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Reliability of a short diet and vitamin supplement questionnaire for retrospective collection of maternal nutrient intake

Rebecca J. Schmidt [a,b,*], Amanda J. Goodrich [a], Lauren Granillo [c], Yunru Huang [c], Paula Krakowiak [a], Adrianne Widaman [d], J. Erin Dienes [e], Deborah H. Bennett [a], Cheryl K. Walker [b,f], Daniel J. Tancredi [g]

[a] Department of Public Health Sciences, University of California Davis School of Medicine, Davis, CA, United States of America
[b] MIND Institute, University of California Davis School of Medicine, Sacramento, CA, United States of America
[c] Graduate Group in Epidemiology, University of California Davis, Davis, CA, United States of America
[d] Graduate Group in Nutritional Biology, University of California Davis, Davis, CA, United States of America
[e] Department of Statistics, University of California Davis, Davis, CA, United States of America
[f] Department of Obstetrics and Gynecology, University of California Davis School of Medicine, Davis, CA, United States of America
[g] Department of Pediatrics, University of California Davis School of Medicine, Sacramento, CA, United States of America

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ABSTRACT

Background: Gestational nutrition can protect against adverse neurodevelopmental outcomes.
Objectives: We developed a short tool for collecting maternal nutritional intake during pregnancy to facilitate research in this area and compared its retrospective use to prospectively-collected food frequency questionnaires (FFQ).
Methods: Maternal nutritional intake was retrospectively assessed using three versions (full interview, full self-administered online, and shortened interview) of the Early Life Exposure Assessment Tool (ELEAT) among participants of the MARBLES pregnancy cohort study of younger siblings of autistic children. Retrospective responses were compared with responses to supplement questions and the validated 2005 Block FFQ prospectively collected in MARBLES during pregnancies 2–7 years prior. ELEAT nutrient values were calculated using reported food intake frequencies and nutrient values from the USDA nutrient database. Correlations between retrospectively- and prospectively-reported intake were evaluated using Kappa coefficients, Youden's J, and Spearman Rank Correlation Coefficients (r_s).
Results: MARBLES FFQ dietary intakes were compared among 54 women who completed the ELEAT full form including 12 online, and among 23 who completed the ELEAT short form. Correlations across most foods were fair to moderate. Most ELEAT quantified nutrient values were moderately correlated ($r_s = 0.3–0.6$) with those on the Block FFQ. Supplement questions in both MARBLES and the ELEAT were completed by 114 women. Kappas were moderate for whether or not supplements were taken, but modest for timing. Correlations varied by version and child diagnosis or concerns, and were higher when mothers completed the ELEAT when their child was 4 years old or younger.
Conclusions: With recall up to several years, ELEAT dietary and supplement module responses were modestly to moderately reliable and produced nutrient values moderately correlated with prospectively-collected measures. The ELEAT dietary and vitamin supplements modules can be used to rank participants in terms of intake of several nutrients relevant for neurodevelopment.

Background

Nutrition needs increase during pregnancy and are critical for brain development [1–3]. A link between maternal gestational nutrition and prevention of neural tube defects is established [4,5], and evidence is accumulating for a role of gestational nutrition in the etiology of autism [6–14] and other neurodevelopmental disorders [8,15–20]. Prospectively collecting information on maternal supplement and dietary intake

* Corresponding author at: Medical Sciences 1C, One Shields Ave, Davis, CA 95616-8638, United States of America.
E-mail address: rjschmidt@ucdavis.edu (R.J. Schmidt).

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using gold standard tools that can quantify numerous macro- and micronutrients, including multiple 24-h dietary recalls [21] or validated food frequencies [22–24] can be burdensome for participants and research staff and often is infeasible for studies of autism and other relatively rare developmental conditions. In addition, few questionnaires are designed to target nutrients and time periods in the pre- and peri-natal periods relevant for neurodevelopmental outcomes [8,25], for example, folic acid intake specifically near the time of conception, which has been shown to be a critical window for neural tube defect prevention [26] and potentially relevant for autism [7,9]. Some validated and shorter nutritional screeners exist, but these each tend to only target a few specific foods or nutrients, such as fruit and vegetable intake, fat, fiber, added sugar, red and processed meat, dairy and calcium, and folate intake [27–31]. Other food frequencies have been designed for retrospective use after a couple of years [32], or use in pregnancy [33,34], but these tend to be burdensome and do not include foods sources of contaminants that could impact neurodevelopment. Although trade-offs need to be made between the length of a tool and the details needed for a valid, accurate estimate of intake, a new shorter tool for collection of maternal nutritional intake around and during pregnancy could facilitate research in this area.

Objectives

We developed a tool to collect maternal dietary and supplement intake with a focus on nutritional factors and timing relevant to neurodevelopment and likely to influence autism risk. This was designed to be administered after pregnancy. We then assessed the tool's reliability in an elevated familial likelihood autism spectrum disorder (ASD) population, and examined whether the tool's reliability varied based on the length of time since pregnancy (child's age / length of recall) and by parental and clinical concerns regarding the child's neurodevelopmental status. We also investigated reliability by the parent's self-reported confidence in their retrospective responses.

Methods

Questionnaire development

Maternal diet and supplement intake modules (Modules D and S, respectively) were constructed as part of the development of the Early Life Exposures Assessment Tool (ELEAT). The ELEAT was designed as a relatively short exposure assessment tool to be used in studies of autism and other neurodevelopmental disorders in a variety of study populations, with the ultimate goal of expanding research on modifiable risk factors by facilitating data collection and potential for pooled data analysis studies. Standardized and/or validated questions were included in the ELEAT when they were available; however, no short set of questions that assessed intake of supplements and foods relevant to nutrition and contaminants relevant to neurodevelopment specifically during the critical periods during/near gestation were found. Thus the ELEAT Modules D and S were developed for this purpose and evaluated for their reliability with retrospective use. The UC Davis Institutional Review Board has approved this study, and informed and written consent was obtained before data collection.

Food and supplement items

Candidate nutritional factors were selected based on a thorough literature review that identified nutrients either associated with risk for ASD or other neurodevelopmental disorders. These included folate and folic acid [7,9,35], iron [10,36], and omega-3 fatty acids [37–39]. Nutrients with increased demand during pregnancy and those likely to become depleted (primarily folate and iron, but also vitamin B-6 and vitamin B-12 [40] were also prioritized. Finally, the ability to quantify nutrients from food and vitamin/supplement sources was also considered, which eliminated zinc, vitamin A and iodine. Prioritized nutrients included: folic acid and folate, iron, omega-3 fatty acids, vitamin B12, calcium, fiber, potassium, and choline. Foods and supplements that were the best sources of primary nutrients of interest, as determined primarily using data from the USDA nutrient database [41], were prioritized. Other foods were added to inform intake of USDA established food groups (fruits, vegetables, protein, dairy, grains, and sweets) and as indicators of healthy diets (whole grains) or unhealthy diets (red meat, fried foods). Consideration was given to whether accurate intake of each food, supplement, or nutrient was likely to be feasible using a short food frequency questionnaire. For example, though maternal fat intake is likely important for neurodevelopment, accurate quantification of fat consumption has been shown to be difficult using food frequency questionnaires [42]. Supplements, foods, and nutrients that were deemed to be of high demand in pregnancy, critical to brain development, and that could be measured using few questions were selected. When possible, items from standardized, validated, and freely available nutrition questionnaires, were modified to fit the context of the ELEAT. This included supplement questions from the Sure-QX [43] derived from *PhenX*: Measure #050501 and dietary items from the NCI Five-Factor Screener 2005 [30] and the NCI Mutli-Factor Screener 2000 [31] of the National Health Interview Survey. Because this questionnaire was part of the ELEAT which was collecting information on other environmental exposures, foods that are important sources of environmental contaminants, such as mercury and other heavy metals and persistent organic compounds in fish [44], perfluorooctanoic acid (PFOA) in popcorn [45,46], acrylamide, heterocyclic amines, polycyclic aromatic hydrocarbons [47,48], aldehyde [49] and acrolein [50] in deep-fat fried foods, were also included. Documentation on the rational, source, and exposures relevant to each item is available on the ELEAT website: https://eleat.ucdavis.edu/.

Versions and administration methods

The full version of the questionnaire (Supplemental Material Module D) was administered by telephone interview by study staff and self-administered through an online version in pilot work that included eligible participants of the Markers of Autism Risk in Babies: Learning Early Signs (MARBLES) ongoing pregnancy cohort study [51] that had collected similar information prospectively. MARBLES recruits and follows pregnant women who already have a child diagnosed with autism spectrum disorder (ASD) and thus have an elevated likelihood of having another child who develops ASD or other neurodevelopmental concerns [51,52]. In efforts to develop the most parsimonious FFQ possible, a shortened version of the ELEAT FFQ was also created where foods within a food group were combined together. Rather than ask about separate types of fruits and vegetables, the entire food group was asked as an item, e.g., 'fruits' instead of 'apples', 'bananas', 'pears', etc. unless the food item was a main source of a priority nutrient (Supplemental Material 'Module D Short Version'). This version was administered by telephone interview. All versions of the ELEAT administered included an Instrument Rating module at the end that included questions that asked respondents how sure they were about their answers in each module (including the Diet and Vitamins/Supplements modules), ranging from 'Very Sure' to 'Very Unsure' (Supplemental Material 'Module I). These responses were used to stratify findings by the respondant's confidence in their responses.

Timing

Because the critical period for ASD is likely to overlap with the critical periods of other neurodevelopmental disorders (e.g., neural tube defects) based on findings from neuropathology and epidemiology studies [8,25], the ELEAT targeted the three months prior to conception, all of pregnancy, and for maternal exposures, the duration of breastfeeding or while feeding the child breast milk. Questions on whether supplements were taken were asked for each of these periods, and because intake tends to change during pregnancy, for each trimester of pregnancy. Because dietary patterns are relatively stable [53,54], and to reduce respondent burden, the ELEAT only asked about maternal dietary intake during pregnancy, with the exception of a few select items that were sources of contaminants (e.g., fish).

Frequency and dose

To reduce respondent burden, the ELEAT dietary questionnaire did not include questions about portion size and number of servings, but rather asked about 'how often' food items were consumed on average, and participants were given a list of frequencies ranging from never to 5 times or more per day. Similarly, supplement questions did not ask about dose taken, but asked about when (before, during, and after pregnancy) and how often (times per day, week, month) each supplement was taken. Timing for supplement use during pregnancy was further divided by months in the first trimester, and into second and third trimester.

Quantification of ELEAT nutrient intake

Nutrient values were calculated for the ELEAT dietary module using reported frequency of intake and nutrient values for foods from the USDA nutrient database [41] obtained through Nutrition Data Systems for Research (NDSR) [55]. Over 146 macronutrient, micronutrients, bioactive components and food group servings (Supplemental Material 1) are calculated, but only nutrients and food groups of primary interest (as described above) are likely to be well-represented by foods included in the ELEAT. Detailed documentation on how each item is scored is available in Supplemental Materials 2–6. We evaluated a subset of 18 nutrients/groups for reliability/validity which included those of priority.

Supplement nutrients were also calculated using reported frequency and nutrient source values that would be found in generic supplements (Supplemental Material 7). Only source supplements with robust response rates were included for the nutrient calculation. This included prenatal vitamins, multivitamins, iron, calcium, folic acid, omega-3/fish oil/flax seed combined, vitamin B12, vitamin C, and vitamin D supplements. From these sources, 11 nutrients were calculated.

Prospective MARBLES maternal nutrient assessments

Food frequency questionnaires (FFQs) are given to all mothers twice during pregnancy to provide a comprehensive history of her usual dietary and supplemental intake across the first half of pregnancy (gestational weeks 1–20), and the second half of pregnancy (gestational weeks 20–40) [51]. MARBLES uses the Block 2005 food frequency questionnaire (http://nutritionquest.com/assessment/list-of-questionnaires-and-screeners/) that was designed to estimate usual and customary intake of a wide array of nutrients and food groups. The approximately 110 food item questionnaire takes 30–40 min to complete. The food list was developed from NHANES 1999–2002 dietary recall data; the nutrient database was developed from the USDA Food and Nutrient Database for Dietary Studies (FNDDS), version 1.0. Individual portion size is asked for each food, and pictures are provided to enhance accuracy of quantification.

This Block FFQ was developed in a scientific and data-based way [56,57], and has been extensively studied and validated [22,23]. The full-length Block questionnaires (e.g. Block98, Block2005) have been shown to come quite close to the point estimates produced by multiple days of diet recalls and records, producing reasonable estimates of an individual's intake, for most individuals. Modified versions of the Block FFQ have also been validated for use during pregnancy [58].

Completed Block FFQ questionnaires are checked for quality and completeness, and quality index scores ranging from 0 to 1 were calculated for key nutrients relevant to pregnancy and development (folate and dietary folate equivalents, iron, vitamins A, B6, B12, C, and E, calcium, choline, omega-3 and omega 6 fatty acids, dietary fiber, fats, and protein) based on the completeness of the information on food items that were major sources; a value of 1 represented complete data. FFQs then are sent to NutritionQuest to be scanned and nutrient information calculated. Dietary and nutrient data are returned to MARBLES investigators, along with individual respondent nutrient reports that summarize the participants' nutrient intake; these reports are sent out to participants whenever a batch of FFQs is analyzed (approximately annually) in order to provide nutrition education.

Environmental exposure questionnaires (EEQ) were also prospectively collected for MARBLES mothers and evaluated monthly intake of supplements, starting 6 months before pregnancy and through delivery. Since ELEAT focused on 3 months prior to pregnancy, only 3 months before pregnancy was used from the EEQ for this study in comparisons with the ELEAT supplemental questions/calculated nutrients. For each type of supplement, mothers were asked whether they took it, what dose/number of tablets they took, and how often they took it. The MARBLES EEQ supplemental questions have been published previously [11].

Retrospective ELEAT maternal nutrient assessments

Retrospective assessments of maternal nutritional intakes during and around pregnancy were conducted using the ELEAT in a subset of participants from the MARBLES pregnancy cohort study of high-risk siblings of children with autism [51]. Mothers were eligible for the ELEAT subset if they were active MARBLES participants whose baby sibling was at least 2 years old. Retrospective responses were compared with responses to supplement intake questions and/or the previously validated 2005 Block food frequency questionnaire (FFQ) prospectively collected by MARBLES during a pregnancy at least 2 years previously. We also conducted stratified analyses by the child's age at the time the mother completed the ELEAT (equivalent to the time since pregnancy) dichotomized at the median age of 4 years old to evaluate the length of recall on reliability.

Parental concerns

To assess recall bias or differential recall accuracy across the parent's perception of their child's health status, we evaluated correlations of maternal ELEAT responses with prospectivelycollected responses by whether the mother reported being worried about their child's health outcomes on the parent concerns form. When the child is 3, 6, 12, 24, and 36 months old, MARBLES mothers are asked to complete a 'Concerns' form assessing whether they have any of a list of concerns about their child's development or behavior (Supplemental Material 8). Parent responses were categorized into 'No concerns' or 'Any concerns' for analyses, using the Parent Concerns form that was completed closest to the date the mother completed the ELEAT if it was done prior, or if the closest parent concerns form was completed after the ELEAT, we checked whether the status of concerns/no concerns was different across forms, and if so, we chose the one reporting concerns.

Child clinical best estimate diagnostic outcome

To assess recall bias or differential recall accuracy across child's health status, we evaluated correlation of maternal ELEAT responses by the child's clinical best estimate (CBE) outcome classification [51] made after 36-month assessments including the Autism Diagnostic Observation Schedule [59,60] and the Autism Diagnostic Interview-Revised [61], where a trained and reliable clinician classified the child as typically developing (TD), having ASD (DSM-5), or other developmental concerns (ODC), which included: DSM-5 Social (Pragmatic) Communication Disorder, broader autism phenotype, attention deficit/hyperactivity disorder concerns, other externalizing behavior problems, anxiety or mood problems, learning difficulties/global developmental delay, speech-language problems, as defined previously [51]. The CBE outcome classification was used rather than the algorithmic outcome classification used for research purposes [62,63] to represent a broader scope of clinical concerns that would have been communicated to parents, and potentially influencing their level of concern about their child's development.

Statistical analysis

Correlations between retrospectively-assessed food and nutrient intakes and prospectively-reported intakes based on supplement questions and the Block FFQ were evaluated using Kappa coefficients and Youden's J index for categorical items (e.g., vitamins taken in a time period, yes or no), and Spearman Rank Correlation Coefficients (r_s) for continuous measures (e.g., servings, calculated nutrient values). Youden's J index was used because, unlike kappa, which treats the compared assessments as of equal validity, Youden's J statistic is an asymmetric measure of correlation that treats one of the compared assessments as more accurate, so we preferred it when comparing the retrospective ELEAT assessment to the prospective EEQ assessment. Youden's J combines together sensitivity and specificity into a single measure and is closely related to the area under the curve index (for the lower-valued binary assessment as predictor of the higher-valued binary assessment), which equals $0.5(J + 1)$ [64]. Asymptotic 95% confidence intervals (CIs) for Spearman correlations are based on Fisher's Z transformation. To create summary measures of correlation by module, timing, age, concerns, outcome, or confidence, we applied Fisher's Z transformation to the correlation coefficient (r_s), averaged the z-transformed values, and then back-transformed the averaged correlation value [65]; to show central tendency, we also reported the first and third quartile correlation values. Sensitivity and specificity were also calculated. These results were further straitified, separately, by child's age at time of ELEAT (> 4 years or ≤ 4 years), parental concern of child's development based on Parent Concern form ('No concerns' or 'Any concerns'), child's CBE outcome (ASD, TD, or ODC), and maternal confidence in their responses ("Somewhat Sure" or "Very Sure").

Spearman's rank correlation coefficients were interpreted based on published categories: 1.0 Perfect, 0.8–0.99 Very Strong, 0.5–0.79 Strong, 0.3–0.49 Moderate, 0.1–0.29 Modest, <0.1 Weak, 0.0 None [66,67]. Kappa coefficients and Youden's J index were interpreted based on published categories for Kappa coefficients: 0.81–1.0 Almost Perfect, 0.61–0.8 Substantial, 0.41–0.6 Moderate, 0.21–0.4 Fair, 0.0–0.2 Slight, <0.0 None [68].

Results

ELEAT diet and supplement modules

The dietary module is comprised of 46 food items and the supplement module asks about 23 supplement items (Supplementary Materials 9–10). In addition, items on consumption of caffeinated beverages from the Lifestyle Module were included because of their nutrient contributions, including caffeine, calories, calcium, fat, and protein. Rationale for each of the selected foods and these nutrients is provided on our web page: www.ELEAT.ucdavis.edu. A total of 120 women completed the ELEAT survey, and the majority, roughly 80%, of the surveys completed were from the long form survey. The average age of the mother at the time of the ELEAT survey was 38 years (± 4.8 years) (eTable 1). Mothers tended to be non-Hispanic White (59%) and Hispanic White (24%), born in California (65%), with at least some college education (91%). The majority of mothers owned their home (66%) and carried a private insurance (84%) at the time of birth. Nearly 70% of respondants felt "very sure" in their repsonses, while none of the responses noted feeling less that "somewhat sure." The average gestational age of the child was 6.6 months (± 3.9 months) at the time of the first EEQ/FFQ and 13.5 months (± 4.1 months) at the time of the second EEQ/FFQ. The average age of the child at the time of the ELEAT survey was 47 months (± 14.1 months) (eTable 1). The majority of children were male (64%) and typically developing (53%).

Reliability of foods

MARBLES FFQ dietary intakes were compared among 54 women who completed the ELEAT long form, including 12 who completed it online, and among 23 who completed the ELEAT short form. For most items that were on both the long and short forms, correlation between the ELEAT and the FFQ was modest to strong (Table 1).

By version

Correlations across most individual food items and categories were moderate, ranging from modest to strong on both the long and short ELEAT modules (Table 1). Correlations for food items on both forms was highest for soda, eggs, and fruit (r_s (95% CI): 0.60 (0.43,0.72), 0.57 (0.39,0.71), and 0.51 (0.31,0.66), respectively). On the long form, correlations were highest for tofu, dried beans, cold cereal, and rice (r_s (95% CI): 0.71 (0.53,0.82), 0.68 (0.50,0.80), 0.57 (0.35,0.73), and 0.57 (0.35,0.73), respectively). Deep fat fried foods had weak correlation on the long form (r_s (95% CI): 0.05 (−0.22, 0.32) (Table 1), but strong correation on the short form (r_s (95% CI): 0.63 (0.27,0.82)) (Table 1). Average correlation across foods on the short form (summary $r_s = 0.45$) was somewhat lower than across foods on the long version (summary $r_s = 0.52$).

By child age, parent concerns, and child clinical outcome

Correlations of individual foods and food groups differed somewhat by whether the child was greater or less than age 4 years at the time the mother completed the ELEAT, with higher correlations observed when the child was less than age 4, especially on the short form (eTable 2). Correlations for reported foods did not differ substantially by whether the mother had concerns about her child's development or behavior at the time she completed the ELEAT, compared to when she did not (eTable 3). There were some differences by the child's clinical classification at 36-months (eTable 4) with lower average correlations for mothers of children with other developmental concerns (summary $r_s = 0.23$) compared to mothers of children with ASD (summary $r_s = 0.47$) and mothers of typically developing children (summary $r_s = 0.45$). There were some differences by whether or not the mother was very sure of her responses (eTable 5) with lower average correlation for mothers who were somewhat sure or somewhat unsure of their answers (summary $r_s = 0.39$) compared to mothers who were very sure of their answers (summary $r_s = 0.48$).

Correlations between quantified dietary nutrient values

By version

Quantified nutrient values from the ELEAT long form had modest to moderate correlatations ($r_s = 0.24$–0.44; summary r_s (Q1, Q3) = 0.30 (0.26, 0.35)) with those quantified from the Block FFQ, and were moderately to very strongly correlated ($r_s = 0.37$–0.83; summary r_s (Q1, Q3) =0.56 (0.50, 0.58)) for nutrients from the online version (Table 2). More nutrients based on the short ELEAT module had only fair, weak or even inverse correlations with the FFQ; however primary nutrients of interest as well as niacin and magnesium displayed strong correlations: dietary folate equivalents, $r_s = 0.73$ (CI: 0.44, 0.87); iron, $r_s = 0.67$ (CI: 0.34, 0.84); fiber, $r_s = 0.60$ (CI: 0.24, 0.81); niacin $r_s = 0.80$ (CI: 0.56, 0.91); and $r_s = 0.57$ (CI: 0.19, 0.79) summary $r_s = 0.31$; Q1 0.10, Q3 0.55 (Table 2).

By child age, parent concerns, child clinical outcome, and quality index score

Correlations between the nutrient values for the ELEAT (all versions combined) and the Block FFQ nutrients were on average slightly stronger for mothers of children 4 years old or younger (summary $r_s = 0.31$) than for mothers of older children (summary $r_s = 0.39$) (eTable 6).

Table 1
Correlations between mean daily consumption of food items during pregnancy[a] collected retrospectively on the ELEAT long and short forms with the prospectively-collected Block Food Frequency Questionnaire (FFQ).

Category	Food	N	FFQ Median (Q1, Q3)	ELEAT Median (Q1, Q3)	r_s (95% CI)
ELEAT Food Items/Groups on Both Long and Short Forms					
Fruit	Fruit	74	0.82 (0.43, 1.25)	1.47 (0.87, 2.50)	0.47 (0.27, 0.63)
	Fruit [2]	73	1.21 (0.70, 2.01)	1.47 (0.87, 2.50)	0.51 (0.31, 0.66)
Juice	Juice	75	0.27 (0.12, 0.55)	0.40 (0.20, 0.53)	0.24 (0.01, 0.44)
Vegetables	Green Salad	75	0.13 (0.08, 0.27)	0.47 (0.20, 0.73)	0.48 (0.28, 0.63)
	Greens	74	0.03 (0.00, 0.07)	0.07 (0.00, 0.20)	0.36 (0.14, 0.54)
	Potatoes	76	0.08 (0.03, 0.13)	0.20 (0.12, 0.40)	0.48 (0.28, 0.63)
	Peas[b]	76	0.08 (0.03, 0.13)	0.03 (0.00, 0.07)	0.28 (0.05, 0.47)
	Other Veggies	73	0.68 (0.43, 1.30)	1.00 (0.47, 1.00)	0.45 (0.24, 0.61)
Proteins	Poultry	76	0.20 (0.11, 0.28)	0.47 (0.20, 0.47)	0.22 (−0.01, 0.42)
	Fish	77	0.06 (0.00, 0.10)	0.03 (0.00, 0.07)	0.46 (0.26, 0.61)
	Other Seafood	77	0.03 (0.00, 0.03)	0.00 (0.00, 0.03)	0.44 (0.23, 0.60)
	Red Meat	74	0.58 (0.39, 0.78)	0.20 (0.20, 0.47)	0.44 (0.23, 0.60)
	Eggs	75	0.12 (0.07, 0.27)	0.20 (0.20, 0.47)	0.57 (0.39, 0.71)
	Diet Shakes	76	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.43 (0.23, 0.60)
	Protein Bars	75	0.00 (0.00, 0.03)	0.00 (0.00, 0.00)	0.37 (0.15, 0.55)
Snacks	Soda	76	0.08 (0.03, 0.47)	0.07 (0.00, 0.20)	0.60 (0.43, 0.72)
	Sugary Drinks	75	0.06 (0.00, 0.20)	0.00 (0.00, 0.07)	0.24 (0.02, 0.45)
Summary r_s (Q1, Q3)					0.43 (0.36, 0.48)
ELEAT Long Form Food Items/Groups					
Dairy	Milk (original)	53	0.73 (0.22, 1.03)	0.20 (0.03, 1.00)	0.39 (0.14, 0.60)
	Milk (match)	52	0.73 (0.19, 1.03)	0.20 (0.07, 1.00)	0.54 (0.31, 0.71)
	Cheese	53	0.47 (0.27, 0.73)	0.73 (0.47, 1.00)	0.46 (0.21, 0.65)
	Yogurt	54	0.08 (0.03, 0.27)	0.20 (0.20, 0.47)	0.51 (0.28, 0.68)
Grains	Hot Cereal	53	0.08 (0.03, 0.13)	0.07 (0.03, 0.20)	0.49 (0.25, 0.67)
	Cold Cereal	53	0.13 (0.08, 0.47)	0.20 (0.07, 0.47)	0.57 (0.35, 0.73)
	Tortillas	53	0.03 (0.00, 0.08)	0.20 (0.07, 0.20)	0.48 (0.24, 0.66)
	Rice	53	0.13 (0.08, 0.27)	0.20 (0.20, 0.47)	0.57 (0.35, 0.73)
	Pasta	53	0.20 (0.12, 0.30)	0.20 (0.20, 0.47)	0.40 (0.14, 0.60)
	Breads	53	0.65 (0.42, 0.88)	0.73 (0.47, 1.07)	0.37 (0.10, 0.58)
Vegetable	Fries	54	0.08 (0.03, 0.13)	0.20 (0.07, 0.20)	0.52 (0.29, 0.69)
Legumes	Dried Beans	53	0.12 (0.07, 0.22)	0.07 (0.03, 0.20)	0.68 (0.50, 0.80)
	Nuts	54	0.03 (0.03, 0.13)	0.20 (0.03, 0.47)	0.44 (0.19, 0.63)
	Tofu	52	0.00 (0.00, 0.00)	0.00 (0.00, 0.00)	0.71 (0.53, 0.82)
Snacks	Sweets	54	0.44 (0.34, 0.68)	0.43 (0.27, 0.73)	0.28 (0.01, 0.51)
	Chips/ Popcorn	54	0.08 (0.03, 0.27)	0.22 (0.10, 0.40)	0.43 (0.18, 0.62)
	Deep Fried	54	0.17 (0.10, 0.25)	0.03 (0.00, 0.07)	0.05 (−0.22, 0.32)
Summary r_s (Q1, Q3)					0.52 (0.40, 0.54)
ELEAT Short Form Food Items/Groups					
Dairy	Dairy	23	1.28 (0.62, 1.87)	2.00 (1.00, 2.00)	0.41 (−0.01, 0.70)
Grains	Cold Cereal	23	0.27 (0.08, 0.73)	0.47 (0.20, 1.00)	0.73 (0.44, 0.88)
	Other Grains	23	1.05 (0.63, 1.57)	2.00 (1.00, 2.00)	−0.10 (−0.49, 0.33)
Snacks	Sweets	22	0.53 (0.34, 0.63)	0.47 (0.20, 0.73)	0.37 (−0.07, 0.68)
	Deep Fried	22	0.13 (0.08, 0.22)	0.07 (0.07, 0.20)	0.63 (0.27, 0.82)
Summary r_s (Q1, Q3)				0.45 (0.37, 0.63)	

FFQ = Prospectively collected Block Food Frequency Questionnaire; ELEAT = Early Life Exposures Assessment Tool Questionnaire; SD = Standard Deviation; r_S = Spearman Rank Correlation Coefficient; CI = Confidence Interval; [a] For ELEAT, average number of times per day consumed, for Block FFQ, average number of servings per day; [b] FFQ question included green beans and peas while ELEAT questions only included peas;
[c] Includes seasonal fruit questions from the FFQ.

Correlations between the nutrient values for the ELEAT (all versions combined) and the Block FFQ nutrients were on average stronger for mothers who had concerns about their child's development or behavior at the time they completed the ELEAT (summary r_s = 0.43) than for mothers who had no concerns (summary r_s = 0.33) (eTables 7). When compared by the child's 36-month clinical classification, average nutrient correlations were on average lower for children with ASD or developental concerns (summary r_s = 0.30) than for children with typical development (summary r_s = 0.42) (eTable 8). Correlations between the nutrient values for the ELEAT (all versions combined) and the Block FFQ nutrients were similar when limited to those with a high quality index score, 0.95 or above (eTable 9).

Reliability of information on vitamin and supplement intake

Vitamin and supplement questions in both MARBLES and the ELEAT were completed by 118 women. We evaluated reliability for vitamins/ supplements in questions that remained the same during the course of ELEAT survey revisions. The following supplements were assessed for reliability: prenatal vitamins, multivitamins, iron, folic acid, vitamin B12, vitamin C, vitamin D, calcium, and omega-3. The data were too sparse to compare vitamin B complex, vitamins B6, A, or E, zinc, or any herbal supplements. Overall, Kappas and Youden's J were fair to moderate for most supplements on whether or not they were taken anytime or in specific times during the index period (Table 3). Correlation across all vitamins/supplements for whether or not they were taken before or during pregnancy was moderate (summary J (Q1, Q3) = 0.39 (0.29, 0.47)) and was slightly higher for the period before pregnancy and second trimester than for other times (Table 3). Correlations tended to be lower for prenatal vitamins and multivitamins compared to nutrient-specific vitamin supplements, with the exception of vitamin B12, which was also low. The strongest correlation was observed for omega-3 + flaxseed (summary J (Q1, Q3) = 0.53 (0.52, 0.59)) and vitamin D (summary J (Q1, Q3) = 0.53 (0.45, 0.57)). Prenatal vitamin comparisons yielded fair correlation between the instruments (summary J (Q1, Q3) = 0.28 (0.23, 0.29)), with higher moderate correlation for the period before pregnancy (J (95% CI) = 0.46 (0.29, 0.63)). Responses to "did the prenatal vitamin contain iron?" showed only slight correlation (J = 0.08, 95%CI: −0.23, 0.38) with a composite Yes/No variable created using iron quantities from prenatal vitamins in the EEQs; a

Table 2
Correlation of nutrients calculated from foods collected retrospectively on the ELEAT long and short forms with nutrients calculated from foods collected prospectively on the Block Food Frequency Questionnaire (FFQ).

Nutrient	N	ELEAT Median (Q1, Q3)	FFQ Median (Q1, Q3)	r_s (95% CI)
ELEAT Long Form Version				
Energy (kcal)	42	1404.4 (1115.1, 1723.0)	1658.9 (1360.7, 1956.3)	0.29 (−0.02, 0.55)
Protein (g)	42	60.7 (51.4, 76.7)	64.0 (47.9, 78.9)	0.33 (0.03, 0.58)
Fat (g)	42	54.2 (41.4, 64.8)	65.1 (51.8, 84.0)	0.35 (0.05, 0.59)
Carbohydrates	42	175.9 (132.2, 230.5)	197.4 (159.8, 244.2)	0.24 (−0.07, 0.51)
Calcium (mg)	42	787.3 (557.0, 936.2)	814.2 (621.7, 1055.2)	0.44 (0.16, 0.66)
Iron (mg)	42	11.9 (8.7, 16.0)	12.4 (9.7, 15.8)	0.27 (−0.04, 0.53)
Potassium (mg)	42	1793.6 (1571.6, 2694.8)	2346.5 (1688.8, 2790.2)	0.40 (0.10, 0.62)
Thiamin	42	1.3 (0.9, 1.7)	1.4 (1.1, 1.6)	0.25 (−0.06, 0.51)
Niacin (mg)	42	17.3 (14.2, 20.9)	17.6 (12.7, 20.3)	0.24 (−0.07, 0.51)
Vitamin C (mg)	42	84.5 (71.9, 114.1)	94.6 (73.0, 136.2)	0.33 (0.02, 0.57)
Satur. Fatty Acids (g)	42	18.3 (14.5, 25.8)	20.6 (17.1, 27.8)	0.29 (−0.01, 0.55)
Fiber (g)	42	14.8 (11.9, 18.9)	16.5 (11.7, 20.3)	0.31 (0.00, 0.56)
DFE	42	467.6 (319.7, 721.1)	477.0 (340.4, 584.4)	0.26 (−0.05, 0.52)
Vitamin E (mg)	42	7.3 (5.8, 9.0)	7.2 (5.1, 8.5)	0.26 (−0.05, 0.52)
Magnesium (mg)	42	232.5 (186.6, 271.5)	265.2 (195.9, 312.3)	0.36 (0.06, 0.59)
Vitamin K (mcg)	42	141.9 (99.8, 215.8)	120.0 (68.6, 188.2)	0.38 (0.09, 0.61)
Omega-3	42	1.1 (0.9, 1.7)	1.3 (0.9, 1.6)	0.31 (0.00, 0.55)
Choline (mg)	42	249.4 (218.9, 389.8)	252.3 (168.4, 313.5)	0.31 (0.00, 0.56)
			Summary r_s (Q1 Q3):	0.30 (0.26, 0.35)
ELEAT Long Form Online Version				
Energy (kcal)	12	1521.5 (1108.7, 2211.9)	1616.4 (1229.2, 1791.8)	0.55 (−0.06, 0.85)
Protein (g)	12	67.2 (52.4, 112.8)	59.3 (38.9, 72.4)	0.55 (−0.07, 0.85)
Fat (g)	12	56.8 (38.7, 108.1)	60.2 (36.3, 85.5)	0.46 (−0.17, 0.81)
Carbohydrates	12	179.5 (134.6, 218.1)	198.3 (164.0, 226.0)	0.83 (0.47, 0.95)
Calcium (mg)	12	715.9 (581.8, 1134.3)	847.6 (606.4, 1085.5)	0.55 (−0.07, 0.85)
Iron (mg)	12	13.3 (9.0, 20.4)	11.8 (7.8, 14.6)	0.48 (−0.16, 0.82)
Potassium (mg)	12	1985.7 (1483.4, 2612.1)	2141.3 (1538.2, 2642.3)	0.66 (0.10, 0.89)
Thiamin	12	1.6 (1.1, 2.2)	1.3 (1.0, 1.6)	0.56 (−0.05, 0.85)
Niacin (mg)	12	22.5 (12.9, 26.0)	15.9 (13.1, 21.2)	0.57 (−0.03, 0.86)
Vitamin C (mg)	12	82.9 (53.6, 134.2)	88.4 (70.4, 186.2)	0.37 (−0.27, 0.77)
Satur. Fatty Acids (g)	12	21.2 (12.5, 41.3)	18.5 (11.1, 27.8)	0.50 (−0.13, 0.83)
Fiber (g)	12	15.2 (13.2, 20.8)	16.1 (12.1, 21.3)	0.50 (−0.13, 0.83)
DFE	12	585.3 (340.5, 861.0)	452.0 (366.0, 561.5)	0.56 (−0.05, 0.85)
Vitamin E (mg)	12	7.4 (5.0, 12.6)	7.2 (4.0, 8.7)	0.55 (−0.07, 0.85)
Magnesium (mg)	12	259.5 (229.8, 317.4)	261.6 (193.5, 352.2)	0.58 (−0.02, 0.86)
Vitamin K (mcg)	12	98.2 (74.5, 194.4)	137.9 (74.1, 167.4)	0.60 (0.01, 0.87)
Omega-3	12	1.0 (0.8, 1.7)	1.2 (0.6, 1.5)	0.61 (0.03, 0.87)
Choline (mg)	12	285.7 (196.2, 444.4)	222.0 (145.9, 288.5)	0.39 (−0.25, 0.78)
			Summary r_s (Q1 Q3):	0.56 (0.50, 0.58)
ELEAT Short Form Version				
Energy (kcal)	23	756.1 (627.2, 849.3)	1349.0 (1092.3, 1960.1)	0.12 (−0.31, 0.51)
Protein (g)	23	48.5 (38.8, 59.7)	49.8 (37.0, 68.8)	0.10 (−0.33, 0.49)
Fat (g)	23	49.5 (35.9, 59.4)	54.4 (40.5, 70.3)	−0.25 (−0.60, 0.18)
Carbohydrates	23	113.5 (86.8, 142.1)	189.6 (151.9, 260.3)	0.18 (−0.26, 0.55)
Calcium (mg)	23	738.3 (458.5, 874.0)	776.1 (595.6, 1074.5)	0.24 (−0.19, 0.59)
Iron (mg)	23	13.0 (9.2, 17.5)	10.5 (7.9, 14.7)	0.67 (0.34, 0.84)
Potassium (mg)	23	1004.7 (852.1, 1279.5)	1946.9 (1712.7, 2650.9)	0.41 (−0.01, 0.70)
Thiamin	23	1.8 (1.2, 2.1)	1.2 (0.9, 1.6)	0.44 (0.02, 0.72)
Niacin (mg)	23	16.4 (12.5, 21.2)	14.1 (10.5, 20.0)	0.80 (0.56, 0.91)
Vitamin C (mg)	23	83.2 (55.8, 112.2)	94.3 (66.1, 153.6)	0.37 (−0.05, 0.68)
Satur. Fatty Acids (g)	23	10.6 (8.6, 13.5)	15.2 (12.8, 22.2)	−0.11 (−0.49, 0.32)
Fiber (g)	23	8.0 (6.5, 12.1)	14.3 (8.9, 18.6)	0.60 (0.24, 0.81)
DFE	23	611.1 (305.8, 869.5)	427.2 (338.0, 577.2)	0.73 (0.44, 0.87)
Vitamin E (mg)	23	4.8 (3.0, 7.1)	5.7 (4.1, 7.8)	0.41 (−0.01, 0.70)
Magnesium (mg)	23	108.0 (87.8, 168.2)	222.4 (170.4, 312.8)	0.57 (0.19, 0.79)
Vitamin K (mcg)	23	108.4 (83.6, 148.8)	73.3 (60.7, 214.4)	0.48 (0.08, 0.74)
Omega-3	23	0.5 (0.4, 0.6)	1.1 (0.8, 1.3)	−0.16 (−0.53, 0.28)
Choline (mg)	23	184.3 (146.1, 229.9)	205.4 (170.8, 295.2)	0.09 (−0.34, 0.48)
			Summary r_s (Q1 Q3):	0.31 (0.10, 0.55)

FFQ = Prospectively collected Block Food Frequency Questionnaire; ELEAT = Early Life Exposures Assessment Tool Questionnaire; SD = Standard Deviation; r_S = Spearman Rank Correlation Coefficient; CI = Confidence Interval.

sizeable proportion (n = 21, 18%) of mothers were excluded because they reported ‘don’t know’ in the ELEAT for this question, plus the response was missing for another 6% (n = 7).

By child age, parent concerns, child diagnosis, and parent rating of confidence in their responses

Stratified analyses by child age at the time the ELEAT was completed, parent concerns about the child’s development, the child’s clinical classification, and the respondent’s confidence in their responses were not conducted for vitamin B12, vitamin C, and vitamin D because data were too sparse to produce reliable estimates.

No significant differences in correlations for supplement use were observed by child’s age, and average correlation across all supplements was similar across the index period for mothers of children under 4 years and mothers of children 4 years and over (eTable 10). Correlations for reported supplement use were overall similar across whether the parents had concerns about their child’s development at the time they

Table 3
Correlations between vitamin and supplement use collected retrospectively on the ELEAT with the prospectively collected Environmental Exposures Questionnaire (EEQ).

Item/Timing	N	$Y/Y_{(EEQ)}$	$Y/N_{(EEQ)}$	$N/Y_{(EEQ)}$	$N/N_{(EEQ)}$	κ (95% CI)	Se (95% CI)	Sp (95% CI)	J (95% CI)
Prenatal vitamins									
Anytime in index period	114	103	4	5	2	0.27 (−0.07, 0.60)	0.95 (0.90, 0.98)	0.33 (0.04, 0.78)	0.29 (−0.09, 0.67)
Before pregnancy	108	31	23	8	46	0.43 (0.26, 0.59)	0.79 (0.64, 0.91)	0.67 (0.54, 0.78)	0.46 (0.29, 0.63)
During pregnancy	114	103	4	5	2	0.27 (−0.07, 0.60)	0.95 (0.90, 0.98)	0.33 (0.04, 0.78)	0.29 (−0.09, 0.67)
1st trimester	113	92	11	6	4	0.24 (−0.01, 0.49)	0.94 (0.87, 0.98)	0.27 (0.08, 0.55)	0.21 (−0.02, 0.43)
2nd trimester	115	94	9	7	5	0.31 (0.05, 0.56)	0.93 (0.86, 0.97)	0.36 (0.13, 0.65)	0.29 (0.03, 0.54)
3rd trimester	114	88	12	10	4	0.16 (−0.07, 0.38)	0.9 (0.82, 0.95)	0.25 (0.07, 0.52)	0.15 (−0.07, 0.37)
With iron [a]	86	73	5	7	1	0.07 (−0.19, 0.33)	0.91 (0.83, 0.96)	0.17 (0.00, 0.64)	0.08 (−0.23, 0.38)
				[1]Summary κ (Q1, Q3)		0.28 (0.25, 0.30)		[1]Summary J (Q1, Q3)	0.28 (0.23, 0.29)
Multivitamins									
Anytime in index period	112	7	4	14	87	0.35 (0.13, 0.58)	0.33 (0.15, 0.57)	0.96 (0.89, 0.99)	0.29 (0.08, 0.50)
Before pregnancy	112	3	4	14	91	0.18 (−0.06, 0.41)	0.18 (0.04, 0.43)	0.96 (0.90, 0.99)	0.13 (−0.05, 0.32)
During pregnancy	112	5	5	13	89	0.27 (0.03, 0.51)	0.28 (0.10, 0.53)	0.95 (0.88, 0.99)	0.22 (0.01, 0.44)
1st trimester	113	4	5	13	91	0.23 (−0.01, 0.47)	0.24 (0.07, 0.50)	0.95 (0.88, 0.98)	0.18 (−0.02, 0.39)
2nd trimester	113	3	4	6	100	0.33 (0.01, 0.64)	0.33 (0.07, 0.70)	0.96 (0.90, 0.99)	0.29 (−0.02, 0.61)
3rd trimester	113	3	6	7	97	0.25 (−0.03, 0.54)	0.3 (0.07, 0.65)	0.94 (0.88, 0.98)	0.24 (−0.05, 0.53)
				Summary κ (Q1, Q3)		0.27 (0.24, 0.32)		Summary J (Q1, Q3)	0.23 (0.19, 0.28)
Iron									
Anytime in index period	111	14	14	10	73	0.4 (0.20, 0.60)	0.58 (0.37, 0.78)	0.84 (0.74, 0.91)	0.42 (0.21, 0.63)
Before pregnancy	102	3	1	4	94	0.52 (0.16, 0.89)	0.43 (0.10, 0.82)	0.99 (0.94, 0.99)	0.42 (0.05, 0.79)
During pregnancy	111	13	14	10	74	0.38 (0.18, 0.58)	0.57 (0.35, 0.77)	0.84 (0.75, 0.91)	0.41 (0.19, 0.62)
1st trimester	111	6	9	6	90	0.37 (0.11, 0.62)	0.5 (0.21, 0.79)	0.91 (0.83, 0.96)	0.41 (0.12, 0.70)
2nd trimester	112	8	13	5	86	0.38 (0.16, 0.61)	0.62 (0.32, 0.86)	0.87 (0.79, 0.93)	0.48 (0.21, 0.76)
3rd trimester	111	9	16	11	75	0.25 (0.04, 0.46)	0.45 (0.23, 0.68)	0.82 (0.73, 0.90)	0.27 (0.04, 0.51)
				Summary κ (Q1, Q3)		0.39 (0.37, 0.40)		Summary J (Q1, Q3)	0.40 (0.41, 0.42)
Folic acid									
Anytime in index period	107	7	14	6	80	0.31 (0.08, 0.54)	0.54 (0.25, 0.81)	0.85 (0.76, 0.92)	0.39 (0.11, 0.67)
Before pregnancy	102	3	7	2	90	0.36 (0.04, 0.68)	0.6 (0.15, 0.95)	0.93 (0.86, 0.97)	0.53 (0.10, 0.96)
During pregnancy	107	7	13	6	81	0.32 (0.09, 0.56)	0.54 (0.25, 0.81)	0.86 (0.78, 0.92)	0.4 (0.12, 0.68)
1st trimester	108	6	14	5	83	0.29 (0.06, 0.53)	0.55 (0.23, 0.83)	0.86 (0.77, 0.92)	0.4 (0.10, 0.70)
2nd trimester	108	6	12	2	88	0.4 (0.15, 0.65)	0.75 (0.35, 0.97)	0.88 (0.80, 0.94)	0.63 (0.32, 0.94)
3rd trimester	108	5	11	4	88	0.33 (0.07, 0.58)	0.56 (0.21, 0.86)	0.89 (0.81, 0.94)	0.44 (0.11, 0.77)
				Summary κ (Q1, Q3)		0.34 (0.31, 0.35)		Summary J (Q1, Q3)	0.47 (0.40, 0.51)
Vitamin B12									
Anytime in index period	109	2	6	5	96	0.21 (−0.10, 0.52)	0.29 (0.04, 0.71)	0.94 (0.88, 0.98)	0.23 (−0.11, 0.56)
Before pregnancy	108	2	3	3	100	0.37 (−0.03, 0.77)	0.4 (0.05, 0.85)	0.97 (0.92, 0.99)	0.37 (−0.06, 0.80)
During pregnancy	109	1	5	4	99	0.14 (−0.18, 0.46)	0.2 (0.01, 0.72)	0.95 (0.89, 0.98)	0.15 (−0.20, 0.50)
1st trimester	110	1	4	3	102	0.19 (−0.18, 0.56)	0.25 (0.01, 0.81)	0.96 (0.91, 0.99)	0.21 (−0.21, 0.64)
2nd trimester	110	1	5	2	102	0.19 (−0.17, 0.56)	0.33 (0.01, 0.91)	0.95 (0.89, 0.98)	0.29 (−0.25, 0.82)

(continued on next page)

Table 3 (*continued*)

Item/Timing	N	$Y/Y_{(EEQ)}$	$Y/N_{(EEQ)}$	$N/Y_{(EEQ)}$	$N/N_{(EEQ)}$	κ (95% CI)	Se (95% CI)	Sp (95% CI)	J (95% CI)
3rd trimester	110	1	5	3	101	0.16 (−0.18, 0.50)	0.25 (0.01, 0.81)	0.95 (0.89, 0.98)	0.2 (−0.22, 0.63)
				Summary κ (Q1, Q3)		0.21 (0.17, 0.21)		Summary J (Q1, Q3)	0.24 (0.20, 0.28)
Vitamin C									
Anytime in index period	107	5	9	4	89	0.37 (0.10, 0.64)	0.56 (0.21, 0.86)	0.91 (0.83, 0.96)	0.46 (0.13, 0.79)
Before pregnancy	106	3	7	2	94	0.36 (0.04, 0.68)	0.6 (0.15, 0.95)	0.93 (0.86, 0.97)	0.53 (0.10, 0.96)
During pregnancy	107	4	8	4	91	0.34 (0.05, 0.63)	0.5 (0.16, 0.84)	0.92 (0.85, 0.96)	0.42 (0.07, 0.77)
1st trimester	108	3	8	3	94	0.3 (0.00, 0.60)	0.5 (0.12, 0.88)	0.92 (0.85, 0.97)	0.42 (0.02, 0.83)
2nd trimester	108	1	9	2	96	0.12 (−0.15, 0.38)	0.33 (0.01, 0.91)	0.91 (0.84, 0.96)	0.25 (−0.29, 0.78)
3rd trimester	108	2	8	3	95	0.22 (−0.08, 0.52)	0.4 (0.05, 0.85)	0.92 (0.85, 0.97)	0.32 (−0.11, 0.75)
				Summary κ (Q1, Q3)		0.29 (0.24, 0.36)		Summary J (Q1, Q3)	0.40 (0.35, 0.45)
Vitamin D									
Anytime in index period	109	5	4	5	95	0.48 (0.19, 0.77)	0.5 (0.19, 0.81)	0.96 (0.90, 0.99)	0.46 (0.15, 0.77)
Before pregnancy	106	2	5	2	97	0.33 (−0.04, 0.70)	0.5 (0.07, 0.93)	0.95 (0.89, 0.98)	0.45 (−0.04, 0.94)
During pregnancy	109	5	4	4	96	0.52 (0.22, 0.81)	0.56 (0.21, 0.86)	0.96 (0.90, 0.99)	0.52 (0.19, 0.84)
1st trimester	110	5	4	4	96	0.55 (0.26, 0.85)	0.63 (0.24, 0.91)	0.96 (0.90, 0.99)	0.59 (0.19, 0.84)
2nd trimester	110	5	4	3	98	0.6 (0.30, 0.89)	0.71 (0.29, 0.96)	0.96 (0.90, 0.99)	0.68 (0.25, 0.92)
3rd trimester	110	5	4	2	99	0.39 (0.05, 0.73)	0.5 (0.12, 0.88)	0.95 (0.89, 0.98)	0.45 (0.34, 1.00)
				Summary κ (Q1, Q3)		0.48 (0.41, 0.54)		Summary J (Q1, Q3)	0.53 (0.45, 0.57)
Calcium									
Anytime in index period	109	17	11	13	68	0.44 (0.25, 0.62)	0.57 (0.37, 0.75)	0.86 (0.76, 0.93)	0.43 (0.23, 0.62)
Before pregnancy	103	5	5	3	90	0.51 (0.22, 0.81)	0.63 (0.24, 0.91)	0.95 (0.88, 0.98)	0.57 (0.23, 0.91)
During pregnancy	109	17	10	13	69	0.45 (0.27, 0.64)	0.57 (0.37, 0.75)	0.87 (0.78, 0.94)	0.44 (0.25, 0.63)
1st trimester	110	7	10	7	86	0.36 (0.12, 0.60)	0.5 (0.23, 0.77)	0.9 (0.82, 0.95)	0.4 (0.13, 0.66)
2nd trimester	111	9	13	12	77	0.28 (0.06, 0.49)	0.43 (0.22, 0.66)	0.86 (0.77, 0.92)	0.28 (0.06, 0.51)
3rd trimester	111	16	11	10	74	0.48 (0.29, 0.67)	0.62 (0.41, 0.80)	0.87 (0.78, 0.93)	0.49 (0.29, 0.69)
				Summary κ (Q1, Q3)		0.42 (0.38, 0.47)		Summary J (Q1, Q3)	0.44 (0.41, 0.48)
Omega-3 + Flaxseed									
Anytime in index period	109	26	8	12	63	0.59 (0.42, 0.75)	0.68 (0.51, 0.83)	0.89 (0.79, 0.95)	0.57 (0.41, 0.74)
Before pregnancy	109	6	14	7	82	0.26 (0.03, 0.49)	0.46 (0.19, 0.75)	0.85 (0.77, 0.92)	0.32 (0.04, 0.60)
During pregnancy	109	25	6	12	66	0.62 (0.46, 0.78)	0.68 (0.50, 0.82)	0.92 (0.83, 0.97)	0.59 (0.43, 0.76)
1st trimester	110	16	12	8	74	0.5 (0.31, 0.69)	0.67 (0.45, 0.84)	0.86 (0.77, 0.93)	0.53 (0.32, 0.73)
2nd trimester	111	19	13	9	70	0.5 (0.32, 0.68)	0.68 (0.48, 0.84)	0.84 (0.75, 0.91)	0.52 (0.33, 0.71)
3rd trimester	111	22	9	8	72	0.62 (0.45, 0.78)	0.73 (0.54, 0.88)	0.89 (0.80, 0.95)	0.62 (0.45, 0.79)
				Summary κ (Q1, Q3)		0.52 (0.50, 0.61)		Summary J (Q1, Q3)	0.53 (0.52, 0.59)
Average Correlation Across All Vitamin Supplements						**Summary κ** (Q1, Q3)			Summary J (Q1, Q3)
Anytime in index period						0.39 (0.31, 0.44)			0.40 (0.29, 0.46)
Before pregnancy						0.37 (0.33, 0.43)			0.43 (0.37, 0.53)
During pregnancy						0.38 (0.27, 0.45)			0.39 (0.29, 0.44)
1st trimester						0.34 (0.24, 0.37)			0.38 (0.21, 0.42)
2nd trimester						0.35 (0.28, 0.40)			0.43 (0.29, 0.52)

(*continued on next page*)

Table 3 (*continued*)

Item/Timing	N	$Y/Y_{(EEQ)}$	$Y/N_{(EEQ)}$	$N/Y_{(EEQ)}$	$N/N_{(EEQ)}$	κ (95% CI)	Se (95% CI)	Sp (95% CI)	J (95% CI)
3rd trimester						0.33 (0.22, 0.39)			0.36 (0.24, 0.45)

EEQ = Prospectively collected Environmental Exposure Questionnaire; ELEAT = Early Life Exposures Assessment Tool Questionnaire; $Y/Y_{(EEQ)}$ = Yes response in ELEAT and Yes response in EEQ; κ = Kappa Coefficient; Se = sensitivity; Sp = specificity; J = Youden's J statistic; CI = Confidence Interval; [a] Summary κ and J (Q1, Q3) for prenatal vitamins excluded the question on whether or not they contained iron.

completed ELEAT. Significant differences by parent concerns only tended to arise when data was sparse (prenatal vitamins and folic acid) and the pattern for which group had stronger correlations was inconsistent across supplements (eTable 11). The data for prenatal vitamins and vitamin B12 became sparse when stratified by clinical classification (i.e., marginal totals <5 for one or more rows/columns). There was some evidence for slightly greater correlations for responses on supplement use before pregnancy for mothers of children with typical development (eTable 12). The correlations by Kappa were slightly higher in the mothers who reported being 'very sure' of their responses compared with those that reported being 'somewhat sure' for most supplements (eTable 13). Correlations by Youden's J were similar for the index period, but differed by before or during pregnancy across confidence in responses. Data was sparse for vitamins B12 and C.

Correlations of nutrient values quantified from vitamins and supplements

Mean values and correlations between nutrient values calculated from vitamins and supplements reported on the retrospective ELEAT and prospective EEQs varied by timing (Table 4), with moderate correlations overall (summary r_s (Q1, Q3) = 0.34 (0.26, 0.45)). Most nutrients were moderately correlated before pregnancy, with a higher summary r_s than for other periods r_s (Q1, Q3) = 0.43 (0.40, 0.46)). During pregnancy the correlations were generally modest to moderate with the exceptions of weak correlations during the first trimester for vitamin E and zinc, and strong correlations for omega-3 in all trimesters. Folic acid, vitamin D, and omega-3 were the most highly and consistently correlated among the nutrients calculated from vitamin and supplement intake.

By child age, parent concerns, child diagnosis, and parent rating of confidence in their responses

More moderate correlations for mothers interviewed when the child was <4 years old compared to those interviewed when the child was 4 or older were found only for supplemental nutrients in the second and third trimesters (eTable 14). Those with no parental concerns and typical development had weak to moderate correlations before and throughout pregnancy, while those with parental concerns and developmental concerns had moderate to strong correlations before and throughout pregnancy (eTables 15–16). Correlations were higher for mothers self-described as somewhat certain in their response compared to those with high certainty in their response for nutrients during pregnancy but not before (eTable 17).

Comments

Principle findings

Few studies have tested the reliability of a short dietary assessment tool aimed at measuring nutrient intake relevant for pregnancy and neurodevelopment. Nutrient values quantified using the ELEAT were on average lower than that of the Block FFQ as expected given fewer food items. Nutrient values in this population from the Block FFQ also tended to be lower than that reported for other populations [69]. Average summary correlations between the Block FFQ and the ELEAT FFQ food items (r_s = 0.36), dietary nutrients (r_s = 0.42), vitamin/supplement intake (J = 0.39), and supplemental nutrients (r_s = 0.34) were fair to moderate overall, and generally lower than those reported in most previous reliability studies of FFQs in women which typically range from 0.4 to 0.7 [69–76]. There are several potential explanations for lower correlations including the fact that in this study, we were not directly measuring reliability of the same instrument but rather compared different FFQs administered at different time points, and although many of the food items were comparable, the questions were not asked in exactly the same way, sometimes differed on foods listed as examples or grouped together, and included different frequency responses. In addition, we asked about pregnancy on the ELEAT, whereas the Block FFQs we compared to asked about intake in the first and second halves of pregnancy, which were then averaged (for those who completed FFQs for both halves). Furthermore, the ELEAT asked about retrospective diet for a period that occurred on average several years prior, and the period of recall was much longer than assessed in previous studies that asked about recent diet two [69] to six months [70] apart; correlations across different instruments in studies with periods of recall up to a year [71,73] were lower (0.25–0.5) and closer to the range in our study.

The correlations of the ELEAT long and short versions were similarly moderate for dietary items represented on both, but the long form covered many more foods. Correlations of nutrient values with the prospective FFQ were also similar overall across the long and short ELEAT versions with similarly moderate summary coefficients; however the correlations for individual nutrients varied greatly across versions with the short version having much weaker correlations for macronutrients and certain other nutrients and much stronger correlations for the focus nutrients (folate, iron, fiber). This suggests that if one is seeking a better tool for overall dietary and nutrient intake, the long version would be preferred, but if one is primarily interested in a few key foods and nutrients important in pregnancy for neurodevelopment, then using the shorter version might be preferred. Given potential importance of additional nutrients (vitamin C, omega-3 fatty acids, choline), the short version would need to modified to better capture other relevant nutrients. Correlation regarding frequency of foods consumed was not higher on average for mothers recalling over shorter periods (4 years or less) compared to those recalling over longer periods (>4 years) as would be expected; however, the correlation of calculated nutrients from the retrospective ELEAT with the nutrients calculated from the prospective FFQ was higher for mothers recalling for shorter periods. This suggests that length of recall has an impact on recall accuracy of certain foods (for example, green salad, greens, cold cereal) that contribute to key nutrients relevant in pregnancy (e.g., folate, iron). Similarly, there were no consistent or strong differences in correlations for foods consumed when stratified by whether or not the parent had concerns about their child's development at the time they recalled their pregnancy diet, but there was higher correlation of calculated nutrients when parents reported concerns, suggesting some evidence for differential recall accuracy in the expected direction.

For both food consumption and calculated nutrients, there were no differences in average correlations by the clinical classification of the child as having ASD or typical development; however, there were weaker correlations for mothers of children clinically classified as having other developmental concerns.

Vitamin and supplement frequencies reported retrospectively on the ELEAT Module S showed higher average correlations with the prospectively-collected responses for single vitamin supplements than for multivitamins and prenatal vitamins, and varied somewhat inconsistently by timing. On the other hand, correlations with calculated

Table 4
Nutrients from supplements reliability analyses of ELEAT by timing.

Nutrient	N	EEQ Median (Q1, Q3)	ELEAT Median (Q1, Q3)	Maximum (EEQ)/(ELEAT)	r_s (95% CI)
Before Pregnancy					
FA (mcg)	87	0.0 (0.0, 800.0)	0.0 (0.0, 800.0)	1800/2200	0.47 (0.29, 0.62)
FE (mg)	95	0.0 (0.0, 18.0)	0.0 (0.0, 28.0)	151/114	0.49 (0.32, 0.63)
Vit D (IU)	81	0.0 (0.0, 400.0)	100.0 (0.0, 400.0)	22,229/4200	0.42 (0.23, 0.59)
Calcium (mg)	86	0.0 (0.0, 200.0)	0.0 (0.0, 200.0)	2000/1254	0.39 (0.20, 0.56)
VitB12 (ug)	90	0.0 (0.0, 8.0)	0.0 (0.0, 8.0)	2003/520	0.39 (0.20, 0.55)
VitB6 (mg)	94	0.0 (0.0, 2.6)	0.0 (0.0, 2.6)	102/7	0.43 (0.25, 0.58)
VitA (IU)	94	0.0 (0.0, 2800.0)	0.0 (0.0, 4000.0)	8250/10424	0.40 (0.21, 0.55)
VitE (IU)	88	0.0 (0.0, 20.0)	3.6 (0.0, 30.0)	400/160	0.44 (0.25, 0.59)
VitC (mg)	88	0.0 (0.0, 80.0)	3.6 (0.0, 120.0)	1000/370	0.51 (0.34, 0.65)
Zinc (mg)	94	0.0 (0.0, 10.0)	0.0 (0.0, 20.0)	29/44	0.44 (0.26, 0.59)
Omega3 (mg)	106	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	7700/1230	0.36 (0.18, 0.51)
			Summary r_s (Q1, Q3)	0.43 (0.40, 0.46)	
Trimester 1					
FA (mcg)	105	666.7 (266.7, 800.0)	800.0 (800.0, 800.0)	3200/2200	0.22 (0.03, 0.40)
FE (mg)	108	18.7 (9.3, 28.0)	28.0 (4.5, 28.0)	179/114	0.26 (0.07, 0.43)
Vit D (IU)	102	400.0 (170.0, 428.6)	400.0 (400.0, 500.0)	22,529/4200	0.43 (0.25, 0.57)
Calcium (mg)	106	200.0 (66.7, 250.0)	200.0 (200.0, 200.0)	2000/1254	0.18 (−0.01, 0.36)
VitB12 (ug)	106	5.3 (2.7, 8.7)	8.0 (8.0, 8.0)	2003/520	0.25 (0.06, 0.42)
VitB6 (mg)	110	2.6 (1.7, 6.7)	2.6 (2.6, 2.6)	102/6.6	0.33 (0.16, 0.49)
VitA (IU)	110	2916.7 (1333.3, 4000.0)	4000.0 (4000.0, 4000.0)	8250/10424	0.10 (−0.09, 0.28)
VitE (IU)	103	20.0 (10.0, 30.0)	30.0 (30.0, 35.0)	297/160	0.09 (−0.11, 0.28)
VitC (mg)	103	80.0 (39.4, 120.0)	120.0 (120.0, 122.1)	853/370	0.21 (0.02, 0.39)
Zinc (mg)	110	15.0 (6.7, 25.0)	20.0 (20.0, 20.0)	27/44	0.04 (−0.14, 0.23)
Omega3 (mg)	107	0.0 (0.0, 178.0)	0.0 (0.0, 0.0)	5415/1230	0.57 (0.43, 0.69)
			Summary r_s (Q1, Q3)	0.25 (0.14, 0.30)	
Trimester 2					
FA (mcg)	106	800.0 (533.3, 800.0)	800.0 (800.0, 800.0)	4800/3000	0.43 (0.26, 0.58)
FE (mg)	108	27.0 (10.7, 28.0)	28.0 (3.6, 28.0)	179/156	0.30 (0.11, 0.46)
Vit D (IU)	101	400.0 (200.0, 400.0)	400.0 (400.0, 514.3)	22,679/4200	0.35 (0.16, 0.51)
Calcium (mg)	106	200.0 (100.0, 250.0)	200.0 (200.0, 200.0)	2700/1614	0.32 (0.14, 0.48)
VitB12 (ug)	107	8.0 (2.7, 12.0)	8.0 (8.0, 8.0)	2155/520	0.28 (0.10, 0.45)
VitB6 (mg)	111	2.6 (1.7, 10.0)	2.6 (2.6, 2.6)	101/9	0.39 (0.22, 0.56)
VitA (IU)	111	4000.0 (333.3, 4, 000.0)	4000.0 (4000.0, 4000.0)	20,000/14424	0.24 (0.05, 0.41)
VitE (IU)	103	30.0 (11.0, 30.0)	30.0 (30.0, 35.0)	273/180	0.20 (0.01, 0.38)
VitC (mg)	103	100.0 (51.4, 120.0)	120.0 (120.0, 122.1)	902/480	0.26 (0.07, 0.43)
Zinc (mg)	111	16.7 (7.5, 25.0)	20.0 (20.0, 20.0)	36/64	0.22 (0.03, 0.39)
Omega3 (mg)	106	0.0 (0.0, 267.0)	0.0 (0.0, 87.9)	7700/1230	0.52 (0.37, 0.65)
			Summary r_s (Q1, Q3)	0.32 (0.25, 0.37)	
Trimester 3					
FA (mcg)	100	800.0 (304.8, 928.0)	800.0 (800.0, 800.0)	9133/3000	0.42 (0.25, 0.57)
FE (mg)	102	27.0 (8.0, 28.0)	28.0 (12.0, 28.0)	208/156	0.37 (0.18, 0.52)
Vit D (IU)	95	400.0 (170.0, 466.7)	400.0 (400.0, 728.6)	3000/4200	0.40 (0.21, 0.56)
Calcium (mg)	99	200.0 (66.7, 250.0)	200.0 (200.0, 342.9)	3200/1614	0.39 (0.21, 0.54)
VitB12 (ug)	101	8.0 (2.5, 12.0)	8.0 (8.0, 8.0)	2155/520	0.35 (0.17, 0.51)
VitB6 (mg)	105	2.6 (1.6, 14.1)	2.6 (2.6, 2.6)	135/9	0.27 (0.09, 0.44)
VitA (IU)	105	3, 952.4 (1, 333.3, 4000.0)	4, 000.0 (4, 000.0, 4000.0)	15,000/14424	0.33 (0.15, 0.49)
VitE (IU)	98	28.6 (8.6, 30.0)	30.0 (30.0, 35.0)	250/180	0.33 (0.14, 0.49)
VitC (mg)	98	100.0 (34.3, 120.0)	120.0 (120.0, 120.0)	902/480	0.19 (−0.01, 0.37)
Zinc (mg)	105	16.7 (7.1, 25.0)	20.0 (20.0, 20.0)	36/64	0.25 (0.06, 0.42)
Omega3 (mg)	100	0.0 (0.0, 271.8)	0.0 (0.0, 43.9)	7700/1230	0.55 (0.40, 0.68)
			Summary r_s (Q1, Q3)	0.35 (0.30, 0.39)	
Across All Time Periods				**Summary r_s (Q1, Q3)**	

(continued on next page)

Table 4 (*continued*)

Nutrient	N	EEQ Median (Q1, Q3)	ELEAT Median (Q1, Q3)	Maximum (EEQ)/ (ELEAT)	r_s (95% CI)
FA (mcg)					0.39 (0.37, 0.44)
FE (mg)					0.36 (0.29, 0.40)
Vit D (IU)					0.40 (0.39, 0.42)
Calcium (mg)					0.32 (0.29, 0.39)
VitB12 (ug)					0.32 (0.27, 0.36)
VitB6 (mg)					0.36 (0.32, 0.40)
VitA (IU)					0.27 (0.21, 0.35)
VitE (IU)					0.27 (0.17, 0.36)
VitC (mg)					0.30 (0.21, 0.32)
Zinc (mg)					0.24 (0.18, 0.30)
Omega3 (mg)					0.50 (0.48, 0.56)
				Summary r_s (Q1, Q3)	0.34 (0.26, 0.45)

EEQ = Prospectively collected Environmental Exposure Questionnaire; ELEAT = Early Life Exposures Assessment Tool Questionnaire; IQR = Interquartile Range; r_S = Spearman Rank Correlation Coefficient; CI = Confidence Interval.

nutrient values for before pregnancy were moderate, while correlations during each trimester and across pregnancy were lower on average, ranging from modest to strong for omega 3. This could be due to more accurate reporting of supplements taken specifically as part of pregnancy planning and/or due to higher regularity of taking supplements before pregnancy and variability of consistency and amount of supplements at different stages of pregnancy. No meaningful differences in correlation of supplement use were observed by recall period, parent concerns, clinical classification, or participant confidence in their responses, but there were higher correlations of calculated nutrients when there were parent and clinical concerns, again indicating differential accuracy of reporting.

Study limitations and strengths

Limitations were that the ELEAT Module D included ELEAT questions that were not directly comparable for item-specific reliability with the FFQ and Module S had different formats for asking about frequency when compared to the EEQ. There was a small sample size when evaluating different subpopulations, especially when considering by version. Further, the sample size was insufficient to evaluate item level reliability in terms of frequency of consumption. Findings might not be generalizable to other populations that are not primarily white, born in California, college-educated, and have a child with autism. Further, nutrients that were not prioritized based on the literature at the time the ELEAT was developed and are later found to be important for neurodevelopment might or might not be captured with this tool.

Strengths included the collection of parent reported concerns for the child, and the ability to obtain the child's clinical diagnosis at the time of ELEAT administration to evaluate potential for recall bias.

Interpretation

Responses on the ELEAT long form dietary and supplement modules were modestly to moderately reliable overall, even with recall after several years, and produced values for certain key nutrients that were moderately correlated to previously collected prospective measures. As with all FFQs, the ELEAT dietary module is not meant to assess exact nutrient intake for each participant, but rather can be used to rank participants on their responses in terms of food group intake, calcium, iron, folate, potassium, fiber, choline, vitamin K and vitamin C intake. It could also be used to assess presence or absence of supplement use before and during pregnancy. While other FFQs like the Block FFQ [23] and the National Cancer Institute's Dietary History Questionnaire [22,24] include a broader range of foods and nutrients, they are much more time consuming to complete, not designed specifically for pregnancy, and have not been assessed for retrospective use for periods up to years later. Other FFQs that were designed and assessed for retrospective use for the prenatal period years later are also longer [77], not designed for self-report [34], designed for specific cultural diets [34,78,79], or not designed to measure micronutrients relevant to neurodevelopment [78]. This relatively short instrument could be useful in studies of pregnancy and neurodevelopment when participant burden is a concern, prospective dietary/supplement information was not collected, and measures of neurodevelopmentally-relevant nutrients are of interest.

Conclusions

The ELEAT dietary and supplement modules are moderately reliable for recall up to several years after pregnancy for most neurodevelopmentally-relevant nutrients, and can be added to autism studies to retrospectively assess maternal nutrient contributions to ASD etiology.

CRediT authorship contribution statement

Rebecca J. Schmidt: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Amanda J. Goodrich:** Writing – review & editing, Validation, Formal analysis, Data curation. **Lauren Granillo:** Writing – review & editing, Validation, Formal analysis, Data curation. **Yunru Huang:** Writing – review & editing, Visualization, Validation, Formal analysis, Data curation. **Paula Krakowiak:** Writing – review & editing, Visualization, Formal analysis, Data curation. **Adrianne Widaman:** Writing – review & editing, Visualization, Formal analysis, Data curation. **J. Erin Dienes:** Writing – review & editing, Visualization, Formal analysis, Data curation. **Deborah H. Bennett:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Cheryl K. Walker:** Writing – review & editing, Supervision, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Daniel J. Tancredi:** Writing – review & editing, Supervision, Methodology, Formal analysis.

Declaration of competing interest

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Excellence in Autism and Developmental Disorders, St. John's Research Institute (Mar 2023) and the Organization of Teratology Information Specialists (OTIS, June 2023). Dr. Schmidt has received funding for consultation services for Beasley Allen Law Firm and Linus Biotechnology, Inc. Dr. Bennett has received funding for consultation services for Linus Biotechnology, Inc. No other authors declare potential competing interests.

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Appendix A. Supplementary data

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