Public Health Nutrition: 12(8), 1276–1283 doi:10.1017/S1368980008003881

# Maternal cereal consumption and adequacy of micronutrient intake in the periconceptional period

Meredith Snook Parrott[1,2], Lisa M Bodnar[1,2,3,*], Hyagriv N Simhan[1,2], Gail Harger[3], Nina Markovic[3] and James M Roberts[1,2,3]
[1]Magee-Womens Research Institute, Pittsburgh, PA, USA: [2]Departments of Obstetrics and Gynecology and Reproductive Sciences, University of Pittsburgh, Pittsburgh, PA, USA: [3]Department of Epidemiology, University of Pittsburgh, A742 Crabtree Hall, 130 DeSoto Street, Pittsburgh, PA 15261, USA

Submitted 22 February 2008: Accepted 15 September 2008: First published online 10 November 2008

## Abstract

*Objective:* To assess the adequacy of periconceptional intake of key micronutrients for perinatal health in relation to regular cereal consumption of pregnant women.
*Design, setting and subjects:* Low-income pregnant women (*n* 596) in Pittsburgh, Pennsylvania, USA, who enrolled in a cohort study at <20 weeks' gestation. These women reported usual dietary intake in the three months around conception on an FFQ. Cereal consumers were women who reported consuming any dry cereal at least three times per week. High risk for nutrient inadequacy was defined as intake less than the Estimated Average Requirement.
*Results:* About 31 % of the women regularly consumed cereal. After adjusting for energy intake, race/ethnicity, marital status, breakfast consumption and supplement use, cereal eaters had significantly higher intakes of folate, Fe, Zn, Ca, fibre and vitamins A, C, D and E (all $P < 0\cdot01$) and were approximately two to six times more likely to have intakes in the highest third of the distribution for folate, Fe, Zn, Ca, vitamins A and D, and fibre (all $P < 0\cdot01$) than cereal non-eaters. Cereal consumption was also associated with reductions of 65–90 % in the risk of nutrient inadequacies compared with non-consumption (all $P < 0\cdot01$).
*Conclusions:* Encouraging cereal consumption may be a simple, safe and inexpensive nutrition intervention that could optimize periconceptional intake for successful placental and fetal development.

**Keywords**
Cereal
Diet
Periconception
Pregnancy

The periconceptional period represents a specific stage in a woman's life in which adequate nutrient intake is especially important for both her and her fetus. Optimal pregnancy outcomes rely on successful implantation and early placental and fetal development. Such physiological processes involve remodelling of the maternal arteries underlying the placenta, extensive cell division and differentiation, and well-regulated responses to increases in inflammation and generation of reactive oxygen species – all of which may be influenced by maternal nutritional status[1–3]. Not surprisingly, inadequate periconceptional nutrition is associated with pregnancy complications such as congenital abnormalities[4], preterm birth[5], fetal growth restriction[6,7] and pre-eclampsia[8]. Thus, ensuring that women receive adequate nutrition around the time of conception is essential. Nevertheless, many US women of reproductive age are at high risk of nutrient inadequacies[9,10].

The consumption of ready-to-eat breakfast cereals may help women meet the high nutrient requirements of pregnancy. Among non-pregnant individuals, breakfast eaters are less likely than breakfast skippers to have nutrient inadequacies[11–13], in part because of the typical intake of ready-to-eat breakfast cereals in the morning meal. Many ready-to-eat cereals are fortified with key nutrients, such as folic acid, Fe, Zn, Ca and vitamins A, C and D, all of which are linked to successful placental and fetal development. Among US adults, cereal is the top food source of folate, Fe and vitamin $B_6$ and is among the top ten food sources for many other micronutrients[14], trends also observed in pregnant women[15]. In fact, micronutrient fortification of cereals makes significant contributions to overall daily intakes, with a higher contribution in women than in men[16]. Indeed, children and non-pregnant adults who consume cereal regularly have higher intakes of most vitamins and minerals[11,12,16–20] and lower prevalences of nutrient inadequacy than those who do not consume cereal[11,13,16,19,20]. Despite the importance of maternal micronutrient status around the time of conception, cereal intake has not been explored in relation to nutrient adequacy in pregnant

*Corresponding author: Email bodnar@edc.pitt.edu

women. As nutrient needs increase dramatically during pregnancy[21] and food preferences may change, studying the association between cereal intake and nutrient adequacy specifically during this stage of the woman's life cycle is important.

Our objective was to assess the adequacy of periconceptional intake of key micronutrients for perinatal health in relation to regular cereal consumption. We hypothesized that pregnant women who ate cereal regularly in the periconceptional period would have higher absolute nutrient intakes and lower risk of nutrient inadequacies compared with women who did not eat cereal regularly.

## Methods

Data came from two pregnancy cohort studies conducted at Magee-Womens Hospital in Pittsburgh, Pennsylvania, USA, from 2003 to 2005. The studies were designed to explore the effects of nutrition and other maternal factors on pregnancy outcomes. Both studies enrolled women at <20 weeks' gestation (mean 17·6 (SD 3·9) weeks). Eligible women were aged 14 to 50 years, carrying singleton pregnancies, planning to deliver at Magee-Womens Hospital and without history of diabetes, hypertension, autoimmune disease or other pre-existing medical conditions. After providing informed, written consent, subjects in both studies completed an interviewer-administered questionnaire at enrolment to collect data on sociodemographics, medical history and health behaviours, including smoking, physical activity and television watching. At enrolment, women completed a self-administered FFQ assessing periconceptional dietary intake, supplement use and meal patterns (discussed below). The University of Pittsburgh Institutional Review Boards approved these studies. A total of 596 out of 829 (72 %) women had complete dietary data and were available for the current analysis.

### *Dietary assessment*

Periconceptional dietary intake was assessed using a modified Block98 FFQ (approximately 120 food/beverage items)[22,23]. The questionnaire asks about usual dietary intake in the one month before and two months after conception. The food list for this questionnaire was developed from the dietary recall data of the third National Health and Nutrition Examination Survey. An individual portion size is asked for each food and pictures are provided to enhance accuracy of quantification. The FFQ has been validated in numerous samples[24–26] and is currently being validated in our own population. Slight modifications were made to the questionnaire to include a more extensive list of fish and seafood items, to focus on a three-month time period and to be specific for pregnancy. Because this FFQ is semi-quantitative, it provides a projection of the amount of nutrients consumed. The questionnaire also included an assessment of the type and frequency of dietary supplements used in the periconceptional period.

Questionnaires were sent to Block Dietary Data Systems (Berkeley, CA, USA) for optical scanning and nutrient analysis using software originally developed at the National Cancer Institute. The software used for nutrient analysis produces estimates of usual intake for a wide array of nutrients. It calculates the frequency of daily intake and total daily grams of food consumed for each food item, and provides the gram weight for each serving size. Nutrient values were calculated by multiplying the nutrient content of the food by the gram weight and frequency, and summing across all food items. The nutrient values were updated based on the US Department of Agriculture (USDA) 1994–1996 Continuing Survey of Food Intake by Individuals for women aged 19–44 years and updated folate values for fortified foods from the USDA Nutrient Database for Standard Reference, Release 12 (USDA Agricultural Research Service, Beltsville, MD, USA). Folate values were adjusted for increased bioavailability of fortified folate. For foods without added folic acid, micrograms of dietary folate equivalents (DFE) were equal to the micrograms of naturally occurring food folate. For foods with added folic acid, DFE were calculated using the following formula[27]: micrograms of naturally occurring food folate + (micrograms of added folic acid × 1·7).

The FFQ included three dry cereal line items: high-fibre cereals, highly fortified cereals and all other dry cereals. We summed the frequency reported for each cereal line item to obtain an overall frequency of any ready-to-eat cereal in the periconceptional period. We classified women as regular cereal eaters if they reported consuming cereal at least three times per week at any point throughout the day.

Women were defined as being at high risk for nutrient inadequacy if their nutrient intake was less than the Estimated Average Requirement (EAR) for pregnant women. The EAR is one of the Dietary Reference Intakes used to assess adequacy of a population's intake[28]. The EAR is the average daily nutrient intake to meet the requirements of half the healthy individuals for the specific life stage and gender group. We elected to assess periconceptional diets relative to the EAR for pregnant women because our definition of the three periconceptional months included two postconception months and one preconception month (a time when women should be preparing for pregnancy). To assess the likelihood of inadequacy for Fe, we used the cut-point approach rather than the full probability approach[29]. Too few data were available for the Institute of Medicine to simulate an Fe requirement distribution for pregnant and lactating women. Because pregnant women have no menstrual losses, it is assumed that the requirements are normally distributed around the EAR (S. Murphy, personal communication, 2008). An EAR has not yet been established for Ca and vitamin D[30], so we did not calculate the risk of nutrient inadequacy for these micronutrients.

### Covariates

Intake of breakfast was determined using a diet pattern questionnaire, which assessed the number, type and timing of meals and snacks consumed in a typical week around conception[31]. The interpretation of what constituted a meal or snack was left up to the participants' discretion. We defined breakfast consumption as a self-reported breakfast meal.

Sociodemographic and behavioural covariate information was acquired through interview-based self-report. Education (<12 years, 12 years, >12 years), pre-pregnancy smoking status (smoker, non-smoker), martial status (married, unmarried) and parity (0, 1 or more) were available. Race/ethnicity was self-reported and subsequently categorized as black or non-black because few women reported races other than black or white. Pre-pregnancy BMI (weight (kg)/height (m)$^2$) was calculated from maternal self-report of pre-pregnancy weight and height measurement at initial visit. Women were asked to categorize their usual amount of time spent watching television in the year before the index pregnancy as 0–1, 2–3 or ≥4 h/d. At enrolment, subjects also self-reported their use of multivitamins or prenatal vitamins in the periconceptional period. Periconceptional supplement users were women who reported using a prenatal vitamin or multivitamin at least once per month in the three months around conception.

### Statistical analysis

We compared maternal characteristics by cereal intake using Pearson $\chi^2$ statistics. Multivariable linear regression was used to assess differences in mean nutrient intake by cereal use after adjustment for confounders. Nutrients were log-transformed because nutrient intake was highly skewed. Mean micronutrient and fibre intakes were energy-adjusted by dividing the total amount of the nutrient by the number of calories, and then multiplying by 2000. These nutrient density values were then divided into thirds based on tertiles. We used $\chi^2$ tests to compare the distribution of cereal eaters and cereal non-eaters among tertiles of nutrient intake. We then used multivariable logistic regression to assess the independent association between cereal intake and the odds of being in the upper tertile of nutrient intake compared with the lower two tertiles. Finally, we calculated the proportion of women who consumed less than the EAR for each micronutrient and used logistic regression to determine the odds of micronutrient inadequacy by regular cereal use. We also performed the aforementioned analyses excluding nineteen women who reported regular consumption of highly fortified cereals to ensure that the results were not driven by their intakes.

We fit parsimonious regression models by specifying a full model with potential confounding variables (energy intake, breakfast consumption, maternal age, race/ethnicity, parity, education, marital status, smoking, pre-pregnancy BMI, supplement use, pre-pregnancy television watching). Potential confounders were considered to not be influential and were removed from the model if their inclusion did not satisfy our a priori change-in-estimate criterion (a change in the coefficient of >10 %).

## Results

About 31 % of women regularly consumed cereal. Cereal eaters were more likely than cereal non-eaters to be married, multiparous and users of dietary supplements (Table 1). Cereal users also tended to be leaner and more likely to consume a breakfast meal compared with cereal non-users, although not statistically significant.

Energy intake was significantly greater among cereal eaters than cereal non-eaters (Table 2). After adjusting for energy intake, race/ethnicity, marital status, breakfast consumption and supplement use, women who regularly consumed cereal had significantly higher mean intakes of folate, Fe, Zn, Ca, vitamins A, C, D and E, and fibre (all $P < 0{\cdot}01$; Table 2). Nutrient intakes were 14–83 % greater among users than non-users.

Compared with women who did not consume cereal regularly, regular consumers were significantly more likely to have folate, Fe, Zn, Ca, vitamin A, vitamin D and fibre intakes in the highest third of the distribution (Table 3). Notably, regular cereal consumers were about five and six times more likely to be in the highest tertile of periconceptional folate and Fe intake, respectively, than non-consumers after confounder adjustment.

Compared with cereal users, a significantly higher proportion of non-users of cereal failed to achieve the EAR for folate, Fe, Zn and vitamins A, C and E (all $P < 0{\cdot}001$; Table 4), and were therefore at high risk of nutrient inadequacy. For instance, about 27 % of cereal users and 71 % of non-users had folate intakes less than the EAR. After adjusting for energy intake, race/ethnicity, marital status, breakfast intake and supplement use, regular cereal consumption was associated with significant reductions in risk of nutrient inadequacies compared with cereal non-consumption (all $P < 0{\cdot}01$). Women who regularly used cereal had approximately 90 % reductions in risk of inadequacy in folate and Fe, and 65–75 % reductions in risk of insufficiency in Zn, vitamin A, vitamin C and vitamin E.

The exclusion of the nineteen cereal users who reported regular consumption of highly fortified cereals did not meaningfully influence the findings (data not shown). Further adjustment for age, education, smoking status, parity, pre-pregnancy BMI and television watching did not considerably alter any of the results (data not shown).

## Discussion

We observed that pregnant women who ate cereal at least three times per week around the time of conception had significantly higher intakes of key micronutrients compared with women who did not eat cereal regularly, even after controlling for confounders such as energy and breakfast intake. Moreover, regular cereal users had

**Table 1** Subject characteristics by regular cereal consumption*: low-income pregnant women (*n* 596), Pittsburgh, PA, USA, 2003–2005

| | Regular cereal consumers | | Cereal non-consumers | | |
|---|---|---|---|---|---|
| Maternal characteristic | *n* | % | *n* | % | *P* |
| Total | 182 | 30·5 | 414 | 69·5 | |
| Age group (years) | | | | | 0·52 |
| <20 | 37 | 20·3 | 102 | 24·7 | |
| 20–30 | 125 | 68·7 | 270 | 65·2 | |
| >30 | 20 | 11·0 | 42 | 10·1 | |
| Race/ethnicity | | | | | 0·45 |
| Black | 67 | 36·8 | 166 | 40·1 | |
| Non-black | 115 | 63·2 | 248 | 59·9 | |
| Education level (years) | | | | | 0·68 |
| <12 | 33 | 18·1 | 81 | 19·6 | |
| 12 | 84 | 46·2 | 175 | 42·3 | |
| >12 | 65 | 35·7 | 158 | 38·2 | |
| Smoking status | | | | | 0·34 |
| Smoker | 97 | 53·3 | 250 | 60·4 | |
| Non-smoker | 85 | 46·7 | 164 | 39·6 | |
| Marital status | | | | | <0·05 |
| Married | 41 | 22·5 | 61 | 14·7 | |
| Unmarried | 141 | 77·5 | 353 | 85·3 | |
| Parity | | | | | <0·05 |
| 0 | 122 | 67·0 | 316 | 76·3 | |
| 1 or more | 60 | 33·0 | 98 | 23·7 | |
| Pre-pregnancy BMI (kg/m$^2$) | | | | | 0·07 |
| <18·5 | 14 | 7·7 | 21 | 5·1 | |
| 18·5–<25 | 97 | 53·3 | 194 | 46·8 | |
| 25–<30 | 30 | 16·5 | 105 | 25·4 | |
| ≥30 | 41 | 22·5 | 94 | 22·7 | |
| Breakfast consumption | | | | | 0·07 |
| Consumers | 117 | 64·3 | 233 | 56·3 | |
| Skippers | 65 | 35·7 | 181 | 43·7 | |
| Pre-pregnancy supplement use | | | | | <0·05 |
| Yes | 72 | 39·6 | 124 | 30·0 | |
| No | 110 | 60·4 | 290 | 70·0 | |
| Television watching (h/d)† | | | | | 0·76 |
| 0–1 | 38 | 21·1 | 97 | 23·6 | |
| 2–3 | 84 | 46·7 | 181 | 43·9 | |
| ≥4 | 58 | 32·2 | 134 | 32·5 | |

*Regular cereal consumption defined as cereal intake ≥3 times/week.
†Data missing on four women.

**Table 2** Adjusted* mean nutrient intakes by regular cereal consumption: low-income pregnant women (*n* 596), Pittsburgh, PA, USA, 2003–2005

| | Regular cereal consumers (*n* 182) | | Cereal non-consumers (*n* 414) | | |
|---|---|---|---|---|---|
| Nutrient | Mean | 95 % CI | Mean | 95 % CI | *P*† |
| Energy (kJ/d) | 12 719 | 11 400, 14 042 | 8817 | 7733, 9902 | |
| Energy (kcal/d) | 3038 | 2723, 3354 | 2106 | 1847, 2365 | <0·001 |
| Folate (μg/d) | 512 | 474, 553 | 351 | 330, 373 | <0·001 |
| Fe (mg/d) | 16·1 | 14·9, 17·3 | 10·9 | 10·2, 11·5 | <0·001 |
| Zn (mg/d) | 9·0 | 8·3, 9·6 | 7·3 | 6·9, 7·8 | <0·001 |
| Ca (mg/d) | 908 | 832, 989 | 675 | 630, 722 | <0·001 |
| Vitamin A (μg/d) | 975 | 884, 1076 | 671 | 621, 726 | <0·001 |
| Vitamin C (mg/d) | 138 | 122, 157 | 113 | 102, 125 | 0·001 |
| Vitamin D (IU/d) | 179 | 148, 219 | 98 | 82, 117 | <0·001 |
| Vitamin E (mg/d) | 8·2 | 7·6, 8·9 | 7·2 | 6·7, 7·7 | <0·001 |
| Fibre (g/d) | 12·5 | 11·5, 13·6 | 10·2 | 9·6, 10·9 | <0·001 |

*Adjusted for daily energy intake, ethnicity, marital status, breakfast consumption and supplement use.
†Derived from multivariable linear regression models with the log nutrient intake as the dependent variable and regular cereal consumption and covariates listed above as independent variables.

https://doi.org/10.1017/S1368980008003881 Published online by Cambridge University Press

**Table 3** Association between regular cereal consumption and adjusted odds of nutrient intake in the highest third of the distribution: low-income pregnant women (*n* 596), Pittsburgh, PA, USA, 2003–2005

| | | Regular cereal consumers | | Cereal non-consumers | | |
|---|---|---|---|---|---|---|
| Nutrient | Tertile (median)* | *n* or OR | % or 95 % CI | *n* or OR | % or 95 % CI | *P*† |
| Folate | T1 (307 μg/d) | 15 | 8·2 | 182 | 43·9 | <0·001 |
| | T2 (430 μg/d) | 59 | 32·4 | 141 | 34·1 | |
| | T3 (595 μg/d) | 108 | 59·4 | 91 | 22·0 | |
| | T3 *v.* T1 + T2: Adj.‡ OR, 95 % CI | 5·0 | 3·4, 7·3 | 1·0 | ref | <0·001 |
| Fe | T1 (9·6 mg/d) | 12 | 6·6 | 183 | 44·2 | <0·001 |
| | T2 (13·1 mg/d) | 55 | 30·2 | 146 | 35·3 | |
| | T3 (18·3 mg/d) | 115 | 63·2 | 85 | 20·5 | |
| | T3 *v.* T1 + T2: Adj. OR, 95 % CI | 6·4 | 4·3, 9·5 | 1·0 | ref | <0·001 |
| Zn | T1 (6·4 mg/d) | 41 | 22·5 | 159 | 38·4 | <0·001 |
| | T2 (8·4 mg/d) | 51 | 28·0 | 149 | 36·0 | |
| | T3 (10·8 mg/d) | 90 | 49·5 | 106 | 25·6 | |
| | T3 *v.* T1 + T2: Adj. OR, 95 % CI | 2·7 | 1·8, 4·1 | 1·0 | ref | <0·001 |
| Ca | T1 (530 mg/d) | 27 | 14·8 | 171 | 41·3 | <0·001 |
| | T2 (763 mg/d) | 60 | 33·0 | 139 | 33·6 | |
| | T3 (1121 mg/d) | 95 | 52·2 | 104 | 25·1 | |
| | T3 *v.* T1 + T2: Adj. OR, 95 % CI | 3·2 | 2·2, 4·6 | 1·0 | ref | <0·001 |
| Vitamin A | T1 (518 μg/d) | 25 | 13·7 | 174 | 42·0 | <0·001 |
| | T2 (836 μg/d) | 71 | 39·0 | 133 | 32·1 | |
| | T3 (1282 μg/d) | 86 | 47·3 | 107 | 25·9 | |
| | T3 *v.* T1 + T2: Adj. OR, 95 % CI | 2·4 | 1·6, 3·5 | 1·0 | ref | <0·001 |
| Vitamin C | T1 (81 mg/d) | 52 | 28·6 | 151 | 36·5 | 0·06 |
| | T2 (152 mg/d) | 71 | 39·0 | 123 | 29·7 | |
| | T3 (255 mg/d) | 59 | 32·4 | 140 | 33·8 | |
| | T3 *v.* T1 + T2: Adj. OR, 95 % CI | 1·0 | 0·6, 1·4 | 1·0 | ref | 0·79 |
| Vitamin D | T1 (62 IU/d) | 23 | 12·6 | 177 | 42·7 | <0·001 |
| | T2 (136 IU/d) | 62 | 34·1 | 139 | 33·6 | |
| | T3 (257 IU/d) | 97 | 53·3 | 98 | 23·7 | |
| | T3 *v.* T1 + T2: Adj. OR, 95 % CI | 3·5 | 2·4, 5·1 | 1·0 | ref | <0·001 |
| Vitamin E | T1 (6·5 mg/d) | 53 | 29·1 | 148 | 35·8 | 0·22 |
| | T2 (8·4 mg/d) | 62 | 34·1 | 138 | 33·3 | |
| | T3 (11·2 mg/d) | 67 | 36·8 | 128 | 30·9 | |
| | T3 *v.* T1 + T2: Adj. OR, 95 % CI | 1·2 | 0·8, 1·7 | 1·0 | ref | 0·78 |
| Fibre | T1 (9·2 g/d) | 41 | 22·5 | 159 | 38·4 | <0·001 |
| | T2 (12·1 g/d) | 61 | 33·5 | 139 | 33·6 | |
| | T3 (17·2 g/d) | 80 | 44·0 | 116 | 28·0 | |
| | T3 *v.* T1 + T2: Adj. OR, 95 % CI | 1·8 | 1·2, 2·6 | 1·0 | ref | <0·01 |

T1, lowest tertile; T2, middle tertile; T3, highest tertile of nutrient distribution; ref, referent category.
*Median energy-adjusted nutrient density for each tertile, calculated as (median nutrient intake/energy intake) × 2000.
†Based on Pearson $\chi^2$ statistics when comparing proportions and logistic regression for odds ratios.
‡All odds ratios were adjusted for ethnicity, marital status, breakfast consumption and supplement use.

significant reductions in risk of periconceptional micronutrient inadequacies, including that of folate and Fe, compared with non-users. These results are meaningful as these micronutrients have been highlighted as shortfall nutrients in women of reproductive age[10]. In addition, the positive effects of eating cereal were not limited to women who regularly consumed highly fortified cereals.

To our knowledge, the present study is the first one to explore the association between cereal intake and micronutrient adequacy in pregnant women. Our findings are consistent with numerous studies relating cereal intake to nutritional status among children and non-pregnant adults[11,16,19]. For example, in a nationally representative US sample of individuals aged 9 years and older, nutrient intakes were 14–63 % higher in cereal consumers than non-consumers as defined by self-report on 24 h dietary recalls[19]. Additionally, another study of children and young adults in the USA found that cereal eaters were significantly more likely to meet at least two-thirds of the Recommended Dietary Allowance for folate, Fe, Ca, Zn and vitamins A, C and D[11]. Similarly, in 717 non-pregnant Irish women aged 18–64 years, it was reported that cereal consumption was associated with lower prevalence of inadequate intakes of folate, Fe, Ca, Zn and vitamin C according to European Average Requirements. Moreover, the proportion of women with nutrient inadequacies decreased as cereal consumption increased[16].

We used an FFQ to assess cereal intake, while most previous studies used dietary recalls or records. Nevertheless, the percentage of pregnant women regularly consuming cereal in our study was comparable to that previously reported in women of reproductive age[17,19,32,33]. Although investigators of past studies tended to focus on cereal intake at breakfast, we included cereal intake throughout the day because a sizeable proportion (36 %) of regular cereal eaters in our study

**Table 4** Association between regular cereal consumption and risk of nutrient inadequacy: low-income pregnant women (*n* 596), Pittsburgh, PA, USA, 2003–2005

| Nutrient | | Regular cereal consumers | | Cereal non-consumers | | |
|---|---|---|---|---|---|---|
| | | % or OR | 95 % CI | % or OR | 95 % CI | *P** |
| Folate | % below EAR (520 μg/d)† | 26·9 | | 70·5 | | <0·001 |
| | Adj.‡ OR, 95 % CI | 0·11 | 0·06, 0·19 | 1·0 | ref | <0·001 |
| Fe | % below EAR (22 mg/d) | 46·7 | | 84·1 | | <0·001 |
| | Adj. OR, 95 % CI | 0·09 | 0·04, 0·18 | 1·0 | ref | <0·001 |
| Zn | % below EAR (9·5 mg/d) | 28·0 | | 61·1 | | <0·001 |
| | Adj. OR, 95 % CI | 0·25 | 0·13, 0·46 | 1·0 | ref | <0·001 |
| Vitamin A | % below EAR (550 μg/d) | 5·5 | | 26·8 | | <0·001 |
| | Adj. OR, 95 % CI | 0·26 | 0·12, 0·56 | 1·0 | ref | 0·001 |
| Vitamin C | % below EAR (70 mg/d) | 5·5 | | 20·1 | | <0·001 |
| | Adj. OR, 95 % CI | 0·36 | 0·17, 0·76 | 1·0 | ref | <0·01 |
| Vitamin E | % below EAR (12 mg/d) | 43·4 | | 72·5 | | <0·001 |
| | Adj. OR, 95 % CI | 0·35 | 0·20, 0·62 | 1·0 | ref | <0·001 |

EAR, Estimated Average Requirements; ref, referent category.
*Based on $\chi^2$ tests when comparing proportions and logistic regression for odds ratios.
†EAR of specified nutrient for pregnant women >18 years. EAR is the average daily energy intake to meet the requirements of half the healthy individuals for the specific life stage and gender group. Intakes lower than the EAR suggest high risk for nutritional inadequacy.
‡All odds ratios are adjusted for daily energy intake, ethnicity, marital status, breakfast consumption and supplement use.

reported not usually consuming breakfast. This suggests that cereal was often consumed as a snack or part of another meal. This finding is consistent with a study of US children and young adults, which found that about 40 % of cereal eaters consumed cereal as lunch, dinner or a snack and that those who consumed cereal at any time of day had higher micronutrient intakes[11]. Taken together, these data highlight that cereal intake may not need to be part of breakfast to have a positive impact on diet quality.

Some health-care professionals may wonder about the negative aspects of promoting cereal intake, such as excessive weight gain, high sugar intakes and/or micronutrient intakes above tolerable levels. Nevertheless, cross-sectional studies have shown that cereal eaters are often leaner[17,33,34] and also have lower daily intakes of fat and cholesterol[16–19,33] than cereal non-eaters. We also found that cereal users tended ($P = 0·07$) to have lower BMI values than cereal non-users. Moreover, ready-to-eat breakfast cereals contribute minimally to overall daily sugar intake[13]. Cereal consumption should, however, be encouraged in moderation, with attention paid to serving size, and in the context of a healthy diet.

The positive effect we observed of cereal intake on micronutrient intake may not have been due to the cereal itself, but rather to foods commonly eaten by cereal users or healthy eating behaviours. For example, the higher intakes of Ca and vitamin D seen among cereal users may be due to the use of milk on cereal. We could not separate these effects because 85 % of the cereal consumers reported regularly using milk on their cereal. In addition, there is unfortunately no gold standard for assessing usual dietary intake. FFQ are limited by a restricted, culture-specific food list; their representation of a person's perceived intake rather than actual intake; and their limited ability to estimate absolute energy intake[35]. However, FFQ have the advantages of capturing usual past intake of micronutrients, having a low respondent burden, and ranking individuals relative to one another (i.e. high *v.* low consumers)[35]. We performed our analyses assessing both tertiles of nutrient intake (to capture a ranking of subjects) and micronutrient intakes less than the EAR (an absolute measure of intake) and came to comparable conclusions. Another limitation was the time lapse between the period of recall (periconceptional period) and completion of the FFQ (mid-pregnancy). A study to validate the FFQ in our population is currently underway. Finally, our small sample size prohibited us from studying whether cereal intake protected against adverse pregnancy outcomes. Future investigations should explore this intriguing research question.

Our results suggest that regularly consuming cereal in the periconceptional period may help reduce the prevalence of deficiencies in essential micronutrients, including folate and Fe. Inquiring about regular intake of cereal could be used as an instant assessment of micronutrient inadequacies in pregnant women. Encouraging cereal consumption as part of a healthy lifestyle around conception may be a simple, safe and inexpensive nutrition intervention that could optimize maternal periconceptional intake for successful placental and fetal development.

## Acknowledgements

*Sources of funding:* The study was partially supported by National Institutes of Health Grants R01 HD041663, P01 HD030367 and M01 RR000056. L.M.B. was supported by K01 MH074092. M.S.P. was supported by a Clinical Scientist Training Program scholarship from the University of Pittsburgh School of Medicine.

*Conflict of interest declaration:* None declared.

*Authorship responsibilities:* L.M.B. originated the idea for this project. H.N.S. and J.M.R. secured the funding for the studies. G.H. and N.M. aided with data collection. M.S.P. conducted analyses with input from L.M.B. All authors contributed to the interpretation of the data. M.S.P. and L.M.B. wrote the manuscript while all authors gave final approval.

## References


1. Cross JC, Werb Z & Fisher SJ (1994) Implantation and the placenta: key pieces of the development puzzle. *Science* **266**, 1508–1518.
2. Goodger AM & Rogers PA (1993) Uterine endothelial cell proliferation before and after embryo implantation in rats. *J Reprod Fertil* **99**, 451–457.
3. Jauniaux E, Watson AL, Hempstock J, Bao YP, Skepper JN & Burton GJ (2000) Onset of maternal arterial blood flow and placental oxidative stress. A possible factor in human early pregnancy failure. *Am J Pathol* **157**, 2111–2122.
4. Czeizel AE & Dudas I (1992) Prevention of the first occurrence of neural-tube defects by periconceptional vitamin supplementation. *N Engl J Med* **327**, 1832–1835.
5. Bloomfield FH, Oliver MH, Hawkins P, Campbell M, Phillips DJ, Gluckman PD, Challis JR & Harding JE (2003) A periconceptional nutritional origin for noninfectious preterm birth. *Science* **300**, 606.
6. MacLaughlin SM, Walker SK, Roberts CT, Kleemann DO & McMillen IC (2005) Periconceptional nutrition and the relationship between maternal body weight changes in the periconceptional period and feto-placental growth in the sheep. *J Physiol* **565**, 111–124.
7. Oliver MH, Hawkins P & Harding JE (2005) Periconceptional undernutrition alters growth trajectory and metabolic and endocrine responses to fasting in late-gestation fetal sheep. *Pediatr Res* **57**, 591–598.
8. Roberts JM, Balk JL, Bodnar LM, Belizan JM, Bergel E & Martinez A (2003) Nutrient involvement in preeclampsia. *J Nutr* **133**, 1684S–1692S.
9. US Department of Health and Human Services (2000) *Healthy People 2010: National Health Promotion and Disease Prevention Objectives*. Washington, DC: DHHS.
10. US Department of Health and Human Services and US Department of Agriculture (2005) *The Report of the Dietary Guidelines Advisory Committee on Dietary Guidelines for Americans, 2005*, 6th ed. Washington, DC: DHHS and USDA.
11. Nicklas TA, O'Neil CE & Berenson GS (1998) Nutrient contribution of breakfast, secular trends, and the role of ready-to-eat cereals: a review of data from the Bogalusa Heart Study. *Am J Clin Nutr* **67**, 757S–763S.
12. Preziosi P, Galan P, Deheeger M, Yacoub N, Drewnowski A & Hercberg S (1999) Breakfast type, daily nutrient intakes and vitamin and mineral status of French children, adolescents, and adults. *J Am Coll Nutr* **18**, 171–178.
13. Williams P (2005) Breakfast and the diets of Australian adults: an analysis of data from the 1995 National Nutrition Survey. *Int J Food Sci Nutr* **56**, 65–79.
14. Cotton PA, Subar AF, Friday JE & Cook A (2004) Dietary sources of nutrients among US adults, 1994 to 1996. *J Am Diet Assoc* **104**, 921–930.
15. Siega-Riz AM, Bodnar LM & Savitz DA (2002) What are pregnant women eating? Nutrient and food group differences by race. *Am J Obstet Gynecol* **186**, 480–486.
16. Galvin MA, Kiely M & Flynn A (2003) Impact of ready-to-eat breakfast cereal (RTEBC) consumption on adequacy of micronutrient intakes and compliance with dietary recommendations in Irish adults. *Public Health Nutr* **6**, 351–363.
17. Barton BA, Eldridge AL, Thompson D, Affenito SG, Striegel-Moore RH, Franko DL, Albertson AM & Crockett SJ (2005) The relationship of breakfast and cereal consumption to nutrient intake and body mass index: the National Heart, Lung, and Blood Institute Growth and Health Study. *J Am Diet Assoc* **105**, 1383–1389.
18. Gibson S (2003) Micronutrient intakes, micronutrient status and lipid profiles among young people consuming different amounts of breakfast cereals: further analysis of data from the National Diet and Nutrition Survey of Young People aged 4 to 18 years. *Public Health Nutr* **6**, 815–820.
19. Song WO, Chun OK, Kerver J, Cho S, Chung CE & Chung SJ (2006) Ready-to-eat breakfast cereal consumption enhances milk and calcium intake in the US population. *J Am Diet Assoc* **106**, 1783–1789.
20. van den Boom A, Serra-Majem L, Ribas L, Ngo J, Perez-Rodrigo C, Aranceta J & Fletcher R (2006) The contribution of ready-to-eat cereals to daily nutrient intake and breakfast quality in a Mediterranean setting. *J Am Coll Nutr* **25**, 135–143.
21. Institute of Medicine, Food and Nutrition Board (2006) *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements*. Washington, DC: National Academies Press.
22. Block G, Coyle LM, Hartman AM & Scoppa SM (1994) Revision of dietary analysis software for the Health Habits and History Questionnaire. *Am J Epidemiol* **139**, 1190–1196.
23. Block G, Hartman AM, Dresser CM, Carroll MD, Gannon J & Gardner L (1986) A data-based approach to diet questionnaire design and testing. *Am J Epidemiol* **124**, 453–469.
24. Block G & DiSogra C (1994) *WIC Dietary Assessment Validation Study. Final Report*. Alexandria, VA: US Department of Agriculture, Food and Nutrition Service.
25. Block G, Thompson FE, Hartman AM, Larkin FA & Guire KE (1992) Comparison of two dietary questionnaires validated against multiple dietary records collected during a 1-year period. *J Am Diet Assoc* **92**, 686–693.
26. Block G, Woods M, Potosky A & Clifford C (1990) Validation of a self-administered diet history questionnaire using multiple diet records. *J Clin Epidemiol* **43**, 1327–1335.
27. Institute of Medicine, Food and Nutrition Board (2000) Folate. In *Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline*. Washington, DC: National Academies Press.
28. Institute of Medicine, Food and Nutrition Board (2002) *Dietary Reference Intakes (DRIs): Estimated Average Requirements for Groups*. Washington, DC: National Academies Press.
29. Institute of Medicine, Food and Nutrition Board (2001) *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. Washington, DC: National Academies Press.
30. Institute of Medicine, Food and Nutrition Board (1997) *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride*. Washington, DC: National Academies Press.
31. Siega-Riz AM, Herrmann TS, Savitz DA & Thorp JM (2001) Frequency of eating during pregnancy and its effect on preterm delivery. *Am J Epidemiol* **153**, 647–652.

32. Siega-Riz AM, Popkin BM & Carson T (2000) Differences in food patterns at breakfast by sociodemographic characteristics among a nationally representative sample of adults in the United States. *Prev Med* **30**, 415–424.
33. Song WO, Chun OK, Obayashi S, Cho S & Chung CE (2005) Is consumption of breakfast associated with body mass index in US adults? *J Am Diet Assoc* **105**, 1373–1382.
34. Cho S, Dietrich M, Brown CJ, Clark CA & Block G (2003) The effect of breakfast type on total daily energy intake and body mass index: results from the Third National Health and Nutrition Examination Survey (NHANES III). *J Am Coll Nutr* **22**, 296–302.
35. Willet WC (1998) *Nutritional Epidemiology*, 2nd ed. New York: Oxford University Press.

https://doi.org/10.1017/S1368980008003881 Published online by Cambridge University Press