in overweight pregnant women during the first trimester of pregnancy. Our hypothesis is that excessive consumption of UPF is associated with increased blood pressure in overweight pregnant women.

Methods

This study used baseline data from the randomized controlled clinical trial titled *"Estudo de intervenção nutricional em gestantes com sobrepeso atendidas em Unidades Básicas de Saúde: um ensaio clínico aleatorizado controlado"* (Nutritional Intervention Study in Overweight Pregnant Women Treated at Primary Health Care Units: A Randomized Controlled Clinical Trial) conducted between 2018 and 2021. The objective of the clinical trial was to evaluate the effectiveness of a nutritional intervention based on encouraging the consumption of fresh and minimally processed food, rather than UPF, along with regular physical activity, in preventing excessive weight gain in overweight pregnant women receiving prenatal care at Primary Health Care Units (PHU) in the Public Health System of Ribeirão Preto, São Paulo, Brazil.[12,13]

Pregnant women were recruited from seven health units in the city of Ribeirão Preto, São Paulo: Waldemar Barnsley Pessoa (Parque Ribeirão), Dr. Marco Antônio Sahão (Vila Virgínia), Dr. Sérgio Botelho da Costa Moraes (Jardim Presidente Dutra), Adalberto Teixeira Andrade (Vila Recreio), Carlos Chagas (Vila Abranches), Rubens Issa Halak (Jardim Juliana), and Dr. Ítalo Baruffi (Castelo Branco Novo).

Pregnant women aged ≥ 18 years, with a gestational age (GA) of up to 15 weeks and six days, and a pre-pregnancy body mass index (BMI) between 25 kg/m² and 29.9 kg/m² were considered eligible. Pregnant women with pre-existing diabetes mellitus or who were taking oral hypoglycemic agents, insulin, and/or weight-loss medications were excluded. In the present study, women with pre-existing hypertension and/or taking antihypertensive medications and/or who had blood pressure greater than 140/90 mmHg at their first prenatal visit were also excluded.

The conduct of the clinical trial was approved by the Research Ethics Committee of the *Centro de Saúde Escola da Faculdade de Medicina de Ribeirão Preto da Universidade de São Paulo* (69997717.6.0000.5414 and 97288818.0.0000.5414). This analysis was also submitted to and approved by the same Research Ethics Committee (72848123.0.0000.5414).

The Informed Consent Form (ICF) was signed by all pregnant women who agreed to participate in the study. The clinical trial was registered on the *Registro Brasileiro de Ensaios Clínicos* (REBEC) (Brazilian Clinical Trials Registry) platform under the following protocols: RBR-2w9bhc, July 30, 2018, and RBR-7yx36h, June 4, 2019.

The sample size for the clinical trial was calculated based on the adequacy of gestational weight gain, the primary outcome of the clinical trial. First, a minimum significance level of 5% (α=0.05), a power of 90% (β=0.1), and a follow-up loss of 20% were assumed, resulting in a sample size of 300 pregnant women Due to the COVID-19 pandemic, the attrition rate of the study was 40%, higher

than expected, and the sample size had to be recalculated, resulting in a sample size of 350 pregnant women.[12,13]

In the present study, a non-probabilistic convenience sampling strategy was adopted, including pregnant women with complete data at the first assessment of the clinical trial who met the eligibility criteria. Of the 350 women randomized, 335 completed the baseline assessment. Of these, 12 were excluded because they had a diagnosis of pre-pregnancy hypertension and 12 due to missing dietary intake data, resulting in 311 eligible participants included in the descriptive analyses. Of the 311 pregnant women evaluated, 20 lacked data on systolic blood pressure (SBP) and/or diastolic blood pressure (DBP). Therefore, for the regression analyses, only those with complete data were considered, resulting in a final sample of 291 participants (Supplementary Figure 1).

The following data were obtained through a structured questionnaire: age, self-reported skin color, marital status, the pregnant woman's schooling and the head of the household, frequency of alcohol consumption, use of supplements and/or medications, smoking status, parity, engagement in paid work, and ownership of consumer goods. The 2019 *Critério de Classificação Econômica Brasil* (CCEB) (Brazilian Economic Classification Criteria) were used to determine socioeconomic status on a scale ranging from A (highest socioeconomic status) to E (lowest socioeconomic status), based on ownership of household items, the head of household's schooling, and access to running water and a paved street.[14]

At the time of data collection, weight (kg) and height (m) were measured using a digital scale (Tanita, HS302) and a portable stadiometer (Sanny, ES2040), respectively. Pre-pregnancy BMI was calculated using the following equation: pre-pregnancy weight (kg) / height (m^2).

SBP and DBP data were obtained using an automatic digital upper-arm blood pressure monitor (OMRON®, model HBP 1100, Omron Health Care Inc.), based on the average of three readings during the first assessment (up to the 15th week of gestation plus six days). Blood pressure readings were taken at non-consecutive intervals throughout the administration of the socioeconomic questionnaire. Pregnant women rested for at least 5 minutes before the first blood pressure measurement, which was taken with the participant seated and her arm resting on a table. Subsequent measurements were taken at approximately 15-minute intervals. The monitor was used on either the right or left arm, with a cuff appropriate for the arm circumference. The measurements were taken at the Basic Health Units (BHU) during prenatal visits; therefore, it was not possible to standardize factors such as room temperature, noise, and prior caffeine consumption.

Dietary intake data were obtained through the administration of two 24-hour recall questionnaires (24h-RQ) on non-consecutive days, up to the 15th week of gestation and 6 days thereafter, by trained nutritionists. The "multiple pass" method was employed in seven stages. The first stage consists of a quick, uninterrupted account by the respondent, noting all food and beverages consumed the previous day. In stages two, three, and four, the respondent is asked to provide details about the food and beverages, specifying the amount consumed (in household measures); the type of food (e.g., whole or skim); whether it was sweetened with sugar or a sweetener; and whether it was homemade or commercially prepared.[4] Finally, in stages five, six, and seven, the interviewee is asked about the time; the name (e.g., breakfast, dinner); and the location where the meal was consumed. At the end, the interviewer reviews the reported food and beverages to ensure that any food or beverages that may have been forgotten and/or omitted by the participant are included.[15,16]

The food consumed by pregnant women were classified according to their degree of processing into: fresh or minimally processed, processed, culinary ingredients, and UPF, based on an analysis of the ingredient lists for processed food and the composition of recipes for home-prepared meals.[4] Only the UPF were selected and subsequently classified into sixteen subgroups: candies and sweets, potato chips, sugary beverages, cookies and crackers, processed meat, cereals and cereal mixes, yogurts and dairy beverages, margarine, breads and toast, powders for dissolving in water and milk, ready-to-eat meals, cheeses, packaged salty snacks, savory snacks, sandwiches, and seasonings, sauces, and pâtés.[17]

Dietary energy intake (kcal) was estimated using the Nutrition Data System for Research (NDSR) software, developed by the University of Minnesota in the United States. The estimate of usual consumption of ultra-processed food was performed in three stages using a statistical modeling program developed by the European Prospective Investigation into Cancer and Nutrition (EPIC), the Multiple Source Method (MSM) is based on two 24-hour dietary recalls.[18] In the first step, the probability of consuming a food or nutrient on a random day is estimated; in the second step, the usual intake on days of consumption is estimated; and finally, in the third step, a calculation is performed in which the product of the probability of consumption on a random day (first step) and the usual intake on a day of consumption (second step) yields the individual's actual intake.[19]

The Goldberg cutoff (EI/BMR ratio) was applied to identify underreporting energy, using a cutoff point of EI/BMR ≤1.20, in accordance with previous studies involving pregnant women.[20] Basal metabolic rate (BMR) was estimated using FAO/WHO/UNU equations: 14.7 × weight (kg) + 496 for women <30 years of age and 8.7

× weight (kg) + 829 for those aged 30 years or older.[21] Sensitivity analyses were conducted by comparing the results of the total sample with those of the sample after excluding sub-reporters, in order to assess the robustness of the observed associations.

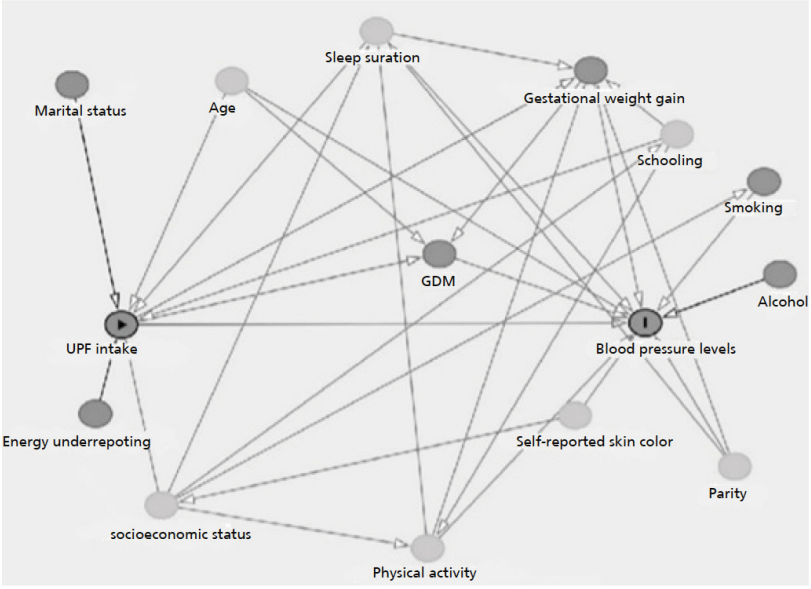
The proportion of missing data was low, with an overall loss of 6.4% in the analytical sample and low values for most variables (<2%), being higher only for socioeconomic status (11.3%). Given the low overall loss, a complete-cases analysis was chosen.

Continuous variables were presented as medians (P25;P75), and categorical variables as absolute and relative frequencies (%). The main analysis was conducted using the percentage of UPF intake as a continuous variable. For descriptive purposes and to facilitate sample categorization, the variable was additionally categorized based on the sample median (<25% and ≥25% of the TEV). The Mann-Whitney test was used to compare the characteristics of pregnant women according to their UPF intake.

Simple and multiple linear regression models were used to investigate the association between usual UPF intake and blood pressure (BP) in pregnant women. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were treated as conceptually integrated co-primary outcomes, reflecting components of the same cardiovascular construct. The Bonferroni method was adopted to control multiple comparisons. Regression assumptions were verified using a Q-Q plot to assess the normality of the residuals, a plot of residuals versus predicted values to assess homoscedasticity and linearity, and Cook's Distance to identify outliers. Using the criterion of Cook's D>1.0, no observations were classified as outliers. Additionally, the normality of the residuals was assessed using the Shapiro-Wilk test, and homoscedasticity was assessed using White's test. The fitted models showed normally distributed residuals (W≥0.989; p≥0.066) and maintained homoscedasticity across all models (p≥0.281). The crude model for DBP showed a slight deviation from normality (W=0.985; p=0.005); however, given the sample size (n = 291) and the maintenance of homoscedasticity, the ordinary least squares estimators remain valid. Detailed results of the tests performed are presented in Supplementary Table 1. A directed acyclic graph (DAG) was constructed to select the variables for the minimal (schooling, socioeconomic status, age, and sleep duration) and extended (schooling, socioeconomic status, age, sleep duration, self-reported skin color, parity, physical activity, and smoking) models (Figure 1).[22] DMG and gestational weight gain were represented in the DAG as potential mediators of the association between UPF intake and BP; for this reason, they were not included as adjustment variables, in accordance with the principle of non-conditionality on mediators when the focus is on the total effect of the exposure. The significance level adopted was 5% (p<0.05). The data were organized in Microsoft Excel® spreadsheets. Descriptive and inferential statistical analyses were performed using IBM SPSS Statistics, version 27.0 (IBM Corp., Armonk, NY, USA), and supplementary analyses and specific modeling were conducted using SAS, version 9.4 (SAS Institute Inc., Cary, NC, USA).

Figure 1

Theoretical model of the association between ultra-processed food consumption (UPF) and blood pressure levels based on a directed acyclic graph (DAG).



Circle with arrow: exposure variable; Circle with "I": outcome variable; Sleep duration, Parity, Age, Schooling, Socioeconomic status, Self-reported skin color, and Physical activity: ancestral variables for both exposure and outcome; Alcohol and Smoking: ancestral variables for the outcome; Marital status and energy underreporting: ancestral variables for both exposure and outcome; Gestational diabetes mellitus (GDM) and gestational weight gain were considered potential mediators of the association between UPF intake and blood pressure levels.

Results

Table 1 presents the sociodemographic characteristics of all pregnant women included in the study, according to the median UPF consumption (25% of the TEV). Pregnant women with lower UPF consumption had higher median ages compared to those in the group with higher UPF consumption (p=0.004). Most pregnant women in the group with lower UPF intake were married or living with a partner,128 (81.5%) versus 105 (68.2%) in the group with high UPF intake (p=0.029). We found more nulliparous pregnant women in the group with high UPF intake compared to the group with low UPF intake (43.5% vs. 29.3%, respectively; p=0.009). In the group with higher UPF intake, a larger number of participants were former smokers 26 (16.9%), compared to the group with lower UPF consumption, in which a smaller number were former smokers 12 (7.6%) (p=0.009).

The subgroups that contributed most to energy consumption of UPF were sugary beverages (16.53%), processed meat (14.48%), and cookies and crackers (10.95%), respectively (Figure 2). It was not possible to determine the average usual consumption for three subgroups of UPF: sandwiches, savory snacks, and packaged salty snacks, because these subgroups had low intake levels, making an estimation by the MSM program unfeasible.

No association was observed between usual consumption of UPF and SBP or DBP in any of the analyzed models (Table 2). In the simple linear regression

Table 1

Characterization of the sample according to the percentage of energy derived from ultra-processed food. Ribeirão Preto, SP, Brazil (n=311).

Maternal characteristics	Total (n =311)	% E of UPF intake		p[a]
		< 25% TEV (n=157)	25% TEV (n=154)	
		P50 (P25; P75)		
Maternal age (years)[b]	27 (23-32)	28 (23.5-33)	26 (22-30)	0.004
Gestational age at randomization (weeks)[b]	11 (9-13)	11 (9-12)	11 (9-13)	0.428
BMI (kg/m²) [b]	27.13 (26.05-28.28)	27.12 (26.04-28.27)	27.15 (26.12-28.29)	0.860
Sleep (hours)	9 (7-10)	8 (7-10)	9 (8-11)	0.302
Physical activity (minutes)	60 (0-180)	70 (0-200)	60 (0-140)	0.165
		n (%)		
Married/living with a partner	233 (74.9)	128 (81.5)	105 (68.2)	0.029
Self-reported skin color[c]				
White	93 (30.5)	51 (32.91)	42 (28)	
Black	48 (15,.3)	24 (15.48)	24 (16)	0.710
Mixed	164 (53.77)	80 (51.61)	84 (56)	
Schooling, years[d]				
≤ 8	70 (22.6)	34 (21.8)	36 (23.4)	
9-11	200 (64.5)	99 (63.5)	101 (65.6)	0.974
≥ 12	40 (12.9)	23 (14.7)	17 (11)	
Socioeconomic status [e]				
A+B	59 (2.4)	33 (24.1)	26 (18.7)	
C	172 (62.3)	78 (56.93)	94 (67.63)	0.183
D+E	45 (16.3)	26 (18.97)	19 (13.67)	
Paid work	183 (58.84)	94 (59.9)	89 (57.8)	0.709
Nulliparous	113 (36.3)	46 (29.3)	67 (43.5)	0.009
Smoking status[f]				
Never smoked	221 (71.1)	120 (76.4)	101 (65.6)	
Current smoker	52 (16.7)	25 (16)	27 (17.5)	0.032
Former smoker	38 (12.2)	12 (7.6)	26 (16.9)	

%E = Energy percentage; TEV = Total energy value; GA = Gestational age; BMI = Body mass index.
[a]According to the Mann-Whitney test for continuous variables or the chi-square test of independence for categorical variables.
[b] Data presented as median and interquartile range
[c]Self-reported skin color is used as a proxy for ethnicity in Brazil. Only five women reported being of Asian descent and one refused to answer; these women were not included in the analysis.
Data available for 305 women.
[d]Data available for 310 women.
[e]Based on the Brazilian Economic Classification Criteria, which categorize socioeconomic status from Class A (highest level) to Class E (lowest level).
Data available for 276 women.
[f]Statistically different between the "Never smoked" and "Former smoker" categories according to post-hoc analyses with Bonferroni correction (p=0.009)

analysis, neither the continuous variable (%E of UPF) nor the categorical variable (<25 and ≥25% of TEV) was associated with SBP or DBP. This lack of association persisted even after minimal adjustment (hours of sleep, schooling, socioeconomic status, and age) and maximal adjustment (hours of sleep, schooling, socioeconomic status, age, skin color, parity, total time spent in physical activity, and smoking status). Even after adjusting for multiplicity using the Bonferroni method (adjusted α=0.025), none of the associations would reach statistical significance, reinforcing the robustness of the null finding. Sensitivity analyses excluding underreporters widened the confidence intervals (95%CI) without altering the qualitative direction of the finding (Supplementary Table 2). Among the 291 pregnant women included in the analysis, 145 were classified as underreporters, corresponding to a prevalence of 49.82%. After excluding these participants, the sensitivity analysis was conducted with 166 pregnant women who were not underreporters. The high prevalence of underreporting observed is consistent with the literature on overweight pregnant women.[20]

In addition, the calculation of the intraclass correlation coefficient (ICC) for systolic blood pressure (SBP) (0.0087) and diastolic blood pressure (DBP) (0.0084) yielded values

Figure 2

Percentage contribution of subgroups to the energy derived of ultra-processed food consumed by pregnant women in the sample. Ribeirão Preto, SP, Brazil (n=311).

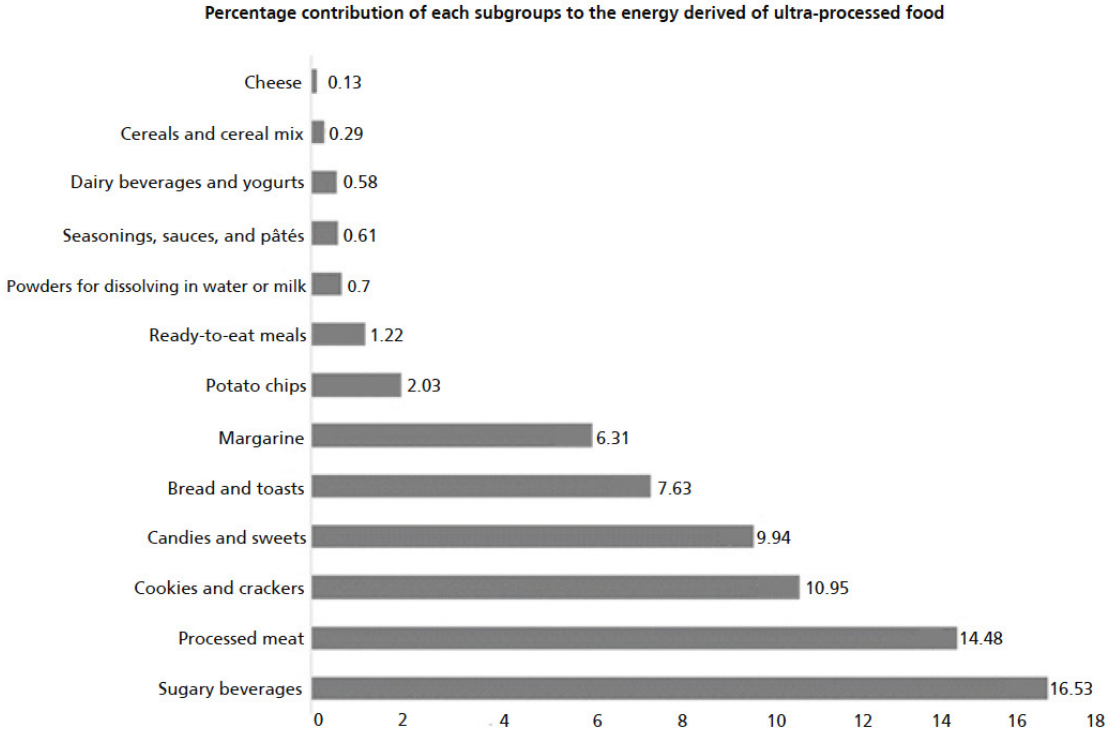


Table 2

Association between the percentage of energy intake of ultra-processed food and blood pressure during pregnancy. Ribeirão Preto, SP, Brazil (n=291).

Variable	β (continuous)	95%CI	*p*	β (dichotomous)	95%CI	*p*
Crude						
SBP (mmHg)	0.04	[-0.070; 0.159]	0.44	-0.19	[-2.409; 2.012]	0.86
DBP (mmHg)	0.03	[-0.065; 0.116]	0.57	-0.44	[-2.190; 1.302]	0.61
Model 1 [A]						
SBP (mmHg)	0.04	[-0.088; 0.164]	0.55	-0.02	[-2.642; 2.228]	0.86
DBP (mmHg)	0.05	[-0.045; 0.151]	0.29	0.08	[-1.828; 1.987]	0.93
Model 2 [B]						
SBP (mmHg)	0.04	[-0.085; 0.167]	0.52	-0.12	[-2.563; .2.321]	0.92
DBP (mmHg)	0.05	[-0.045; 0.153]	0.28	0.09	[-1.832; 2.017]	0.92

SBP = systolic blood pressure; DBP = diastolic blood pressure; β = β-coefficient of linear regression; CI = confidence interval; *p*: *p*-value.
β (continuous): per 1% increase in %E of UPF;
β (dichotomous): ≥25% vs. <25% of TEV;
A Minimum set of variables defined by the DAG: hours of sleep, schooling, socioeconomic status, and age;
B Maximum set of variables defined by the DAG: hours of sleep, schooling, socioeconomic status, age, skin color, parity, total time spent in physical activity, and smoking.

<0.01, indicating that clustering by primary care unit is negligible. The models were further re-estimated using robust standard errors clustered by primary health care unit (Supplementary Table 3), confirming that the estimates and conclusions remain unchanged.

Discussion

The present study investigated the association between the %E of usual UPF intake and blood pressure in overweight pregnant women during the first trimester of pregnancy. No significant association was observed between UPF intake and systolic or diastolic blood pressure among the participants included in the study. An important aspect to consider is that the women in this study sample were evaluated up to the 16th week of gestation. It is known that, as part of the physiological process of pregnancy, blood pressure decreases during the first and second trimesters in response to hemodynamic changes and a reduction in systemic vascular resistance. In the third trimester, blood pressure returns to pre-pregnancy levels [23] The pregnant women included in our study had median SBP (109.33 mmHg) and DBP (64 mmHg) values consistent with the expected course of vascular changes during pregnancy, which could explain the lack of association between blood pressure values and UPF intake at the time of pregnancy assessed.

Our findings are consistent with other studies in the literature that found no association between dietary patterns and systolic and/or diastolic blood pressure in the first trimester of pregnancy, including dietary patterns rich in UPF. Eshriqui *et al*.[24] investigated the association between dietary patterns and blood pressure in 191 healthy Brazilian pregnant women and found no association between the dietary pattern labeled "processed" (characterized by high consumption of meat, sweets and sugar, pasta, roots and tubers, fast food and snacks, sausages and cold cuts, and soft drinks) and systolic and/or diastolic blood pressure (SBP and/or DBP) levels in the first trimester of pregnancy.

Previous studies have observed a direct association between the consumption of UPF and gestational hypertension, but not with absolute SBP and DBP values. A cohort study evaluated the association between dietary patterns and the development of hypertensive disorders of pregnancy. In this study, dietary intake was assessed during the second trimester, the same period from which a diagnosis of gestational hypertension and preeclampsia can be made. The authors found an association between the so-called Western dietary pattern (characterized by high consumption of potatoes, processed meat, margarine, and white bread) and the development of gestational hypertension.[25] Thus, the diagnosis of gestational hypertension might be a better marker to analyze than the absolute blood pressure value.

The present study has some limitations. The fact that blood pressure measurements were interspersed with questionnaire administration, along with the inability to standardize environmental factors, may introduce variability in the obtained values. Furthermore, the original sample size calculation was performed for the primary outcome of the clinical trial and was not specifically tailored for this secondary analysis. Thus, the interpretation of the results should take into account the precision of the 95%CI. Although no association was observed between UPF intake and BP, the 95%CI does not allow for the complete exclusion of effects of small to moderate magnitude. For systolic blood pressure (SBP), for example, the upper limit of the 95% CI corresponds to approximately 4.3 mmHg for a 25 percentage point difference in the %E of UPF. Thus, the findings do not show an association, but they also do not allow us to firmly rule it out for magnitudes that are potentially clinically relevant.[26]

Furthermore, the exclusion of pregnant women with a prior diagnosis of hypertension may, in theory, introduce bias selection by reducing the variability of the outcome (blood pressure levels), with a possible attenuation of the associations. In the present study, however, the number of pregnant women excluded due to this condition was small (n=12), suggesting a limited impact on the overall variability of the outcome and on the estimates obtained.

Among the strengths of this study, it is worth noting that food recall data were collected by trained dietitians following established protocols, and BP data were obtained directly by the research team using a validated automatic monitor, which may help reduce potential random errors resulting from human variability. Additionally, methodological strategies were adopted to minimize biases inherent in the assessment of dietary intake and BP, which represents a significant advantage. Furthermore, the classification of UPF, based on analysis of the ingredient list and the composition of homemade preparations, allows for a more precise identification of the food, unlike studies that incorporate them into broader dietary patterns. This aspect contributes to the robustness of the findings and suggests that the observed lack of association is likely not due to limitations in exposure measurement.

In the present study, no association was observed between the %E of UPF intake and BP in overweight women during the first trimester of pregnancy. Future studies should investigate whether the %E of UPF intake affects BP throughout pregnancy and the development of hypertensive disorders of pregnancy.

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Authors' Contributions

Costa AS: conceptualization (equal); formal analysis (lead); research (lead); project management (lead); manuscript drafting (lead).

Lima MC: conceptualization (equal); formal analysis (equal); methodology (equal); supervision (equal); review and editing (equal).

Pinto, LMD: conceptualization (equal); formal analysis (equal); methodology (equal); supervision (equal); review and editing (equal).

Barbosa PO: formal analysis (supporting); research (supporting); review and editing (equal).

Sartorelli DS: methodology (lead); supervision (lead); review and editing (equal).

All authors approved the final version of the article and declare that they have no conflict of interest.

Use of artificial intelligence

The authors declare the use of the generative AI tool Claude Sonnet version 4.6 (Anthropic PBC, San Francisco, CA, USA), available in June 2026, for the purpose of grammatical review.

Data availability

The individual data supporting the findings of this study are available upon reasonable request to the corresponding author, subject to ethical restrictions related to participant confidentiality and the guidelines of the research ethics committee.

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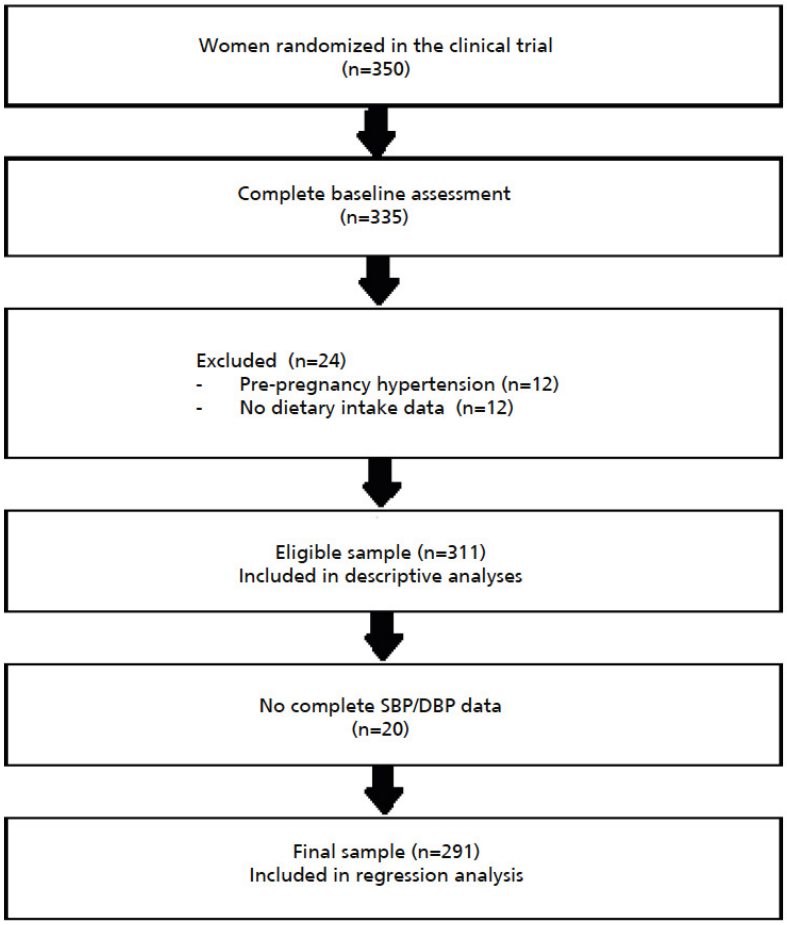
Supplementary Figure 1

Study flowchart.



SBP= systolic blood pressure; DBP= diastolic blood pressure.

Supplementary Table 1

Results of the normality assumption tests for each of the models.

	Shapiro-Wilk W	*p*	White Test	*p*
Crude				
SBP (mmHg)	0.991	0.092	1.28	0.528
DBP (mmHg)	0.985	0.005	2.54	0.281
Model 1[A]				
SBP (mmHg)	0.991	0.153	22.46	0.316
DBP (mmHg)	0.989	0.067	14.88	0.783
Model 2[B]				
SBP (mmHg)	0.990	0.078	45.64	0.362
DBP (mmHg)	0.989	0.066	34.68	0.813

β: β-coefficient of linear regression; *p*= statistical significance;
A: Minimum set of variables defined by the DAG: hours of sleep, schooling, socioeconomic status, and age;
B: Maximum set of variables defined by the DAG: hours of sleep, schooling, socioeconomic status, age, skin color, parity, total time spent in physical activity, and smoking.

Supplementary Table 2

Sensitivity analysis: association between the percentage of energy consumption of ultra-processed food and blood pressure during pregnancy after excluding the sub-reports. Ribeirão Preto, SP, Brazil (n=166).

Variable	β (continuous)	95%CI	*p*	β (dichotomous)	95%CI	*p*
Crude						
SBP (mmHg)	0.11	[-0.036; 0.258]	0.14	0.21	[-2.673; 3.097]	0.88
DBP (mmHg)	-0.02	[-0.139; 0.099]	0.74	-1.89	[-4.200; 0.408]	0.11
Model 1 [A]						
SBP (mmHg)	0.08	[-0.074; 0.240]	0.16	-0.19	[-3..272; 2.890]	0.23
DBP (mmHg)	-0.014	[-0.141; 0.113]	0.23	-1.56	[-4.035; 0.899]	0.13
Model 2 [B]						
SBP (mmHg)	0.08	[-0.074; 0.250]	0.29	-0.29	[-3.498; 2.907]	0.27
DBP (mmHg)	-0.03	[-0.163; 0.098]	0.62	-2.12	[-4.671; 0.426]	0.12

β: β-coefficient of linear regression; CI= confidence interval; *p*= statistical significance;
β (dichotomous): ≥25% *vs.* <25% of TEV;
β (continuous): per 1% increase in %E of UPF;
A Minimum set of variables defined by the DAG: hours of sleep, schooling, socioeconomic status, and age;
B Maximum set of variables defined by the DAG: hours of sleep, schooling, socioeconomic status, age, skin color, parity, total time spent in physical activity, and smoking.

Supplementary Table 3

Models of the association between the percentage of energy intake of ultra-processed food and blood pressure during pregnancy, with cluster-adjusted standard errors from primary health care unit (PHU). Ribeirão Preto, SP, Brazil (n=291).

Model	β (unclustered)	EP (unclustered)	*p* (unclustered)	β (clustered)	EP (clustered)	*p*
Crude						
SBP (mmHg)	0.04	0.06	0.44	0.04	0.05	0.42
DBP (mmHg)	0.03	0.05	0.57	0.03	0.03	0.45
Model 1[A]						
SBP (mmHg)	0.04	0.06	0.55	0.04	0.06	0.56
DBP (mmHg)	0.05	0.05	0.29	0.05	0.03	0.15
Model 2[B]						
SBP (mmHg)	0.04	0.06	0.52	0.04	0.06	0.55
DBP (mmHg)	0.05	0.05	0.28	0.05	0.03	0.14

β: β-coefficient of linear regression; SE = standard error; *p* = statistical significance;
A: Minimum set of variables defined by the DAG: hours of sleep, schooling, socioeconomic status, and age;
B: Maximum set of variables defined by the DAG: hours of sleep, schooling, socioeconomic status, age, skin color, parity, total time spent in physical activity, and smoking.