# Relationships between consumption of ultra-processed foods, gestational weight gain and neonatal outcomes in a sample of US pregnant women

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**Background.** An increasingly large share of diet comes from ultra-processed foods (UPFs), which are assemblages of food substances designed to create durable, convenient and palatable ready-to-eat products. There is increasing evidence that high UPF consumption is indicative of poor diet and is associated with obesity and metabolic disorders. This study sought to examine the relationship between percent of energy intake from ultra-processed foods (PEI-UPF) during pregnancy and maternal gestational weight gain, maternal lipids and glycemia, and neonatal body composition. We also compared the PEI-UPF indicator against the US government's Healthy Eating Index-2010 (HEI-2010).

**Methods.** Data were used from a longitudinal study performed from 2013-2014 at the Women's Health Center and Obstetrics & Gynecology Clinic in St. Louis, MO, USA. Subjects were pregnant women in the normal and obese weight ranges, as well as their newborns (n=45). PEI-UPF and the Healthy Eating Index-2010 (HEI-2010) were calculated for each subject from a one-month food frequency questionnaire (FFQ). Multiple regression (ANCOVA-like) analysis was used to analyze the relationship between PEI-UPF or HEI-2010 and various clinical outcomes. The ability of these dietary indices to predict gestational weight gain was also compared with the predictive abilities of total energy intake and total fat intake.

**Results.** An average of 54.4 ± 13.2% of energy intake was derived from UPFs. A 1%-point increase in PEI-UPF was associated with a 1.33 kg increase in gestational weight gain ($p = 0.016$). Similarly, a 1%-point increase in PEI-UPF was associated with a 0.22 mm increase in thigh skinfold ($p = 0.045$), 0.14 mm in subscapular skinfold ($p = 0.026$), and 0.62 percentage points of total body adiposity ($p = 0.037$) in the neonate.

**Discussion.** PEI-UPF was associated with and might be a useful predictor of several maternal and neonatal clinical outcomes. PEI-UPF was a better predictor of all tested outcomes than either total energy or total fat intake, and a better predictor of the three infant body fat measures than HEI-2010. UPF consumption should be limited during pregnancy and diet quality should be maximized in order to improve maternal and neonatal health.

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## Abstract

**Background.** An increasingly large share of diet comes from ultra-processed foods (UPFs), which are assemblages of food substances designed to create durable, convenient and palatable ready-to-eat products. There is increasing evidence that high UPF consumption is indicative of poor diet and is associated with obesity and metabolic disorders. This study sought to examine the relationship between percent of energy intake from ultra-processed foods (PEI-UPF) during pregnancy and maternal gestational weight gain, maternal lipids and glycemia, and neonatal body composition. We also compared the PEI-UPF indicator against the US government's Healthy Eating Index-2010 (HEI-2010).

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## Introduction

It has been well-documented that nutrition before and during pregnancy can have long lasting effects on maternal and neonatal health outcomes (Imhoff-Kunsch & Martorell 2012). In particular, consumption of ample fruits, vegetables, whole grains, and lean meats, and limited consumption of caffeine, alcohol, and foods high in saturated fat during pregnancy has been recommended. Evidence has emerged showing that consumption of foods high in sugar (Petherick et al. 2014), saturated fat (Park et al. 2013) and sodium during pregnancy can be particularly harmful to both the pregnant woman and their neonates (Tay et al. 2012). Many of these foods can be categorized as ultra-processed foods (UPF), which are assemblages of food substances designed to create durable, accessible, convenient and palatable ready-to-eat or ready-to-heat food products (Monteiro et al. 2017). These products are often consumed as snacks instead of home-prepared dishes, are low in fiber, whole grains, and vitamins (Monteiro et al. 2017) and include artificial colors, flavors, and preservatives, which can be particularly harmful for pregnant women (Halldorsson et al. 2010).

Ultra-processed foods (UPFs) are merely one group in a four-category classification system (NOVA) that was developed to guide consumers towards a healthy diet using food-based, rather than nutrient-based, dietary guidelines (Monteiro et al. 2017). There is increasing evidence that high consumption of UPFs is indicative of poor diet and is associated with obesity, metabolic syndrome and cardiovascular disease in non-gravid adults (Canella et al. 2014; Costa Louzada et al. 2015; Louzada et al. 2015a; Louzada et al. 2015b; Martinez Steele et al. 2016; Moubarac et al. 2013). However, the relationship between the percent of energy intake from ultra-processed foods (PEI-UPF) during pregnancy and maternal and neonatal health outcomes has not been examined. Therefore, the purpose of this study was to determine the association between UPF consumption in pregnant US women and selected maternal/newborn health outcomes. We hypothesize that the percent of energy intake coming from UPF could serve as a concise measure of the diet quality of a selected sample of pregnant US women. Further, we hypothesize that PEI-UPF could be an efficient predictor of maternal and neonatal health outcomes. These include maternal gestational weight gain (GWG) and neonatal anthropometrics. The ability of UPF to predict these outcomes is clinically important as high GWG is generally associated with high postpartum weight retention (Gunderson & Abrams 1999), and with the child having a higher

BMI early in life (Lau et al. 2014; Mourtakos et al. 2016). These patterns almost certainly do not end at birth: Catalano et al. found that infant body fat percentage in particular (as opposed to body weight) can be a significant predictor of early childhood, and possibly adult, obesity (Catalano et al. 2003). Additionally, skinfold thickness measurements can be a predictor of insulin resistance and diabetes later in life (Yajnik et al. 2003).Therefore, the ability to determine the role of UPF consumption in maternal and neonatal health is critical.

A secondary aim of the study was to compare the abilities of PEI-UPF and another dietary quality index, the Healthy Eating Index-2010 (HEI-2010), to predict maternal GWG and neonatal body composition. The HEI-2010 measures diet quality according to the 2010 Dietary Guidelines for Americans (Guenther et al. 2014), and has been shown to have significant associations with biomarkers and clinical outcomes in gravid and non-gravid adults (Reedy et al. 2014; Shapiro et al. 2016). However, HEI-2010 has not been directly compared with PEI-UPF in this regard.

## Methods

### *Study Design*

This study used data collected by Tinius et al. on the health of 45 pregnant women and their neonates in St. Louis, MO, USA (Tinius et al. 2015; Tinius et al. 2016b). Approval for this study was granted by the Institutional Review Board at Washington University (IRB ID: 201306109). Written informed consent was obtained from each participant. More information about how maternal and neonatal outcomes were collected can be found elsewhere (Tinius et al. 2015; Tinius et al. 2016b). In the original study's design, only women within the normal or obese weight ranges were included (BMI between 18.0 kg/m$^2$ and 24.9 kg/m$^2$ or between 30.0 kg/m$^2$ or 45.0 kg/m$^2$). Overweight women (BMI between 25.0 kg/m$^2$ and 29.9 kg/m$^2$) were excluded. All women had viable singleton pregnancies and no evidence of fetal abnormalities (both confirmed by ultrasound), and were recruited near the end of their second trimester. The majority of maternal health markers were measured during two visits, both of which occurred between 32 and 37 weeks gestation. Visit 1 occurred, on average, at 34 weeks, while Visit 2 occurred, on average, at 35 weeks. Neonatal measurements were obtained after delivery and before discharge from the hospital. In our study, key outcomes included maternal GWG and net triglyceride levels, as well as neonatal percent body fat and site-specific skinfold measurements. Free fatty acids, fasting insulin/glucose and C-reactive protein were measured in both mother and infant. These data were obtained as part of previously published studies (Tinius et al. 2015; Tinius et al. 2016b).

The lean and obese study groups were compared, and it was found that the groups only differed in gestational weight gain and maternal weight. There was no association between lean/obese study group and the proportion of African Americans/other minorities (from $\chi^2$-test, p = 0.9834), or between study group and the proportion of patients visiting a primarily low-income level clinic (from $\chi^2$-test, p = 0.6388). Although no significant differences in PEI-UPF or other clinical outcomes were found between the two groups in our study, prior research has shown that maternal obesity can negatively influence neonatal outcomes in a variety of ways (Castro & Avina 2002). For this reason, it was decided to model the two groups as having different slopes (with respect to PEI-UPF) as well as intercepts. The slopes are denoted by PEI-UPF * Obese in the results, and the intercepts are denoted by Maternal Weight Status (ref: Lean) - Obese.

*Survey Instrument*

As part of Visit 1, Tinius et al. administered the US National Institutes of Health's Diet History Questionnaire II (DHQ II) (2010), in which subjects reported their consumption of various unprocessed, prepared, and packaged foods over the past month. Previous research has shown that respondents tend to underestimate food intake when completing food frequency questionnaires, or FFQs (Horner et al. 2002). However, another study found that food frequency questionnaires (FFQs) inquiring about consumption over a several-month period provide reproducible and valid measures of relative dietary intakes in pregnant populations (Vioque et al. 2013). The DHQ II is typically used to calculate the Healthy Eating Index-2010 (HEI-2010). The HEI-2010 is a number ranging from 0 (worst) to 100 (best) that reflects the consumption of desirable macronutrients and food groups (fruits, vegetables, etc.), and avoidance of unhealthy foods (refined grains, sodium, and empty calories). HEI-2010 is often measured using 24-hour food recalls or FFQs, such as the questionnaire used in the present study. For the present study, the DHQ II was used to calculate both the percentage of energy intake that comes from ultra-processed foods (PEI-UPF) as well as the HEI-2010. For each food on the DHQ II, the participant was asked to choose one of eight options that best characterized the frequency of consumption, ranging from "never" to "2 or more times per day". For beverages, options ranged from "never" to "6 or more times per day". Participants also chose one of three options of typical serving sizes that best described the amount consumed (e.g. "less than one cup", "one cup", or "more than one cup"). The total amount consumed per month was determined by multiplying the average of the frequency range with the average of the amount range. For amount ranges expressed as "Less than" or "More than", the upper or lower end of the range, respectively, was used in place of the average.

For condiments, participants chose one of five options reflecting what fraction of the time it was added to the main food. This provided an additional multiplicative factor when calculating the total amount consumed of a condiment. Vitamin, mineral, and herbal supplements were not considered. We also omitted foods for which the survey did not ask the amount consumed.

The amount of each food consumed per month was converted to grams using a US Department of Agriculture (USDA) database. Each food was classified, according to the NOVA classification scheme, as (1) an unprocessed or minimally processed food, (2) a processed culinary ingredient, (3) a processed food, or (4) an ultra-processed food. Thirty-three subgroups (nested within the main groups) were used to further classify the foods. The quantities of seven different nutrients obtained from each group/subgroup were then calculated for each subject. Due to energy content inaccuracies in the USDA database, the energy in 100 g of each food had to be recalculated as follows:

$$\text{Energy (MJ)} = 0.017\frac{\text{MJ}}{\text{gram}} \cdot (\text{Grams Carbohydrate} + \text{Grams Protein}) + 0.037\frac{\text{MJ}}{\text{gram}} \cdot \text{Grams Fat}$$

where MJ represents megajoules.

In general, when several different foods (such as jam, jelly, and honey) were combined in a single question, nutrient information from the most commonly consumed food was used.

*Data Management*

Microsoft Excel 2013 was used for data entry, and spreadsheets were imported into R 3.2.3 (Team 2015) for calculations and statistical analysis. Several tables were automatically constructed using the stargazer package (Hlavac 2015) within R. Missing frequency or amount data for individual foods were estimated using random forest imputation, through the missForest package in R (Stekhoven 2013).

The HEI-2010 was primarily computed in order to compare its predictive ability, in terms of maternal and neonatal outcomes, with that of PEI-UPF. In the first step, Diet*Calc Analysis Program (2012) was used to compute each woman's consumption of various food groups according to the USDA's Food Patterns Equivalents Database. SAS version 9.4 (Institute 2012) (2002-2012, SAS Institute, Cary, NC, USA) was then used to run the National Cancer Institute's HEI-2010 scoring program.

*Statistical Analysis*

Simple matrix operations yielded the percentage of energy intake from ultra-processed foods (PEI-UPF) for each study participant. This number was used as the primary measure of diet quality. Diagnostic tests (for normality, linearity, independence, and homoscedasticity) were carried out to determine the appropriateness of linear modelling. Then, an ANCOVA-like model was used to analyze the relationship between PEI-UPF and various clinical outcome variables. In our study, key outcomes included maternal GWG and net triglyceride levels, as well as neonatal percent body fat and skinfold measurements. Fasting insulin/glucose, C-reactive protein and free fatty acids were also measured in both mother and infant.

For the analysis of maternal health outcomes, age (continuous), race (Caucasian or African American/other), weight status (lean or obese), socioeconomic status (Primarily Low-Income Clinic or Primarily High-Income Clinic), average daily energy and fat intake (continuous), and percent of time spent in moderate physical activity (continuous) were controlled for (Table 1). In the neonatal outcome analyses, we controlled for maternal age, race, weight status, socioeconomic status, average daily energy and fat intake, percent of time spent in moderate physical activity, and gestational age at which neonatal measurements were taken (continuous). All interactions with PEI-UPF were tested, and only significant interaction terms were included in the final models. However, the PEI-UPF * Obese Weight Status interaction was forced into all models, due to the special effect maternal obesity can have on neonatal outcomes. Essentially, the lean and obese groups each had a separate slope coefficient ($\beta$) for the effect of UPF consumption on the clinical outcome.

Extra sum-of-squares F-tests and adjusted $R^2$ values were used to compare the predictive ability of PEI-UPF and HEI-2010. Adjusted $R^2$ measures the predictive power of a model, while correcting for the number of regressors (models with many extraneous regressors are penalized).

Finally, since the assumption of normality was met, we used Pearson correlation to determine the association between HEI-2010 and PEI-UPF. All tests were two-sided, and $p < 0.05$ was considered significant.

**Results**

Subject characteristics are presented in Table 1. The majority of women visited a primarily high-income clinic (57.8%), were nulliparous (55.6%), and obese (64.4%). Equal numbers of women were Caucasian and African American (46.7% each), and the remaining 6.7% were Hispanic or Asian. The average PEI-UPF was 54.4 ± 13.2% and the average percentage of energy intake for both processed and ultra-processed foods together was 63.2% (not shown in table). Among ultra-processed foods, the most consumed subgroup was Cakes, Cookies and Pies (5.8% of total energy). Only two out of all thirty-three subgroups had higher average consumption - fruits (9.1% of total energy intake) and grains (9.8%) (not shown in table).

Further detail showing the quantity of nutrients obtained from each main food group is given in Table 2. As with energy intake, the participants' total carbohydrate, fat, sugar and sodium intakes were primarily derived from ultra-processed foods (57.0%, 58.8%, 57.9% and 65.7% of total dietary intake, respectively). On the other hand, 39.9% of fiber was obtained from Group 4 foods. Indeed, pregnant women who limited their intake of ultra-processed foods tended to have better health outcomes for themselves (Table 3) and their infants (Table 4). The association between PEI-UPF and GWG was observed only in the fully adjusted model, after controlling for maternal age, race, socioeconomic status, weight status, average daily energy and fat intake, and time spent in moderate physical activity. Likewise, the association of PEI-UPF with newborn body composition was observed only after controlling for maternal age, race, socioeconomic status, weight, average daily energy and fat intake, time spent by the woman in moderate physical activity, and gestational age at time of measurement. However, in each of the four models, the mother's weight status (lean or obese) had no significant slope or intercept effect on the relation between PEI-UPF and the clinical outcome. A number of biomarkers including blood levels of triglycerides (data available for mother only), free fatty acids, fasting glucose/insulin, and C-reactive protein had no significant association with PEI-UPF in either mothers or infants.

Various interaction terms with PEI-UPF were tested, and only the interaction with age was found to be significant. Thus, for older pregnant women, increased PEI-UPF has less of an effect on poor health outcomes than for younger women, as indicated by the negative coefficients for the interaction terms. All other interaction terms with PEI-UPF were not significant.

The predictive ability of PEI-UPF was also compared with several other measures. In adjusted models with only one dietary predictor (PEI-UPF, HEI-2010, total energy intake or total fat intake), PEI-UPF was more strongly associated with all clinical outcomes than either total energy or fat intake (Table 5). Indeed, PEI-UPF retained a significant relationship with GWG ($p = 0.016$) (Table 3), as well as neonatal thigh skinfold thickness ($p = 0.045$), subscapular skinfold thickness ($p = 0.026$) and body fat percentage ($p = 0.037$) (Table 4), even after controlling for total energy and fat intake. This suggests that PEI-UPF measures an aspect of diet that is independent of total energy and total fat intake.

Overall, PEI-UPF had a strong negative correlation with HEI-2010, with $r = -0.74$ (95% CI: -0.85, -0.56), indicating that both measures of diet quality are fairly consistent. Additionally, in models with one dietary predictor, maternal HEI-2010 scores were strongly associated with HDL cholesterol ($p = 0.0020$) (not shown in table), GWG, and neonatal subscapular skinfold thickness (Table 5).

In fully adjusted models including total energy and fat intake, the HEI-2010 was a better predictor of gestational weight gain than PEI-UPF (Adj. $R^2 = 0.26$, as opposed to 0.14 for PEI-UPF). However, PEI-UPF was still a better predictor of infant body fat percentage, thigh skinfold thickness, and subscapular skinfold thickness than the HEI-2010 (Adj. $R^2 = 0.01$, 0.14, and 0.10, as opposed to -0.09, -0.02, and -0.02, respectively) (not shown in table). Furthermore, adding HEI-2010 as a predictor in our four fully adjusted PEI-UPF models did not significantly improve fit ($p \geq 0.097$ from extra sum-of-squares F-test in all cases). The failure of HEI-2010 to improve model fit was likely caused by the strong (negative) correlation between PEI-UPF and HEI-2010.

## Discussion

The results show a strong positive association of PEI-UPF with GWG and with neonatal anthropometrics (i.e. subscapularis and thigh skinfold thicknesses and body fat percentage). This study demonstrates that many pregnant women are obtaining the majority of their energy from ultra-processed foods, and these ultra-processed foods may also be worsening health outcomes for themselves and their children. These relationships are essentially the same in both lean and obese mothers. Indeed, the majority of participants' carbohydrate, fat, sugar, sodium, and energy were obtained from UPF, which is consistent with the refined ingredients and highly palatable nature of such foods. As such, it is not surprising that UPF consumption negatively affects health.

The identification of causes of excessive gestational weight gain is clinically important as excessive gestational weight gain can have serious consequences for the postpartum women and their neonates. It leads to excessive postpartum weight retention (Gunderson & Abrams 1999), which in turn can contribute to long-term obesity and associated comorbidities including type 2 diabetes, cardiovascular disease, mental health issues, and cancer (2009). For the neonate, excess adiposity is likely to continue into childhood (Mei et al. 2003), and childhood obesity is a strong predictor of adult obesity (Freedman et al. 2005). Thus, higher body fat as an infant may contribute to long-term risk for obesity and its associated comorbidities (Catalano & Ehrenberg 2006; Tinius et al. 2016a). Because UPF consumption was related not only to excessive gestational weight gain, but also neonatal adiposity, maternal diet quality modification could substantially improve long-term health outcomes for mother and child.

Interestingly, a number of successful interventions to limit excessive GWG emphasize energy or fat restriction, or other macronutrient targets (Gardner et al. 2011; Phelan et al. 2011). Despite the popularity of energy- and fat-restricting diets, GWG was more strongly associated with PEI-UPF than total energy or fat intake ($p = 0.017$ for PEI-UPF compared to $p = 0.73$ and $p = 0.88$ for total energy and fat intake). More generally, although low fat ultra-processed foods are ubiquitous, such results cast doubt on the health benefits of these low fat foods. We believe interventions to limit GWG could be even more successful if they also emphasized a minimally-processed diet, since our results show that PEI-UPF captures information about diet quality, which total fat or energy intake cannot. In general, our results suggest that consumption of UPF may be a key factor contributing to unfavorable maternal and neonatal outcomes. This study showed that poor diet quality during pregnancy increases neonatal adiposity independent of maternal weight and maternal moderate physical activity; thus, maternal diet quality is an important direction of future study. Specifically, diet quality seems to be more important than the amount of energy consumed. Thus, from a clinical standpoint, pregnant women should be educated to focus less on the total energy consumed, and more on the source of that energy.

Interestingly, the nutrient profiles indicate that processed foods generally have less fiber and more sodium than UPF. Thus, while small amounts of processed foods are part of any diet and acceptable in moderation, clear preference should be given to unprocessed/minimally processed foods. It is also important to highlight the need for moderation when using salt, sugar and oil in home based meal preparations.

Furthermore, almost all currently used tools for assessing diet are largely quantity based instead of quality based, which is one of the main reasons for measuring UPF consumption. Because many currently used tools assess quantity, we also wanted to assess the ability of the HEI-2010 to predict maternal and neonatal outcomes. As part of our secondary aim, our results did show that a quantity-focused measure such as HEI-2010 can be a useful predictor of gestational weight gain. Despite the high correlation between PEI-UPP and HEI-2010, PEI-UPP is a better predictor of neonatal body fat percentage and skinfold thickness at the subscapularis and thigh. Interestingly, Shapiro et al. found that a low maternal HEI-2010 score was associated with higher neonatal body fat percentage, in a sample size of >1,000 woman and infant pairs (Shapiro et al. 2016). We were unable to confirm this finding (in our study, $p = 0.334$ for association with body fat percentage). The differences in predictive ability between HEI-2010 and PEI-UPF indicate that each statistic measures different aspects of the diet, and therefore both are useful. To achieve the optimal diet, one must both limit intake of UPFs as well as eat a variety of different nutrients.

This study has several notable strengths, including being the first effort to measure UPF consumption in pregnant women, and to correlate PEI-UPF with maternal and neonatal clinical outcomes. Additionally, it is only the second study to examine PEI-UPF in the United States, where the percent of the diet coming from UPFs is much higher than in some other countries (Canella et al. 2014; Martinez Steele et al. 2016; Monteiro et al. 2013). However, this study presents some limitations. Due to the design of the original longitudinal study, only women within the normal or obese weight ranges were included (BMI between 18.0 kg/m$^2$ and 24.9 kg/m$^2$ or between 30.0 kg/m$^2$ or 45.0 kg/m$^2$). Thus, women in the overweight range were excluded, and the study results may not be applicable to such women. Additionally, the racial composition, with essentially equal numbers of Caucasians and African Americans, and very few other minorities, is not representative of the entire US population. The design of the survey instrument presents further limitations. Since food frequency and portion sizes were collected in a semi-quantitative/categorical format, often with as few as three options, there was some error simply because respondents had to round off quantities. Additionally, somewhat subjective researcher input was required to categorize each DHQ II food according to the NOVA scheme. For example, homemade bread would be a processed food, but for this study, bread was classified as ultra-processed since most bread consumed in the US meets this definition. A full listing of classifications (along with justification) can be found in the Appendix.

A greater error we could not eliminate is the fact that pregnant women may underreport their food intake. Previous research found that postmenopausal women underestimated their energy intake by 21% on a FFQ (Horner et al. 2002). However, since we are using percentages of energy intake as the main predictor rather than absolute energy, we feel our data may not be subject to the same degree of error. Finally, another major limitation is that administering the DHQ II once, at Visit 1, effectively only assesses maternal diet at 30-34 weeks gestation. It is unlikely that this assessed diet accurately represents diet across the entire pregnancy, since previous research indicates that intake of certain foods and overall caloric intake vary across the three trimesters (Durnin 1991; Rifas-Shiman et al. 2006).

**Conclusions**

This study showed that consumption of ultra-processed foods leads to unfavorable pregnancy outcomes including excessive maternal gestational weight gain and increased neonatal body fatness. Excessive gestational weight gain may then lead to long-term obesity and its associated comorbidities (Type II diabetes, cardiovascular disease, mental health issues, cancer). For the neonate, excess adiposity is likely to continue into childhood and adulthood, contributing to many of the same associated comorbidities. In addition, diet quality seems to be more important than the amount of food consumed. Thus, from a clinical standpoint, pregnant women should be educated to focus less on the total energy consumed, and more on the source of that energy. Reducing dietary consumption of ultra-processed foods may be a potential avenue for improving short and long term maternal and neonatal health, making this an important direction for future research. A natural, minimally-processed diet centered on home cooking should be promoted among pregnant women.

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## Table 1 (on next page)

Demographic and lifestyle characteristics of analyzed respondents, n=45.

Table 1 gives the frequencies for each level of relevant categorical variables, as well as mean and standard deviation for continuous variables.

Table 1 gives the frequencies for each level of relevant categorical variables, as well as mean and standard deviation for continuous variables.

**Table 1. Demographic and lifestyle characteristics of analyzed respondents, n=45.**

| Maternal Characteristics | Percentage |
|---|---|
| Race | |
| Caucasian | 46.7% |
| African-American | 46.7% |
| Other | 6.7% |
| Clinic Visited | |
| Primarily Low-Income | 42.2% |
| Primarily High-Income | 57.8% |
| Parity | |
| Nulliparous | 55.6% |
| Multiparous | 44.4% |
| Weight Status at beginning of study (i.e., before 32 weeks gestation) | |
| Lean | 35.6% |
| Obese | 64.4% |
| **Maternal Characteristics (mostly at 32-37 weeks gestation)** | **Mean ± SD** |
| PEI-UPF (%) in the month preceding Visit 1 | 54.4 ± 13.2 |
| HEI-2010 (0-100) based on the month preceding Visit 1 | 62.2 ± 13.0 |
| Age (years) at Visit 1 | 27.2 ± 5.1 |
| Gestational Age at Visit 1 (weeks) | 33.6 ± 1.4 |
| Gestational Age at Visit 2 (weeks) | 34.7 ± 1.3 |
| Pre-Pregnancy BMI at initiation of prenatal care | 30.1 ± 7.3 |
| Body Fat (%) at Visit 1 | 31.8 ± 8.5 |
| Gestational Weight Gain (kg) between beginning of study and admission for labor/delivery | 12.0 ± 7.2 |
| HDL (mg/dL) at Visit 2 | 67.6 ± 15.3 |
| LDL (mg/dL) at Visit 2 | 121.4 ± 36.7 |
| Time Spent in Moderate Physical Activity (%) in the week following Visit 1 | 13.8 ± 4.1 |
| **Newborn Characteristics (within 48 hours of delivery)** | **Mean ± SD** |
| Gestational Age when Neonatal Measurements Taken | 39.6 ± 1.2 |
| Thigh Skinfold Thickness (mm) | 6.6 ± 1.4 |
| Subscapular Skinfold Thickness (mm) | 4.4 ± 0.8 |
| Body Fat (%) | 11.5 ± 3.5 |

Note: Due to rounding, not all percentages may add to exactly 100.

## Table 2(on next page)

Average nutrient intake by food group, n=45.

Table 2 shows that a majority of energy intake (54.4%, on average) was obtained from ultra-processed foods, but at the same time processed foods represent a significant source of fat and sodium, and cannot be disregarded.

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**Table 2. Average nutrient intake by food group, n=45.**

| | Mean Intake | | | | | | |
|---|---|---|---|---|---|---|---|
| Food Groups | Absolute (MJ/day) | Carbohydrate (% of total intake) | Protein (% of total intake) | Fat (% of total intake) | Total Sugars (% of total intake) | Fiber (% of total intake) | Sodium (% of total intake) |
| 1. Unprocessed or minimally processed foods | 3.7 | 39.7 | 40.8 | 27.3 | 37.5 | 56.4 | 16.0 |
| 2. Processed culinary ingredients | 0.2 | 0.9 | 0.1 | 3.6 | 1.3 | 0 | 0.8 |
| 3. Processed foods | 0.8 | 2.4 | 22.6 | 10.3 | 3.3 | 3.7 | 17.6 |
| 4. Ultra-processed foods | 5.8 | 57.0 | 36.5 | 58.8 | 57.9 | 39.9 | 65.7 |
| TOTAL | 10.5 | 100 | 100 | 100 | 100 | 100 | 100 |

## Table 3 (on next page)

Associations between PEI-UPF and Gestational Weight Gain, adjusted for maternal characteristics, n=45.

According to Table 3, PEI-UPF as well as the interaction between PEI-UPF and Age are significantly associated with GWG.

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**Table 3. Associations between PEI-UPF and Gestational Weight Gain, adjusted for maternal characteristics, n=45.**

| | Gestational Weight Gain (kg) | | |
|---|---|---|---|
| **Subject Characteristic** | **β** | **95% CI** | **P-value** |
| PEI-UPF (%) in the month preceding Visit 1 | 1.3 | (0.3, 2.4) | 0.016* |
| Age (years) | 2.6 | (0.6, 4.6) | 0.014* |
| PEI-UPF * Age | -0.05 | (-0.09, -0.01) | 0.012* |
| Maternal Weight Status (ref: Lean) | | | |
| Obese | -5.1 | (-25.1, 15.0) | 0.61 |
| PEI-UPF * Obese | 0.06 | (-0.3, 0.4) | 0.72 |
| Avg. Daily Energy Intake (kcal) | 0.003 | (-0.002, 0.008) | 0.20 |
| Avg. Daily Fat Intake (g) | -0.06 | (-0.2, 0.07) | 0.38 |
| Race (ref: Caucasian) | | | |
| African-American/Other | -7.9 | (-13.7, -2.2) | 0.0085* |
| Clinic Visited (ref: Primarily Low-Income) | | | |
| Primarily High-Income | -2.0 | (-7.6, 3.6) | 0.47 |
| Time Spent in Moderate Physical Activity (%) in the week following Visit 1 | -0.2 | (-0.8, 0.5) | 0.58 |

Note: Gestational weight gain was measured from beginning of study until admission for labor/delivery.
* represents P-value < 0.05.

## Table 4(on next page)

Associations between PEI-UPF and neonatal outcomes, adjusted for maternal characteristics, n=45.

Table 4 shows that PEI-UPF as well as the interaction between PEI-UPF and Age are significantly associated with thigh skinfold thickness, subscapular skinfold thickness, and body fat percentage in the newborn.

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**Table 4. Associations between PEI-UPF and neonatal outcomes, adjusted for maternal characteristics, n=45.**

| | NEWBORN OUTCOME (measured within 48 hours of delivery) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Thigh Skinfold Thickness (mm) | | | Subscap. Skinfold Thickness (mm) | | | Body Fat (%) | | |
| **Subject Characteristic** | **β** | **95% CI** | **P-value** | **B** | **95% CI** | **P-value** | **β** | **95% CI** | **P-value** |
| PEI-UPF (%) in the month preceding Visit 1 | 0.2 | (0.005, 0.4) | 0.045* | 0.1 | (0.02, 0.3) | 0.026* | 0.6 | (0.04, 1.2) | 0.037* |
| Age (years) | 0.4 | (0.03, 0.8) | 0.035* | 0.3 | (0.06, 0.5) | 0.015* | 1.3 | (0.2, 2.4) | 0.023* |
| PEI-UPF * Age | -0.008 | (-0.02, -0.0008) | 0.030* | -0.006 | (-0.01, -0.001) | 0.014* | -0.02 | (-0.05, -0.004) | 0.020* |
| Maternal Weight Status (ref: Lean) - Obese | -2.6 | (-6.6, 1.4) | 0.19 | -0.8 | (-3.1, 1.4) | 0.46 | -3.0 | (-13.7, 7.7) | 0.58 |
| PEI-UPF * Obese | 0.06 | (-0.01, 0.1) | 0.098 | 0.02 | (-0.02, 0.06) | 0.35 | 0.09 | (-0.1, 0.3) | 0.35 |
| Maternal Avg. Daily Energy Intake (kcal) | -0.0009 | (-0.002, 0.0001) | 0.081 | 0.0002 | (-0.0004, 0.0007) | 0.55 | 0.0009 | (-0.002, 0.004) | 0.48 |
| Maternal Avg. Daily Fat Intake (g) | 0.03 | (0.003, 0.06) | 0.030* | -0.0008 | (-0.02, 0.01) | 0.91 | -0.01 | (-0.08, 0.06) | 0.70 |
| Race (ref: Caucasian) - African-American/Other | -0.3 | (-1.4, 0.9) | 0.62 | -0.2 | (-0.8, 0.5) | 0.63 | 0.3 | (-2.7, 3.4) | 0.83 |
| Clinic Visited (ref: Primarily Low-Income) - Primarily High-Income | 0.3 | (-0.8, 1.5) | 0.57 | -0.08 | (-0.7, 0.6) | 0.81 | 1.4 | (-1.7, 4.6) | 0.36 |
| Gestational Age when Neonatal Measurements Taken (weeks) | 0.3 | (-0.05, 0.7) | 0.082 | 0.2 | (0.01, 0.5) | 0.041* | -0.1 | (-1.2, 1.0) | 0.83 |
| Time Spent in Moderate Physical Activity (%) in the week following Visit 1 | -0.05 | (-0.2, 0.08) | 0.45 | -0.004 | (-0.08, 0.07) | 0.91 | 0.04 | (-0.3, 0.4) | 0.83 |

* represents P-value < 0.05.

## Table 5 (on next page)

P-values for various dietary indices in models with only one dietary index.

Table 5 shows that for most of the clinical outcomes, PEI-UPF is a significant predictor even in the absence of other dietary predictors. HEI-2010 is sometimes a significant predictor, but Total Energy Intake and Total Fat Intake are not significant for any of the outcomes tested.

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**Table 5. P-values for various dietary indices in models with only one dietary index.**

| | Maternal or Newborn Outcome | | | |
|---|---|---|---|---|
| **Dietary Index** | **Gestational Weight Gain (kg)** | **Thigh Skinfold Thickness (mm)** | **Subscap. Skinfold Thickness (mm)** | **Body Fat (%)** |
| PEI-UPF | 0.017* | 0.12 | 0.036* | 0.035* |
| HEI-2010 | 0.0011* | 0.41 | 0.026* | 0.30 |
| Total Energy Intake | 0.73 | 0.45 | 0.80 | 0.97 |
| Total Fat Intake | 0.88 | 0.59 | 0.75 | 0.76 |

Note: All models were adjusted for age (continuous), race (Caucasian or African American/other), weight status (lean or obese), socioeconomic status (Primarily Low-Income Clinic or Primarily High-Income Clinic), and percent of time spent in moderate physical activity (continuous). Models for newborn outcomes were also adjusted for gestational age at which neonatal measurements were taken (continuous).
* represents P-value < 0.05.

## Table 6 (on next page)

Appendix: Classification of foods from DHQ II, along with justification.

The appendix shows the 33 food subgroups within the four main NOVA groups, and explains why the ultra-processed subgroups were classified in this manner.

1 Appendix: Classification of foods from DHQ II, along with justification.

| Classification | | Subclassification | Justification for Classification (for ultra-processed foods only) |
|---|---|---|---|
| Unprocessed or Minimally Processed Food | 1 | Meat (includes poultry) | |
| | 2 | Fruit | |
| | 3 | Milk | |
| | 4 | Grains | |
| | 5 | Roots and tubers | |
| | 6 | Eggs | |
| | 7 | Legumes | |
| | 8 | Fish and sea food | |
| | 9 | Vegetables | |
| | 10 | Other unprocessed or minimally processed foods | |
| Processed Culinary Ingredients | 11 | Table sugar | |
| | 12 | Animal fats | |
| Processed Foods | 13 | Cheese | |
| | 14 | Ham and other salted, smoked or canned meat or fish | |
| | 15 | Vegetables and other plant foods preserved in salt | |
| | 16 | Other processed foods | |
| Ultra-processed Foods | 17 | Breads (stuffing, dressing, dumplings, bagels, English muffins, bread, dinner rolls, corn bread/muffins, biscuits) | In 1955, 94% of families bought bread, while only 5% baked bread. Most bought breads contain monoglycerides and high fructose corn syrup. |
| | 18 | Cakes, cookies and pies (also includes pancakes, waffles, | Most cakes, cookies and pies in American are bought in a ready to |

| | | |
|---|---|---|
| | French toast, brownies, doughnuts, sweet rolls, Danish, pop-tarts, sweet muffins, dessert breads, fruit crisp/cobbler/strudel) | eat presentation at the store, and similar to bread only a small percentage of people bake such items from scratch. |
| 19 | Salty-snacks (potato chips, crackers, corn/tortilla chips, popcorn, pretzels) | Most popular popcorn brand (Orville Redenbacher) contains artificial flavors and TBHQ. |
| 20 | Frozen and shelf-stable plate meals (lasagna, stuffed shells, stuffed manicotti, ravioli, or tortellini, macaroni and cheese, beef stew/ pot pie, beef and noodles, beef and vegetables) | Most ready-to-eat meals contain mono- and diglycerides and/or modified food starch, both of which are chemically processed. |
| 21 | Soft drinks, carbonated | Soft drinks in the US are generally made from high fructose corn syrup. |
| 22 | Pizza (ready-to-eat/heat) | 74% of Americans never make pizza at home. Store-bought pizzas often contain preservatives, soy-protein isolates, and/or oil-based cheese substitutes. |
| 23 | Fruit drinks (sports drinks, energy drinks, applesauce, cranberry cocktail, Hi-C, lemonade, Kool-Aid) | All such drinks contain added sugar, and often have artificial sweeteners or colors. |
| 24 | Breakfast cereals | Seven of top 10 cereal brands contain artificial colors, preservatives, and/or high fructose corn syrup. |
| 25 | Sauces, dressings and gravies | Major brands of ketchup (Heinz, |

| | | |
|---|---|---|
| | (mayonnaise, ketchup, gravy, salad dressing) | Del Monte) contain high fructose corn syrup. 94.7% of households buy prepared salad dressing, and the most popular dressing (ranch) often contains xantham gum. |
| 26 | Reconstituted meat or fish products (bologna, salami, corned beef, pastrami, sausage) | These products often contain additives such as sodium erythorbate or BHT. |
| 27 | Ice cream and ice pops (frozen yogurt, sorbet, ices, ice cream, ice cream bars, sherbet) | Majority of ice cream brands contain additives such as xantham gum. |
| 28 | Sweet-snacks (energy/high-protein/breakfast bars, candy) | Such foods generally contain artificial flavors and sweeteners. |
| 29 | Milk drinks (chocolate milk, meal replacement/high protein beverages, yogurt) | Major brands of chocolate milk (TruMoo, Darigold, Purity) contain additives such as carrageenan or guar gum. Most yogurt is sweetened, and contains additives and/or high fructose corn syrup. |
| 30 | French fries and other potato products (also includes potato salad) | French fries and potato salad are generally store-bought, and often contain TBHQ, Calcium Disodium EDTA and/or xantham gum. |
| 31 | Sandwiches and hamburgers on bun (ready-to-eat/heat) | 'Homemade' sandwiches are generally made using store-bought bread, which is ultra-processed (see above). |
| 32 | Instant and canned soups | 64% of US households consume store-bought soup, which often contains MSG, modified food starch, and/or high fructose corn |

| | | | |
|---|---|---|---|
| | | | syrup. |
| | 33 | Other ultra-processed foods (see list below) | Nondairy creamers generally contain high fructose corn syrup and/or partially hydrogenated oils. |

Note: Other ultra-processed foods include syrup, artificial sweetener, nondairy creamer, fish sticks, fried fish, chicken salads/sandwiches/casseroles/stews, hot dogs, frankfurters, roast beef/steak sandwiches, pasta salad, macaroni salad, tacos, tostados, burritos, tamales, fajitas, enchiladas, quesadillas, and chimichangas, chili, liquor, mixed drinks, tofu, soy burgers, soy meat-substitutes, cold/iced tea.

2