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## Validation of a Food Frequency Questionnaire for Estimating Micronutrient Intakes in an Urban US Sample of Multi-Ethnic Pregnant Women

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### Abstract

**Objective(s)**—To validate the Block98 food frequency questionnaire (FFQ) for estimating antioxidant, methyl-nutrient and polyunsaturated fatty acids (PUFA) intakes in a pregnant sample of ethnic/racial minority women in the United States (US).

**Methods**—Participants (n = 42) were from the Programming of Intergenerational Stress Mechanisms study. Total micronutrient intakes from food and supplements was ascertained using the modified Block98 FFQ and two 24-h dietary recalls collected at random on nonconsecutive days subsequent to completion of the FFQ in mid-pregnancy. Correlation coefficients (r) corrected for attenuation from within-person variation in the recalls were calculated for antioxidants (n = 7), methyl-nutrients (n = 8), and PUFAs (n = 2).

**Result(s)**—The sample was largely ethnic minorities (38 % Black, 33 % Hispanic) with 21 % being foreign born and 41 % having less than or equal to a high school degree. Significant and adequate deattenuated correlations ( $r = 0.40$ ) for total dietary intakes of antioxidants were observed for vitamin C, vitamin E, magnesium, and zinc. Reasonable deattenuated correlations

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were also observed for methyl-nutrient intakes of vitamin B6, betaine, iron, and n:6 PUFAs; however, they did not reach significance. Most women were classified into the same or adjacent quartiles ( 70 %) for total (dietary + supplements) estimates of antioxidants (5 out of 7) and methyl-nutrients (4 out of 5).

**Conclusions**—The Block98 FFQ is an appropriate dietary method for evaluating antioxidants in pregnant ethnic/minorities in the US; it may be less efficient in measuring methyl-nutrient and PUFA intakes.

### Keywords

Validation study; Micronutrients; Pregnancy; Minorities; United States

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### Introduction

Adequate intakes of a range of micronutrients during critical periods of fetal development play a role in the programming of key physiological mechanisms in offspring that contribute to chronic disease [10]. For instance, one's risk for preterm birth, low birth weight, allergic and respiratory diseases, obesity, and adverse neurodevelopmental outcomes can be affected by maternal prenatal dietary patterns and dietary intakes of antioxidants (e.g., vitamins A, C, and E), nutrients serving as methyl-donors (e.g., vitamin B, Choline, Betaine), and polyunsaturated fatty acids (e.g., omega 3, omega 6) [1, 2, 37, 41, 42, 48, 68]. Other studies demonstrate that prenatal micronutrient supplementation, to ensure adequate intakes, may mitigate effects of environmental chemical toxins that may also influence chronic disease development. For example, a recent randomized controlled trial found that supplemental vitamin C taken by pregnant smokers was associated with improved pulmonary function in newborns as well as reduced incidence of wheezing respiratory illnesses up to age 1 year [44]. While data are still sparse in pregnant women, epidemiological studies of typical prenatal nutrient consumption patterns in both the United States (US) and Europe document unmet dietary recommendations for most of these micronutrients [15, 22].

A large body of research also documents socioeconomic and ethnic/minority disparities in chronic childhood conditions including asthma [32], obesity [43], and neurodevelopmental disorders [40]. While the etiology of the observed disparities have not been fully elucidated [55], evolving research has begun to focus on prenatal maternal nutritional status [36, 39] with a few studies documenting sociodemographic disparities in both dietary and supplement intakes in pregnant women and women of child-bearing age [15, 18]. Methods are needed among pregnant minorities in order to ensure the success of accurately measuring prenatal intake. Use of dietary data collection instruments validated within ethnically diverse prenatal populations can lead to inclusion of culturally sensitive food preparation methods, ingredients, and foods representing nutrient intakes during the prenatal period. On the other hand, use of instruments not validated within ethnically diverse populations may result in potential misclassification of intakes among such populations [31, 59, 65].

The Food frequency questionnaire (FFQ) is a retrospective method useful for obtaining estimates of usual intake of foods/beverages over an extended period of time (e.g., months), including during pregnancy when assessing trimester-specific intakes are of interest [15, 16].

In addition to assessing usual patterns of food intake over time, FFQs have several other advantages including their ease of administration, relative low cost, and ability to rank individuals based on dietary intake [16, 19, 71]. Unfortunately, validation data on FFQs in samples including a significant number of ethnic minorities in the US are lacking, and few include pregnant women. A systematic review published in 2009 included seventeen validation studies among non-pregnant samples; eight were performed in the US [50]. Of the US studies, two included racial/ethnic minorities and two were conducted among English-speaking women only. Of the two studies that included ethnic minorities, only one included supplements and this study was conducted among low-income American Indian and Caucasian women [6]. Since 2009, additional validation papers have been published [5, 9, 45, 54]; however, they again did not include pregnant minorities, lacked information on supplement use, and included limited micronutrients and/or focused on food group intakes or dietary patterns. While the prevalence of supplement use during pregnancy has been reported to be as high as 80 % [4], there are few such studies conducted in the US [51]. The National Health and Nutrition Examination Survey (NHANES) has monitored the use of dietary supplements in the US population since the 1970s, but the sample size of pregnant women is too small to draw conclusions regarding dietary supplement use during pregnancy among US women [7]. Supplement use is also reported to be related to sociodemographic variables. Supplement use during pregnancy appears to vary among ethnic and socioeconomic groups and interact with factors such as supplement use before pregnancy, smoking and BMI in the Nordic countries [3]. Including supplemental use is unique to this validation study.

Validation involves assessing how well an FFQ measures what it was designed to measure and requires comparison with a “more accurate” reference measure of intake, usually multiple dietary recalls, records or biomarkers [19]. Consistent with what other researchers have utilized and reported in epidemiological studies with ethnically diverse populations, the present study used energy adjusted and energy adjusted de-attenuated correlations between FFQ estimates and the mean of two 24 h dietary recalls to establish the validity of the Block98 FFQ in measuring total micronutrient intakes from food and supplements in an urban US sample of primarily Black and Hispanic pregnant women [19].

## Methods

### Study Sample

Women were from the Programming of Intergenerational Stress Mechanisms (PRISM) study, a prospective pregnancy cohort originally designed to examine how perinatal stress influences respiratory health in children when controlling for other environmental exposures (chemical stressors, nutrition). Women were recruited in prenatal clinics from the Beth Israel Deaconess Medical Center and East Boston Neighborhood Health Center from March 2011 to August 2012, and the Mount Sinai Obstetrics and Gynecology Practice beginning in April 2013 and ongoing. Eligibility criteria included: (1) English- or Spanish-speaking; (2) age 18 years at enrollment; and (3) singleton pregnancy. All women approached to participate completed a screener questionnaire including data on maternal age, race/ethnicity, education and nativity status. Briefly, women completed the FFQ during the second trimester; this was

followed by two unannounced 24-h dietary recalls (one weekday, one weekend) proximate to the FFQ with the first being conducted within 2–3 weeks after completing the FFQ. The protocol for data collection is described in further detail below. Research was conducted in accord with prevailing ethical principles and all procedures were approved by the human studies committee at the Brigham and Women’s Hospital and Icahn School of Medicine at Mount Sinai; written consent was obtained in the participant’s primary language.

### Food Frequency Questionnaire

Prenatal maternal dietary intakes in the past 3 months were assessed during the second trimester using an interviewer-administered modified Block98 FFQ (Block 2006\_Bodnar FFQ, version 98.2, NutritionQuest, Berkeley, CA) consisting of approximately 120 food/beverage items [14, 57]. The Block98 FFQ incorporates dietary and questionnaire changes suggested by American national consumption data collected from the third National Health and Nutrition Examination Survey (NHANES III) [16, 72]. The measure has been validated in multi-cultural populations including women [57, 65]. Given the interest in studying the health effects of prenatal omega-3 and omega-6 intakes, the modified Block98 FFQ was utilized in this study as it included a more extensive list of fish and seafood items. The modifications queried about the participants consumption (frequency and quantity) of the following fish/seafood items: (1) fish sticks, fried fish, or fish sandwich, (2) tuna, tuna salad, or tuna fish casserole, (3) salmon, (4) halibut, (5) trout, (6) mackerel, (7) herring, (8) sardines, and (9) other white fish, such as cod, sole, flounder, catfish, perch, or haddock [14, 57]. The FFQ was administered in English or Spanish by bilingual research assistants and took approximately 20–30 min to complete. The food list developed from NHANES III dietary recall data includes nine response options ranging from “never” to “every day”, and portion size pictures used to increase the accuracy of their estimates. The FFQ also assessed the type, dose and frequency (“didn’t take” to “every day”) and duration of use of dietary supplements, including, prenatal and regular type vitamins, minerals and omega supplements used in the prenatal period.

FFQs were reviewed for completion and processed through the online Block Dietary Data Systems (Berkeley, CA) for micronutrient analysis directly using software developed at the National Cancer Institute (NCI). The program calculates energy, and macronutrient and micronutrient intake per day by using nutrient values based on data from NHANES III, the 1994–1996 Continuing Survey of Food Intakes by Individuals (CSFII), and the USDA Nutrient Database for Standard Ref. [12, 14, 60]. For each item on the FFQ, an average daily intake of the nutrient was calculated based on the nutrient content of the item and the frequency and portion size in which it was consumed. Nutrient values were calculated by multiplying the nutrient content of the food by the gram weight and frequency, and summing across all food items. Nutrient values were determined based on updated folate values for fortified foods from the USDA 1998 nutrient database [60] and adjusted for bioavailability through nutrient-equivalent estimates when relevant [18, 29]. Missing data from FFQs and resulting imputations were handled using methods consistent with the literature for FFQ data [13, 14]. In brief, when computing nutrient values for missing portion amount data, middle amount values were assigned. For missing frequency, a response of “never consumed” was assumed. Based on the skip patterns noted for the PRISM population, and according to the

reported intakes for specific FFQ food line items, <10 % had missing data, where imputation was necessary. Errors of estimation or assumptions which are reported commonly in population based studies have similarly been addressed by other researchers using a variety of imputations [25].

The following nutrients were assessed in this validation study: essential fatty acids (n – 3, n – 6), individual antioxidants (vitamins A, C and E), nutrients associated with one-carbon metabolism (choline, methionine, betaine, folic acid, B12, B6, riboflavin), and additional nutrients important for fetal development (iron, zinc, magnesium, beta-carotene, selenium). Betaine and choline values were derived from two USDA publications: the USDA Database for the Choline Content of Common Foods and the USDA Database for the Choline Content of Common Foods, Release 2 [61, 62]. Values that were not listed were imputed using recipes, or applying values from similar foods. Nutrient intakes of n:6 PUFAs [as the sum of linoleic acid (LA, g/d) and arachidonic acid (ARA, g/d)] and n:3 PUFAs [as the sum of alpha-linolenic acid (ALA, g/d), eicosapentaenoic acid (EPA, g/d), docosapentaenoic acid (DPA, g/d), and docosahexaenoic acid (DHA, g/d)] were estimated.

### 24-h Dietary and Supplement Recalls

The 24-h dietary recalls were conducted by trained interviewers using the USDA automated multiple pass methods (AMPM) [52]—fully computerized recall method that uses multiple memory cues with standardized wording to elicit recall of all possible foods [47]. With the help of the adapted AMPM multiple pass template, trained bilingual (English–Spanish) interviewers asked study participants to recall foods and beverages they consumed in the 24-h prior to the interview using a four step process: (1) Quick Chronological List of consumed foods, (2) Meal Preparation Location, Consumption Location, and Amount Eaten, (3) Ingredient and Meal/Food Preparation Details and (4) Review of the Completed Recall. The AMPM 24-h recall approach is considered a gold standard for validation studies as it has been used since 2002 to collect dietary recalls for NHANES and the data generated has been used to develop nutrition and food-related regulations, programs, policies, and dietary standards and recommendations [24, 47]. These data were supplemented with the following documents tailored for PRISM: (1) Herbs and Spices Guide (2) Sugars and Sweeteners (3) Cultural Foods Guide (4) Portion Sizes Guide incorporating household weights and measures, standard units and standard portions from the USDA Dietary Guidance manual. In addition telephone scripts providing sample probing questions for different sections of the AMPM recall were developed. In the recall, special days (travel, get-togethers) were noted.

Trained and certified bilingual (English–Spanish) interviewers conducted 24 h recalls from April 2013 to March 2014. Two 24-h dietary recalls were collected at random on nonconsecutive days (one weekend day and one weekday) from n = 42 PRISM participants in mid-pregnancy with the first being done within 2–3 weeks after the FFQ. The time between the two recalls ranged from 1 to 3 weeks for most women (n = 33) and between one to three months for n = 5; all were completed in pregnancy. The remaining four women completed only one recall. Interviewers asked the participants to recall foods and beverages consumed in the 24 h prior to the interview using a four-step process. In addition to dietary intakes, interviewers assessed supplement use during the same 24-h recall period. This recall

included all types of dietary supplements (vitamins and minerals) and over-the-counter antacids. The 24 h dietary and supplement recall data were reviewed and analyzed using the University of Minnesota Nutrition Data System for Research (NDSR, version 2007; <http://wee.ncc.umn.edu/products/ndsr.html>).

### Data Analysis

The data analysis plan included five steps: (1) calculate energy adjusted intakes of micronutrients from FFQs and recalls, (2) calculate total (dietary + supplement) intakes of micronutrients, (3) generate descriptive statistics for demographic and micronutrient variables, (4) compare intakes from the FFQs and recalls using Pearson Correlation Coefficients, and (5) perform a cross-classification analysis. Each step is described in detail below. Validation correlations will vary with the nutrient, but typically range from 0.40 to 0.70 [16, 58]. According to other researchers, validity correlations less than 0.40 suggest FFQ shortcomings based on the assumption that two recalls represent true intake [16].

The frequencies of categorical variables and means (SD) of continuous variables were calculated for demographic characteristics. Nutrient intakes were energy-adjusted using the residual method [70]; the residual serves as an estimate of nutrient intake uncorrelated with total energy intake and directly related to overall variation in food choice and composition. The purpose of performing energy-adjustments is twofold: (1) to account for the fact that total energy requirements are related to body size, metabolic efficiency, and physical activity, thereby providing a measure of diet composition, and (2) to mitigate the effects of measurement error in data collection using self-reported dietary assessments. Energy-adjustments were completed by first regressing dietary micronutrient intakes on total energy intakes (kcal). The mean micronutrient intake of the study population was added to the residuals derived from the regression to calculate the energy-adjusted intake for each micronutrient. Supplemental intakes were then added to the energy-adjusted dietary intakes to provide total energy-adjusted intakes of each micronutrient. Means (SD) were calculated for energy-adjusted dietary and total micronutrient intakes from the average of two 24-h recalls (except for those four completing one recall) and the FFQ. Micronutrient distributions were tested for normality with the Shapiro–Wilk test; most micronutrient distributions were skewed, thus all micronutrients were log-transformed using the natural log.

Raw and deattenuated Pearson's correlation coefficients were calculated. Deattenuated correlation coefficients were applied to correct for random within-person error in the 24-h recalls using a freely accessible SAS macro (<http://analytics.ncsu.edu/sesug/2008/PO-089.pdf>) [35, 69]. Agreement between the 24-h dietary recalls and the FFQ were also compared by cross-classification analysis. Subjects were classified into quartiles based on energy-adjusted micronutrient intakes, and percentages of agreement and disagreement were calculated between the two dietary methods. All statistical analyses were performed using SAS software (version 9.3 SAS Institute Inc., Cary, NC).

## Results

General characteristics of the subjects ( $n = 42$ ) are shown in Table 1. Participants were largely ethnic minorities (38 % Black, 33 % Hispanic) with 21 % being foreign born. Over 40 % of the women had less than or equal to a high school degree. The mean age of the women at recruitment was  $28.7 \pm 6.7$  years, 52 % were overweight or obese prior to pregnancy and 7 % smoked during pregnancy.

Energy-adjusted mean daily intakes of micronutrients estimated by the dietary recalls and FFQs are provided in Table 2. When considering dietary intakes of antioxidants, there was no consistent pattern observed with the FFQ or 24-h recalls estimating higher or lower intakes; however, the inclusion of supplements led to the FFQs estimating higher intakes of all antioxidants except vitamin A and zinc. Daily mean dietary intakes of methyl-nutrients were higher on the FFQ than the 24-h recalls, with the exception of iron and methionine. After consideration of supplements, daily mean total intakes of folate from the FFQ remained higher than those reported through the recalls; the 24-h recalls estimated higher intakes for all other methyl-nutrients. Higher PUFA intakes were estimated using the 24-h recalls.

Table 3 shows the crude and deattenuated Pearson's correlations for dietary and total micronutrient intakes for antioxidants, methyl-nutrients, and PUFAs. Significant (based on the 95 % CI) crude Pearson's correlations for antioxidants were observed for vitamin C ( $r = 0.34$ ), vitamin E ( $r = 0.40$ ), and magnesium ( $r = 0.39$ ). Significant correlations were again observed for these three antioxidants following the inclusion of supplements; in addition, the correlation for magnesium was strengthened ( $r = 0.45$ ). The crude correlations for dietary intakes or total intakes observed for methyl-nutrients or PUFAs were not significant; however, the correlation for dietary intakes of n:6 PUFAs was marginal ( $r = 0.28$ ).

Deattenuated correlations for most micronutrients showed improvement over raw correlations. Significant and reasonable deattenuated correlations ( $r \geq 0.40$ ) for dietary intakes of antioxidants were observed for vitamin C, vitamin E, and magnesium. After the inclusion of supplements, the deattenuated correlation for zinc ( $r = 0.41$ ) became significant. Reasonable deattenuated correlations were also observed for dietary methyl-nutrient intakes of betaine and iron, as well as n:6 PUFAs; however, they did not reach significance based on the 95 % CI. The results of the cross-classification can be found in Table 4. The number of women correctly classified or classified within one quartile was adequate (70 %) for total and dietary intakes of antioxidants (vitamins A, C, E and magnesium and zinc), total intakes of methyl-nutrients (vitamin B6, folate, riboflavin, and iron), and dietary intakes of n:6 PUFAs.

## Discussion

This validation study demonstrates that the modified Block98 FFQ provides a reasonable assessment of antioxidant intakes among this ethnically mixed population of urban pregnant US women. We observed antioxidant correlations between the FFQ and dietary recalls across both dietary and total intakes (dietary + supplements) ranging from 0.33 (zinc) to

0.97 (magnesium). In other studies, reported ranges for antioxidants were 0.12–0.90 [66], 0.35–0.64 [6], and 0.36–0.79 [17]. For some antioxidants we have similar or better correlations compared to other studies—these include vitamins A [66], C [17, 27, 66], E [6], and magnesium [6, 66]. When considering dietary intakes and supplements together, the correlation for zinc ( $r = 0.41$ ) was similar to those observed in other studies of total intakes [6]. Compared to non-US studies, correlations reported herein were slightly higher or similar for vitamin C, E, magnesium, and zinc [9] and lower for vitamin A [9, 45]. It is notable that the micronutrients with the strongest correlations in this validation study include antioxidants vitamins C, E, and zinc. The generation of oxidative stress during placental development is a normal phenomenon; however, when the supply of antioxidant micronutrients is limited, exaggerated oxidative stress can result in adverse pregnancy outcomes (e.g., preeclampsia, growth restriction) and fetal development (e.g. brain and allergic/respiratory development) [26, 46, 49, 63, 67]. The FFQ may not be adequate for assessing other antioxidants (e.g., selenium) and others have suggested that duplicate portion sampling may be a more accurate method for assessing selenium because it reflects actual selenium intake [34].

Methyl-nutrients and fatty acids are also important nutrients for early development and function of the central nervous system [20, 53, 56, 74]. The Block98 FFQ was less efficient in measuring methyl-nutrient intakes and PUFAs in our sample; while three methyl-nutrients (e.g., vitamin B6, Iron and betaine) and the n:6 PUFAs had correlation coefficients 0.40, they did not reach statistical significance at the  $p = 0.05$  level. In comparison to other reports, our correlations for methyl-nutrients were similar or higher for vitamin B6 and iron and lower for folate and B12 [6, 9, 17, 27, 66]. Choline, betaine, methionine, and riboflavin were not available for comparison with other validation studies; population studies of choline and betaine intakes have been limited because a food-composition database was not available until recently. For those nutrients for which we could make comparisons, the differences observed could partly be due to differences in sample size, ethnic/racial background, reference method used (e.g., recalls vs. food records), and/or number of recalls included in the analysis. Despite the lack of significance, the strong correlations for vitamin B6 and iron are of interest given their importance in preeclampsia, birth weight, neuromotor development, and maternal anemia in pregnancy [21, 23]. Betaine is a relatively new methyl-nutrient being explored and thus the exact role of betaine during pregnancy is unclear, however it also appears to be important for fetal development, birth weight, and early brain development [28, 73].

Given data suggesting that pregnant women in the US and other developed countries are at risk for suboptimal micronutrient intakes [15] and these dietary factors may have implications for socioeconomic and racial disparities in chronic disease risk in offspring [11], epidemiologists need valid tools for assessing maternal diet during pregnancy in ethnically mixed samples. While our small sample size may be seen as a limitation, this validation study was performed in a prospective pregnancy cohort with two major strengths. The first is the inclusion of a significant proportion of Black and Hispanic pregnant women. Although the Block98 FFQ has been used in multicultural populations [57, 65], according to Nutrition Quest, the standard references related to the development and validation of the Block98 FFQ, occurring before 1995, included only one study of pregnant ethnic/racial



minorities (African Americans and Hispanics) and it was limited to vitamins A and C and iron [13]. In comparison to Block and DiSogra [13], our correlations were similar for vitamin A and better for vitamin C and iron. More recently, two validation studies of the Block98 FFQ have been conducted using modified versions of the full-length Block98 FFQ. The first study was conducted among Canadian women over the age of 40 [16]; while this study included ethnic minorities, 82 % were Caucasian. The second study was conducted among African American and White women but focused exclusively on folate intakes [30].

The validation of FFQs to assess diet during pregnancy has not typically included the use of dietary supplements [50]; thus, the second strength of this study is that data on supplemental intakes were collected. For many nutrients, we observed that data from the FFQ and recalls correlated better when supplements were included (e.g., magnesium, zinc, vitamins B12 and B6, folate, and iron). For instance, dietary zinc alone may correlate poorly with plasma zinc because FFQs estimate annual intake whereas plasma zinc reflects recent intake consisting of both dietary and supplemental sources (total intake). The bioavailability of zinc may also differ according to dietary sources and other components of the diet including supplements [38]. These analyses may have been limited by the relatively small sample size albeit this is similar to prior reported studies [8, 33]. Future studies in ethnically mixed pregnant women may consider an increased number of dietary recalls which can further facilitate validation. Methods such as the assessment of micronutrient concentrations in plasma are another approach to validating FFQs [64]. Given variations in intake specific to the state of being pregnant and the importance of culturally centered foods and practices, a “triad” approach including two interview methods (diet recalls and FFQ) and biomarker assays to further optimize dietary assessments in ethnically mixed samples of pregnant women should be considered in future research. Additional limitations to consider which may affect validity include potential differences in inclusions and accuracy of the databases used to generate intakes [16], generalizability to other populations, and the inherited recall bias that may occur when using FFQs despite their widespread use [16].

In conclusion, our findings support the validity of the modified Block98 FFQ for total micronutrient intakes in this urban, ethnically mixed US population when compared with 24-h dietary recalls. The FFQ was most efficient for antioxidant intakes and acceptable for methyl donors and n:6 fatty acids providing maternal and child health practitioners with a useful tool for assessment of mechanistically relevant dietary and supplemental micronutrient intakes in multi-ethnic prenatal populations. Ultimately, this may help design culturally tailored nutrition education and counseling materials, and will positively impact innovative evidence-based maternal child health programming via the development and implementation of culturally centered interventions.

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### Significance

Research has documented ethnic/minority disparities in childhood diseases. While the etiology of these disparities is unclear, evolving research has focused on maternal prenatal nutrition. Data supporting the validity of food frequency questionnaires for estimating micronutrient intakes in pregnant, ethnic/racial minority women in the United States are scarce. Our study addresses many research gaps as it includes a large panel of antioxidants, methyl-nutrients, and polyunsaturated fatty acids, as well as emerging essential micronutrients (i.e., choline and betaine), intakes from food and dietary supplements, and is conducted in an urban US population-based sample of largely Black and Hispanic pregnant women.

**Table 1**

Demographic characteristics of the validation sample set (n = 42)

Characteristic	n	%
<i>Maternal education</i>		
HS degree or GED	17	41
Some college/college degree	25	59
<i>Race</i>		
White	9	21
Black	16	38
Hispanic	14	33
Other (i.e., Haitian, mixed)	3	7
Foreign Born	9	21
Smoking during pregnancy	3	7
<i>BMI category</i>		
Normal (BMI < 24.9) <sup>a</sup>	20	48
Overweight (25 < BMI < 29.9)	8	19
Obese (BMI > 30)	14	33
Maternal age in years (mean/SD)	28.7	6.7

HS High school, GED General Education Development degree

<sup>a</sup>Includes two individuals with a body mass index (BMI) < 18.5

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**Table 2**  
Energy (kcal)-adjusted mean daily intakes (dietary and dietary + supplements) of nutrients estimated from FFQs and 24-h dietary recalls

Nutrients	Dietary intakes				Total intakes <sup>d</sup>			
	FFQs		Recalls		FFQs		Recalls	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Antioxidants</i>								
Vitamin A (mcg)	1033.01	306.92	1188.2	1753.76	1794.38	1028.72	3860.82	2260.15
Vitamin C (mg)	184.77	98.35	127.63	101.88	244.8	119.16	212.63	112.73
Vitamin E (mg)	10.69	3.73	13.19	5.37	38.57	137.89	22.92	16.37
β-carotene (mcg)	5163.71	3195.61	3236.7	2695.36	5930.38	4889.07	3311.55	2685.96
Magnesium (mg)	381.82	90.83	331.61	70.8	396.11	104.17	343.41	71.99
Selenium (mcg)	128.08	36.41	138.21	37.95	156.37	68.49	141.34	37.68
Zinc (mg)	13.69	3.04	13.21	2.83	20.28	11.74	30.82	11.28
<i>Methyl-nutrients<sup>b</sup></i>								
Vitamin B12 (mcg)	6.31	1.93	5.97	3.26	7.93	2.82	15.59	4.76
Vitamin B6 (mg)	2.37	0.63	2.32	0.8	3.19	1.15	6.42	3.81
Folate (mcg)	708.12	198.96	542.72	261.85	980.23	348.34	542.72	261.85
Riboflavin(mg)	2.61	0.55	2.47	0.6	3.29	1.05	8.94	31.29
Iron (mg)	18.24	3.78	19.07	7.81	31.95	20.97	58.06	63.43
Methionine (mg)	1.91	0.52	2.28	0.61	-	-	-	-
Betaine (mg)	229.59	100.92	173.98	61.13	-	-	-	-
Choline (mg)	390.79	89.83	375.94	99.82	-	-	-	-
<i>PUFAs<sup>b</sup></i>								
n:3 sum (gms)	2.33	0.62	2.82	1.86	2.37	0.62	2.85	1.86
n:6 sum (gms)	19.45	5.17	19.76	8.01	19.45	5.17	-	-

<sup>a</sup>Dietary + supplement intakes

<sup>b</sup>Supplemental intakes not available for methionine, choline, betaine, and n:6 sum (recalls)



**Table 3**  
Pearson correlation coefficients of nutrients estimated from FFQs and 24-h recalls

Nutrients	Dietary intakes			Total intakes <sup>d</sup>		
	Crude	De-attenuated <sup>b</sup>	Crude	Crude	De-attenuated <sup>b</sup>	Crude
	r	95 % CI <sup>d</sup>	r <sup>e</sup>	95 % CI <sup>d</sup>	r <sup>e</sup>	95 % CI <sup>d</sup>
<i>Antioxidants</i>						
Vitamin A (mcg)	0.07	-0.24,0.36	0.08	-0.26,0.40	0.19	-0.11,0.47
Vitamin C (mg)	0.34*	0.04,0.58	0.51*	0.06,0.88	0.32*	0.02,0.56
Vitamin E (mg)	0.40*	0.11,0.63	0.67*	0.18,1.04	0.37*	0.07,0.60
β-carotene (mcg)	0.14	-0.17,0.43	0.24	-0.29,0.74	0.12	-0.19,0.41
Magnesium (mg)	0.39*	0.10,0.62	0.97*	0.24,1.55	0.45*	0.16,0.66
Selenium (mcg)	-0.26	-0.53,0.04	-1.00	-3.01,0.27	-0.11	-0.39,0.20
Zinc (mg)	-0.32*	-0.57,-0.02	-0.88*	-1.57,-0.04	0.33*	0.03,0.57
<i>Methyl-nutrients<sup>c</sup></i>						
Vitamin B12 (mcg)	0.01	-0.29,0.31	0.03	-0.98,1.04	0.11	-0.19,0.40
Vitamin B6 (mg)	0.04	-0.27,0.34	0.13	-0.89,1.13	0.19	-0.12,0.46
Folate (mcg)	-0.07	-0.36,0.24	-0.14	-0.73,0.47	0.14	-0.17,0.42
Riboflavin(mg)	-0.03	-0.33,0.26	-0.08	-0.85,0.71	-0.02	-0.32,0.27
Iron (mg)	0.16	-0.14,0.45	0.57	-0.53,1.56	0.21	-0.09,0.48
Methionine (mg)	-0.08	-0.38,0.22	-0.17	-0.78,0.47	-	-
Betaine (mg)	0.19	-0.12,0.46	0.55	-0.34,1.34	-	-
Choline (mg)	-0.16	-0.44,0.14	-0.40	-1.11,0.37	-	-
<i>PUFAs<sup>c</sup></i>						
n:3 sum (gms)	-0.13	-0.42,0.18	-0.19	-0.62,0.26	-0.09	-0.38,0.22
n:6 sum (gms)	0.28	-0.003,0.53	0.47	-0.04,0.91	-	-

\* Significant at the 0.05 level

<sup>a</sup> Dietary + supplement intakes

<sup>b</sup> Corrected for within-person variation

<sup>c</sup> Supplemental intakes not available for methionine, choline, betaine, and n:6 sum (recalls)

Disattenuated values greater than 1.00 or less than -1.00 that indicates that measurement error is not randomly distributed. Disattenuated correlation is reported as 1.00 or -1.00, respectively

% 56<sub>p</sub> CI based on Fisher's transformation

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**Table 4**  
The proportion of agreement in quartile distribution of micronutrients from FFQs and 24-hr recalls

Nutrients	Dietary intakes			Total intakes <sup>a</sup>		
	% Correctly classified	% Classified within one quartile	% Misclassified	% Correctly classified	% Classified within one quartile	% Misclassified
<i>Antioxidants</i>						
Vitamin A (mcg)	26	48	26	33	53	14
Vitamin C (mg)	30	40	30	35	37	28
Vitamin E (mg)	29	41	30	31	39	30
β-carotene (mcg)	24	45	31	29	38	33
Magnesium (mg)	28	43	29	29	43	28
Selenium (mcg)	26	38	36	17	43	40
Zinc (mg)	19	38	43	45	33	21
<i>Methyl-nutrients<sup>b</sup></i>						
Vitamin B12 (mcg)	24	45	31	38	19	43
Vitamin B6 (mg)	38	38	24	29	45	26
Folate (mcg)	21	43	36	37	33	30
Riboflavin(mg)	24	40	36	36	38	26
Iron (mg)	36	33	31	24	50	26
Methionine (mg)	21	43	36	-	-	-
Betaine (mg)	38	31	31	-	-	-
Choline (mg)	26	36	38	-	-	-
<i>PUFAs<sup>b</sup></i>						
n:3 sum (gms)	26	41	33	28	42	30
n:6 sum (gms)	33	45	22	-	-	-

<sup>a</sup>Dietary + supplement intakes

<sup>b</sup>Supplemental intakes not available for methionine, choline, betaine, and n:6 sum (recalls)