Pregnant Canadian Women Achieve Recommended Intakes of One-Carbon Nutrients through Prenatal Supplementation but the Supplement Composition, Including Choline, Requires Reconsideration1–3

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Abstract

Background: Folate, vitamin B-6, vitamin B-12, and choline are involved in one-carbon metabolism and play critical roles in pregnancy including prevention of birth defects and promotion of neurodevelopment. However, excessive intakes may adversely affect disease susceptibility in offspring. Intakes of these nutrients during pregnancy are not well characterized.

Objective: Our aim was to determine dietary and supplemental intakes and major dietary sources of one-carbon nutrients during pregnancy.

Methods: In pregnant women (n = 368) at ≤16 wk postconception, supplement use >30 d before pregnancy was assessed by maternal recall and supplement and dietary intakes in early (0–16 wk) and late pregnancy (23–37 wk) were assessed by food-frequency questionnaire.

Results: Preconception, 60.1% (95% CI: 55.8, 64.3) of women used B vitamin–containing supplements. This increased to 92.8% (95% CI: 89.6, 95.2) in early and 89.0% (95% CI: 85.0, 92.3) in late pregnancy. Median supplemental folic acid, vitamin B-12, and vitamin B-6 were 1000 μg/d, 2.6 μg/d, and 1.9 mg/d, respectively. Forty-one percent and 50% of women had dietary intakes of folate and vitamin B-6 less than the estimated average requirement (520 mg/d dietary folate equivalents and 1.6 mg/d, respectively). Eight-seven percent of women had choline intakes less than the Adequate Intake (450 mg/d). Dietary intakes did not change appreciably during pregnancy. Fruits and vegetables and fortified foods contributed ~57% to total dietary folate intake. Fruits and vegetables contributed ~32% to total dietary vitamin B-12 intake and dairy and egg products contributed ~37% to total dietary vitamin B-12 intake.

Conclusions: Vitamin supplements were an important source of one-carbon nutrients during pregnancy in our sample. Without supplements, many women would not have consumed quantities of folate and vitamin B-6 consistent with recommendations. Given the importance of choline in pregnancy, further research to consider inclusion in prenatal supplements is warranted. This trial was registered at clinicaltrials.gov as NCT02244684. J Nutr 2015;145:1824–34.

Keywords: betaine, choline, dietary intake, folate, folic acid, one-carbon nutrients, pregnancy, prenatal supplements, vitamin B-6, vitamin B-12

Introduction

Requirements for one-carbon nutrients such as B vitamins (folate, vitamin B-12, and vitamin B-6), choline, and Met are increased during pregnancy to facilitate adequate growth and development of fetal and maternal tissue (1). Although adverse pregnancy and birth outcomes associated with insufficient intake of one-carbon nutrients during pregnancy are well

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documented, there is a growing body of evidence demonstrating that excessive exposure to one-carbon nutrients in utero can potentially affect disease susceptibility in the offspring later in life, which may in part be mediated by epigenetic mechanisms such as DNA methylation (2).

It is well established that periconceptional folic acid supplementation reduces the risk of neural tube defects (NTDs) (3, 4). Similarly, higher intakes or blood concentrations of vitamin B-12 (5, 6), choline (7), betaine (7), and Met (9–11) during the periconceptional period have been inversely associated with the risk of NTDs, albeit less consistently, compared with folic acid. Additionally, high periconceptional folate exposure has been associated with improved neurodevelopment (12–15) and a reduction in the risk of various pediatric cancers (16–18) in offspring. In contrast, high periconceptional folic acid exposure has been shown in some studies, but not all, to increase the risk of asthma (19), atopic dermatitis (20), obesity, and metabolic syndrome (21) and in one study to increase the risk of a detrimental effect on psychomotor development (22). Higher choline intakes during pregnancy have been associated with improved cognitive development (23, 24), whereas low intakes of vitamin B-12 or an imbalance between folic acid and vitamin B-12 intakes have been associated with intrauterine growth restriction, reduced cognitive function, and increased risk of adiposity and diabetes (21, 25, 26).

Women of childbearing age and during pregnancy are advised, as part of routine prenatal care, to consume 400 μg/d of folic acid from fortified foods or from a supplement in addition to folate-rich foods to help reduce the risk of NTDs (1). We and others have reported a notable increase in folate intakes and blood concentrations among North American women as a result of the 1998 introduction of mandatory folic acid fortification and increased adherence with periconceptional supplement recommendations (27–30). Although studies describing folate intakes during pregnancy have begun to emerge (27), there is a paucity of data describing the intakes of one-carbon nutrients. National surveys generally preclude the evaluation of micronutrient intakes during pregnancy because of an inadequate sample size of pregnant women. Assessing intakes of one-carbon nutrients in pregnancy will help identify inadequate and/or excessive intakes that may affect pregnancy and birth outcomes as well as health outcomes in the offspring later in life, given the role that these nutrients play in nucleotide biosynthesis and biological methylation reactions. We, therefore, undertook this study to 1) determine dietary and supplemental intakes of one-carbon nutrients in early and late pregnancy and how they change during pregnancy and 2) identify the most common dietary sources of these nutrients during pregnancy.

Methods

Participants and study design. Between November 2010 and January 2012, pregnant women attending prenatal clinics at St. Michael’s Hospital (Toronto, Ontario, Canada) between 12 and 16 wk gestation were invited to participate in a prospective study, Prenatal Folic Acid Exposure on DNA Methylation in the newborn infant (NCT02244684) to determine the effect of maternal intake of folate on DNA methylation of cord blood lymphocytes. A sample size of 260 mother-child pairs was estimated to provide 90% power to detect a correlation of ≥0.2 between red blood cell folate concentration and global lymphocyte DNA methylation in the umbilical cord blood. This calculation took into consideration the anticipated unequal number of mothers who report periconceptional (~60%) and prenatal (~40%) supplement use containing folic acid.

St. Michael’s Hospital, situated in downtown Toronto, serves a demographically diverse inner-city population and delivers >3000 neonates annually. Inclusion criteria included healthy women between the ages of 18 and 45 y with an uncomplicated singleton pregnancy who were <16 wk postconception at the time of enrollment. Women were excluded if they were taking medications known to interfere with folate metabolism, planned to deliver at another hospital, or planned to bank umbilical cord blood.

At enrollment, women completed a Baseline Demographic and Health Questionnaire, which consisted of selected sections of the Canadian Community Health Survey, Cycle 2.2 (31). Information was obtained on maternal age and self-reported height and weight, race/ethnicity, highest level of education attained, gravidity, parity, whether they were single, existence of any chronic health conditions, and whether household income was below the Statistics Canada low-income cutoff (32). The study was approved by the St. Michael’s Hospital Research Ethics Board and written informed consent was obtained from all women.

Assessment of dietary nutrient intake. During the first study visit, between 12 and 16 wk gestation, and again during the second study visit, between 35 and 37 wk gestation, participants completed a 110-item semiquantitative Block FFQ (NutritionQuest) that was either self- or interviewer-administered using a paper copy or an on-line version. Labonte et al. (33) previously reported that the on-line version of this FFQ yielded comparable results with the paper version. Participants were asked to report the frequency of consumption of specific foods and beverages in the previous 3 mo. During the first study visit, participants were asked to recall habitual intake between 0 and 16 wk gestation (early pregnancy) and during the second study visit between 23 and 37 wk gestation (late pregnancy).

The Block FFQ has been validated in a number of populations including pregnant women and in a sample of Ontario women of reproductive age (34–36) and was shown to be a moderately accurate estimate of B vitamin intake (34). Specifically, the median deattenuated Pearson correlation coefficients between the Block FFQ and two 24-h recalls were reported to be 0.76 for folate, 0.70 for vitamin B-6, and 0.65 for vitamin B-12 from supplements and food (34).

Eight frequency of consumption options were available for each food item on the FFQ, ranging from “never” or “once per month” to “once per day.” Subjects were asked to indicate the typical portion size consumed for each food item from a preset list of common serving sizes (e.g., number of slices) or by using photographs of servings on a plate or a bowl (e.g., 125–250 ml). Study personnel checked for completeness of the FFQ during study visits. Nutrient intakes were then computed by NutritionQuest. For these computations, NutritionQuest used the 2001–2002 NHANES dietary recall data and nutrient composition data primarily from version 1.0 of the USDA Food and Nutrient Database for Dietary Studies (37). Because different fortification regulations exist for ready-to-eat breakfast cereals and rice in Canada and the United States, the folic acid, vitamin B-6, and vitamin B-12 composition values were modified for these food items using values from the Canadian Nutrient File (38).

Choline, betaine, and Met were not assessed in the 2001–2002 cycle of NHANES; hence, the choline and betaine values for each FFQ food item in the present study were derived from the “2004 and 2008 USDA Databases for the Choline Content of Common Foods” (39). For food items in the FFQ where Met values were not listed in the USDA Food and Nutrient Database for Dietary Studies, an appropriate substitution was made from the USDA Nutrient Database for Standard Reference (40).

Assessment of supplemental nutrient intake. Vitamin supplement use was assessed over 3 time periods: preconception (30 d before pregnancy), early pregnancy (conception to 16 wk gestation), and late pregnancy (23–37 wk gestation) using the Baseline Demographic Questionnaire (preconception) and the Block FFQ (early and late pregnancy). Intake of one-carbon nutrients during pregnancy 1825

11 Abbreviations used: AI, Adequate Intake; DFE, dietary folate equivalent; EAR, estimated average requirement; NTD, neural tube defect; UL, Tolerable Upper Intake Level.
pregnancy). Information was obtained about brand/type of supplement; doses of folic acid, vitamin B-12, and vitamin B-6; frequency of supplement use; and reason(s) for using the supplement for the preconception and early pregnancy time points. Information on the nutrient composition of each supplement was obtained from product labels or product information found on manufacturer websites. In late pregnancy, information on the type and frequency of supplement use was collected but women were not asked again about the dose consumed.

Statistical analysis. Data were analyzed using SAS version 9.3 (SAS Institute, Inc.) and for all tests, $P < 0.05$ was considered significant. Descriptive statistics (means and frequencies) were used to report demographic data, supplement use, daily nutrient intakes, and reasons for supplement use.

To determine stability of nutrient intakes from early to late pregnancy, Pearson correlation coefficients for intakes of each one-carbon nutrient were computed. A cutoff point of $r = 0.2$ was used to indicate relative stability in nutrient intakes between the 2 time points (41). Differences in mean nutrient intakes between early and late pregnancy were also assessed using paired $t$ tests. To identify important food sources of folate, vitamin B-6, and vitamin B-12, we used the method described in detail by Block et al. (42). Briefly, the nutrient contribution of each FFQ item, expressed as a percent of total intake for that nutrient, was calculated. For example, to determine the percent contribution of vitamin B-12 from the FFQ item, “milk or milk substitutes on cereal,” the vitamin B-12 contribution from this item was divided by the total amount of vitamin B-12 consumed from all 110 FFQ items.

Univariate analyses ($t$ tests for continuous variables and $\chi^2$-tests for categorical variables) were used to identify significant differences in baseline demographic characteristics between supplement users and nonusers. Multivariate logistic regression analyses were performed to determine the adjusted association between demographic characteristics and prepregnancy supplement use.

For statistical analyses requiring paired data (i.e., Pearson’s correlation and paired $t$ test), only participants with complete data sets were included.

Results

Subject characteristics. As described in Figure 1, 1315 pregnant women were approached to participate. Of these, 906 met eligibility criteria and 368 women agreed to participate. Fourteen of the enrolled women were lost to follow-up during the early pregnancy visit and of those remaining in the cohort ($n = 354$), 339 completed the first FFQ. A total of 35 participants did not complete the late pregnancy study visit and of those remaining ($n = 319$), 305 completed the second FFQ. The reasons for not completing study visits are described in Figure 1.

On average, the pregnant women in this sample were 32 $\pm$ 5 y of age and had a BMI of 24.6 $\pm$ 4.6. Almost one-half of the participants were Caucasian and 25% were of Asian ethnicity (including Chinese, Filipino, Japanese, Korean, South Asian, and Southeast Asian). The most recent Statistics Canada Census of Metropolitan Areas (2006) reports a similar distribution of these 2 groups in the city of Toronto (43). Women were generally well educated with 85% reporting completion of a college/vocational diploma, university degree, or more. The Statistics Canada 2011 National Household Survey in the City of Toronto reports a similar distribution of postsecondary education (44). Only a small proportion of women reported household income below the poverty line (11.0%) and even fewer women were single (5.8%). Approximately 40% of mothers were primiparous.

Supplemental intakes. Overall, 60.1% (95% CI: 55.8, 64.3) of the women reported using a B vitamin–containing supplement at least once each week 30 d before pregnancy. This increased to 92.8% (95% CI: 89.6, 95.2) in early pregnancy (between 0 and 16 wk gestation) and remained at 89.0% (95% CI: 85.0, 92.3) in late pregnancy (between 23 and 37 wk gestation).

The most common type of B vitamin–containing supplement used before conception and in early and late pregnancy was a prenatal multivitamin formulation, which contained folic acid, vitamin B-12, vitamin B-6, and other vitamins and minerals. Before conception, women consumed folic acid alone (13.7%), folic acid, vitamin B-12, and vitamin B-6–containing multivitamins designed for nonpregnant adults (11.1%), and vitamin B complex (7.6%), which contained folic acid, vitamin B-12, and vitamin B-6. Furthermore, 19.7% (95% CI: 14.6, 25.7), 14.9% (95% CI: 11.2, 19.2), and 24.9% (95% CI: 19.8, 30.6) reported using a combination of $\geq 2$ of the aforementioned B vitamin–containing supplements before and during early and late pregnancy, respectively.

Before conception and during early pregnancy, women reported median supplemental intakes of 1000 $\mu$g/d of folic acid, 1.9 mg/d of vitamin B-6, and 2.6 $\mu$g/d of vitamin B-12 (Table 1). The RDA for folate, vitamin B-6, and vitamin B-12 during pregnancy is 600 $\mu$g of dietary folate equivalent (DFE)/d, 1.9 mg/d, and 2.6 $\mu$g/d, respectively (1). None of the prenatal multivitamin formulations consumed contained choline or betaine.

Given the high prevalence of prenatal supplement use and the amounts of folic acid, vitamin B-6, and vitamin B-12 contained in them, most women had intakes of these vitamins above the RDA from supplements alone (Table 1). For example in early pregnancy, a majority of women had supplemental folic acid intakes that met their RDA (600 $\mu$g DFE/d) (1). After conversion of supplemental folic acid intake to DFE, all women met the RDA for folate from supplements alone. Similarly, 92% and 91% of women were consuming vitamin B-12 and vitamin B-6 at or above the RDA for B-12 (2.6 $\mu$g/d) (1) and vitamin B-6 (1.9 mg/d) (1), respectively, from supplements alone. Seventy-one (23%) and one (0.3%) of the women had supplemental intakes of folic acid and vitamin B-6 above the Tolerable Upper Intake Level (UL) of 1000 $\mu$g/d (1) and 100 mg/d (1), respectively.

The most commonly reported reasons for supplemental use were a belief that they “helped the baby grow” (29%), followed by “not getting enough vitamins” (26%), “doctor recommended it” (22%), “believe it makes one healthier” (14%), “not eating right” (5%), and other (4%).

Demographic differences between prepregnancy supplement users and nonusers. Univariate analyses of the associations between demographic characteristics and supplement use showed that, on average, supplement users were older ($P < 0.0001$), less likely to be single ($P = 0.01$), more likely to be living above the poverty line ($P = 0.0035$), and born in Canada ($P = 0.0005$) compared with nonusers (Table 2). To determine which of the demographic characteristics listed in Table 2 were best associated with prepregnancy supplement use, multivariate logistic regression analysis was performed using supplement use as the binary response variable (Table 3). These results revealed that the odds of using a supplement at least 30 d before pregnancy increased with each additional year of age (OR = 1.13; 95% CI: 1.07, 1.20), was higher for those with a postgraduate degree compared with those with some postsecondary education (OR = 1.93; 95% CI: 1.05, 3.57), and was higher for those who were born in Canada (OR = 2.16; 95% CI: 1.34, 3.49). In contrast, the odds of supplement use before pregnancy was lower for primiparous compared with nulliparous women (OR = 0.56; 95% CI: 0.38, 0.92) and in single women (OR = 0.25; 95% CI: 0.09, 0.72).

Stability of dietary intakes during pregnancy. The FFQ was completed during early and late pregnancy by 92% and 83% of
the enrolled women, respectively. The analysis of changes in dietary nutrient intakes was restricted to the 290 participants (79%) who completed both the first and the second FFQ (Table 4). The mean time that elapsed between the completion of the 2 FFQs was 150.3 ± 25.1 d. Dietary intakes of energy, carbohydrate, fat, and protein did not differ between early and late pregnancy. Similarly, there were no significant differences between the one-carbon nutrient intakes in early and late pregnancy, with the exceptions of naturally occurring folate (P = 0.02), glycerophosphocholine (P = 0.02), and phosphatidylcholine (P = 0.005), although the magnitude of the change was small for each nutrient.

As illustrated in Table 4, dietary intakes of all one-carbon nutrients assessed in early pregnancy were significantly correlated with corresponding intakes in late pregnancy (r = 0.49–0.67; all, P < 0.0001), suggesting stability in the intake of one-carbon nutrients over the course of pregnancy.

**Major dietary contributors of folate, folic acid, vitamin B-6, and vitamin B-12.** The major contributors of folate, vitamin

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**TABLE 1** Daily folic acid, vitamin B-6, and vitamin B-12 intakes from supplements at least 30 d before pregnancy and in early pregnancy in a sample of Canadian women

<table>
<thead>
<tr>
<th>Vitamin B</th>
<th>DRI 3</th>
<th>UL 4</th>
<th>At least 30 d before pregnancy, n = 191</th>
<th>Early pregnancy, n = 312</th>
</tr>
</thead>
<tbody>
<tr>
<td>Folate, μg/d</td>
<td>6005</td>
<td>10006</td>
<td>10007 (800, 1000)</td>
<td>10007 (1000, 1000)</td>
</tr>
<tr>
<td>Vitamin B-6, mg/d</td>
<td>1.9</td>
<td>100</td>
<td>1.9 (1.9, 10.0)</td>
<td>1.9 (1.9, 10.0)</td>
</tr>
<tr>
<td>Vitamin B-12, μg/d</td>
<td>2.6</td>
<td>N/A</td>
<td>2.6 (2.6, 12.0)</td>
<td>2.6 (2.6, 10.0)</td>
</tr>
</tbody>
</table>

1 DFE, dietary folate equivalent; N/A, not applicable; UL, Tolerable Upper Intake Level.

2 Values are medians (IQRs).

3 RDA refers to the average daily intake sufficient to meet the nutrient requirements of nearly all (97–98%) healthy people (1).

4 UL refers to the maximum daily intake unlikely to cause adverse health effects (1).

5 Expressed as DFE. 1 DFE = 1 µg of food folate or 0.6 µg of folic acid from fortified food or 0.5 µg of supplemental folic acid ingested on an empty stomach (1).

6 The UL for folate only applies to synthetic forms (i.e., folic acid) obtained from supplements and/or fortified foods.

7 Expressed as synthetic folic acid (µg) from supplements only.
B-6, and vitamin B-12 in the diet of pregnant women in early pregnancy are presented in Tables 5–7 and those in late pregnancy are presented in Supplemental Tables 1–3. The most common sources of folate during early pregnancy were green salad and orange juice, which contributed 14.8% and 7.9% to total dietary folate intake, respectively (Table 5). As a group, fruits and vegetables (excluding juice) were the largest contributor of dietary folate, providing 37.7%, followed by cereals and grains providing 19.5% of total folate intake, including both natural sources and synthetic folic acid from fortified foods. The top-ranked source of folic acid from fortified foods was bagels and English muffins, providing 14.4% of total synthetic folic acid intakes, followed by cold cereals contributing 9.3% (data not shown). Altogether, fortified foods contributed 31.1% to total dietary folate intakes.

The most common contributor of vitamin B-6 was vegetarian stew and soups followed by bananas contributing 10.9% and 5.8%, respectively, to total vitamin B-6 in the diet (Table 6). The fruits and vegetables food group (excluding juice) was the largest dietary source of vitamin B-6, contributing 32.3% of total intake. Grains and cereals were the second-largest contributor, providing 11.3% of total vitamin B-6 intake.

Finally, the most common source of vitamin B-12 was milk, which contributed 21.0% to total intake of vitamin B-12 followed by vegetarian stew and soups at 7.6% (Table 7). As a group, dairy and egg products represented the most common contributors, providing 36.7% of total vitamin B-12 intake. The second-largest contributing food group was meat, fish, and seafood, which cumulatively provided 24.4% to the total.

**Discussion**

A majority of women in the present study reported using a B vitamin–containing supplement (commonly containing a combination of folic acid, vitamin B-12, and vitamin B-6) at least 30 d before pregnancy (60.1%), increasing to 92.8% and 89.0% in early and late pregnancy, respectively. These data are similar to those of the national 2006 Canadian Maternity Experiences Survey, which reported 57.7% and 89.7% using a folic acid–containing supplement 3 mo before pregnancy and during the

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**TABLE 2** Differences in demographic characteristics among supplement users and nonusers before pregnancy

<table>
<thead>
<tr>
<th>Variable</th>
<th>Overall</th>
<th>Supplement user</th>
<th>Nonuser</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants, n</td>
<td>353</td>
<td>212</td>
<td>141</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>31.7 ± 4.9</td>
<td>32.8 ± 4.3</td>
<td>30.0 ± 5.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>24.5 ± 4.8</td>
<td>24.3 ± 4.5</td>
<td>24.9 ± 4.9</td>
<td>0.23</td>
</tr>
<tr>
<td>Parity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participants, n</td>
<td>351</td>
<td>211</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>189 (53.8)</td>
<td>120 (56.9)</td>
<td>69 (49.3)</td>
<td></td>
</tr>
<tr>
<td>≥1</td>
<td>162 (46.2)</td>
<td>91 (43.1)</td>
<td>71 (50.7)</td>
<td></td>
</tr>
<tr>
<td>First pregnancy&lt;sup&gt;4&lt;/sup&gt;</td>
<td>140 (39.9)</td>
<td>86 (40.8)</td>
<td>54 (38.6)</td>
<td>0.68</td>
</tr>
<tr>
<td>Born in Canada</td>
<td>173 (49.0)</td>
<td>120 (56.6)</td>
<td>53 (37.6)</td>
<td>0.0005</td>
</tr>
<tr>
<td>Single</td>
<td>21 (6.0)</td>
<td>7 (3.4)</td>
<td>14 (10.0)</td>
<td>0.01</td>
</tr>
<tr>
<td>Income below the low-income cutoff</td>
<td>37 (10.5)</td>
<td>14 (6.6)</td>
<td>23 (16.3)</td>
<td>0.0035</td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participants, n</td>
<td>352</td>
<td>212</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td>High school education or less</td>
<td>63 (17.9)</td>
<td>24 (11.3)</td>
<td>39 (27.9)</td>
<td></td>
</tr>
<tr>
<td>Some postsecondary education</td>
<td>206 (58.8)</td>
<td>125 (59.0)</td>
<td>81 (57.9)</td>
<td></td>
</tr>
<tr>
<td>Graduate degree</td>
<td>83 (23.6)</td>
<td>63 (29.7)</td>
<td>20 (14.3)</td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participants, n</td>
<td>352</td>
<td>141</td>
<td>211</td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>157 (44.6)</td>
<td>107 (50.7)</td>
<td>50 (35.5)</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>61 (17.3)</td>
<td>29 (20.6)</td>
<td>32 (15.2)</td>
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<tr>
<td>Latin American</td>
<td>31 (8.8)</td>
<td>15 (7.1)</td>
<td>16 (11.4)</td>
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</tr>
<tr>
<td>Black</td>
<td>24 (6.8)</td>
<td>10 (4.7)</td>
<td>14 (9.9)</td>
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<tr>
<td>South Asian</td>
<td>21 (6.0)</td>
<td>12 (5.7)</td>
<td>9 (6.4)</td>
<td></td>
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<tr>
<td>Other</td>
<td>58 (16.5)</td>
<td>35 (16.6)</td>
<td>23 (16.3)</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Values are means ± SDs or n (%).
<sup>2</sup> Independent samples t test.
<sup>3</sup> χ²-test.
<sup>4</sup> Gravidity = 1.
first trimester, respectively (45). In the present study, 85% of the women consumed folic acid at or above the UL (1000 μg/d) through supplements alone. This is not surprising, because the dose of folic acid in prenatal supplements in Canada is typically 1000μg. The UL for folic acid was set at 1000μg/d to reduce the risk of masking vitamin B-12 deficiency. Because vitamin B-12 is provided in all prenatal supplements in Canada, masking may not be a concern. It is worthwhile noting that pregnant women are being exposed to a dose of folic acid that is 2.5 times the recommended dose of 400μg/d (1). Furthermore, >90% of supplement users achieved the RDAs of 1.9 mg/d of vitamin B-6 and 2.6 μg/d of vitamin B-12, respectively, through supplements alone.

The estimated average requirement (EAR) is the appropriate DRI level to estimate the prevalence of inadequate intakes in our sample, because use of RDA generally overestimates inadequate intakes in a group (1). Using the EAR cutoff, 41% and 47% of our study participants did not meet their requirements of folate through diet alone during early and late pregnancy, respectively. Similarly, Sherwood et al. (46) reported that 36% of women in a sample from Toronto at 36 wk gestation had folate intakes below the EAR from dietary sources alone, assessed using 3-d weighed-food records. However, in the latter study when dietary and supplemental intakes were combined, the prevalence of inadequacy was reduced to 0% and, moreover, 67% had intakes above the UL. In the present study, the likelihood of inadequate intakes of folate, taking into account both dietary and supplemental intakes, was close to zero. However, a small proportion of women (~7–10%) did not use a B vitamin–containing supplement and therefore might be at risk of inadequate intakes during pregnancy.

Using the EAR cutoff (2.2 μg/d), the prevalence of vitamin B-12 inadequacy from diet alone was only 11% and 12% in early and late pregnancy, respectively. Furthermore, 92% consumed vitamin B-12 at or above the RDA (≥2.6 μg/d) (1) in early pregnancy from B vitamin–containing supplements (most commonly prenatal multivitamins), suggesting that inadequate intakes in this cohort were unlikely. The EAR for vitamin B-6 during pregnancy is 1.6 mg/d (1), corresponding to the median intake of our sample in both early and late pregnancy. This suggests inadequate vitamin B-6 intakes, from dietary sources only, in at least one-half of the participants. However, 91% were consuming vitamin B-6 at or above the RDA (≥19 mg/d) (1) from B vitamin–containing supplements (most commonly prenatal multivitamins), which reduces the likelihood of inadequate intakes. An analysis of the 2004 Canadian Community Health Survey (47) demonstrated that the prevalence of inadequate dietary intakes of vitamin B-12 and vitamin B-6 in women (14–50 y) was reduced to <5% after accounting for supplement intake.

The Adequate Intake (AI) level for choline is 450 mg/d during pregnancy (1), which corresponded to the 86th and the 87th percentile of total choline intake in early and late pregnancy, respectively. This indicates that the majority of the study participants had dietary choline intakes below the AI level. Similarly, findings from the Nurses’ Health Study demonstrated that 95% of participants had choline intakes below the AI (48). Additionally, an analysis of the 2003–2004 NHANES data revealed that >90% of pregnant women had choline intakes below the AI (49).

There are currently no established recommended intakes for betaine. The mean betaine intake in the present cohort was 209 ± 156 mg/d and 207 ± 118 mg/d in early and late pregnancy, respectively, which are slightly higher than those reported in US population-based studies that used an FFQ (48, 50).

Median Met intakes in early pregnancy among women in our sample were 1360 mg/d. Median intakes are generally lower than those reported in 3 large US case-control studies investigating the

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Early pregnancy</th>
<th>Late pregnancy</th>
<th>Mean difference</th>
<th>% Change</th>
<th>Pearson’s correlation coefficient (r)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy, kcal/d</td>
<td>1840 ± 667</td>
<td>1836 ± 686</td>
<td>−4.6 ± 548.0</td>
<td>−0.3</td>
<td>0.89</td>
<td>0.67</td>
</tr>
<tr>
<td>Carbohydrates, g/d</td>
<td>229 ± 82</td>
<td>232 ± 84</td>
<td>3.1 ± 72.1</td>
<td>1.4</td>
<td>0.47</td>
<td>0.63</td>
</tr>
<tr>
<td>Fat, g/d</td>
<td>75 ± 31</td>
<td>74 ± 33</td>
<td>−0.7 ± 25.0</td>
<td>−0.9</td>
<td>0.62</td>
<td>0.69</td>
</tr>
<tr>
<td>Protein, g/d</td>
<td>73 ± 31</td>
<td>72 ± 29</td>
<td>−1.5 ± 25.1</td>
<td>−2.1</td>
<td>0.30</td>
<td>0.65</td>
</tr>
<tr>
<td>Folate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural dietary folate, μg/d</td>
<td>313 ± 140</td>
<td>297 ± 131</td>
<td>−15.5 ± 115.9</td>
<td>−4.9</td>
<td>0.02</td>
<td>0.64</td>
</tr>
<tr>
<td>Folic acid, fortified food, μg/d</td>
<td>96 ± 54</td>
<td>96 ± 50</td>
<td>0.1 ± 100.5</td>
<td>−0.1</td>
<td>0.91</td>
<td>0.49</td>
</tr>
<tr>
<td>Total dietary folate, μg DFE/d</td>
<td>483 ± 203</td>
<td>465 ± 186</td>
<td>−9.8 ± 230.7</td>
<td>−3.8</td>
<td>0.13</td>
<td>0.56</td>
</tr>
<tr>
<td>Vitamin B-6, mg/d</td>
<td>1.8 ± 0.9</td>
<td>1.7 ± 0.7</td>
<td>−0.1 ± 0.8</td>
<td>−5.1</td>
<td>0.09</td>
<td>0.61</td>
</tr>
<tr>
<td>Vitamin B-12, μg/d</td>
<td>4.7 ± 3.1</td>
<td>4.5 ± 2.6</td>
<td>−0.2 ± 2.0</td>
<td>−2.0</td>
<td>0.66</td>
<td>0.60</td>
</tr>
<tr>
<td>Total choline, mg/d</td>
<td>306 ± 127</td>
<td>302 ± 122</td>
<td>−4.6 ± 101.0</td>
<td>−1.5</td>
<td>0.44</td>
<td>0.67</td>
</tr>
<tr>
<td>Free choline, mg/d</td>
<td>77 ± 28</td>
<td>77 ± 27</td>
<td>−0.1 ± 23.9</td>
<td>−0.1</td>
<td>0.95</td>
<td>0.63</td>
</tr>
<tr>
<td>Phosphocholine, mg/d</td>
<td>14 ± 6</td>
<td>15 ± 6</td>
<td>0.6 ± 5.2</td>
<td>0.9</td>
<td>0.05</td>
<td>0.59</td>
</tr>
<tr>
<td>Glycerophosphocholine, mg/d</td>
<td>151 ± 80</td>
<td>142 ± 75</td>
<td>−9.1 ± 63.1</td>
<td>−6.0</td>
<td>0.02</td>
<td>0.67</td>
</tr>
<tr>
<td>Phosphatidylcholine, mg/d</td>
<td>49 ± 22.0</td>
<td>53 ± 23.7</td>
<td>4.2 ± 20.4</td>
<td>8.6</td>
<td>0.0005</td>
<td>0.60</td>
</tr>
<tr>
<td>Sphingomyelin, mg/d</td>
<td>15 ± 8.0</td>
<td>15.2 ± 8.7</td>
<td>−0.0 ± 8.0</td>
<td>−0.1</td>
<td>0.97</td>
<td>0.55</td>
</tr>
<tr>
<td>Betaine, mg/d</td>
<td>209 ± 159.0</td>
<td>207 ± 118.3</td>
<td>−2.5 ± 235.8</td>
<td>−1.2</td>
<td>0.75</td>
<td>0.55</td>
</tr>
<tr>
<td>Met, mg/d</td>
<td>1460 ± 644.6</td>
<td>1454 ± 623.8</td>
<td>−6.0 ± 531.5</td>
<td>−4.0</td>
<td>0.86</td>
<td>0.65</td>
</tr>
</tbody>
</table>

1 Values are means ± SDs, n = 290.
2 P value generated from paired t test to assess the difference in mean nutrient intakes between early and late pregnancy.
3 Nutrient value adjusted to reflect Canadian food fortification regulations.
4 Total dietary folate = natural dietary folate + (folic acid from fortified food × 1.7).
5 DFE, dietary folate equivalent.
6 Total choline intake = free choline + choline from phosphocholine, glycerophosphocholine, phosphatidylcholine and sphingomyelin.
relation between periconceptional Met intakes and the risk of NTDs (9–11). Across these 3 studies, median Met intakes during pregnancy estimated using FFQs were 1750 (9), 2070 (10), and 2961 mg/d (11). Some of the variation in these estimates of betaine and Met intakes may be attributed to the different FFQs used to assess intakes and the nutrient databases used to derive intakes.

To date, to our knowledge, this is the first study in Canada that assessed changes in one-carbon nutrient intakes over the course of pregnancy. Dietary intakes of all one-carbon nutrients were similar in early and late pregnancy, as demonstrated by modest Pearson correlation coefficients ($r = 0.49$–0.67; $P < 0.0001$) between intakes at these 2 time points. A US study conducted by

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
<th>Total folate, %</th>
<th>Cumulative folate, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Green salad</td>
<td>14.8</td>
<td>14.8</td>
</tr>
<tr>
<td>2</td>
<td>Real orange juice</td>
<td>7.9</td>
<td>22.8</td>
</tr>
<tr>
<td>3</td>
<td>Vegetarian stew and soups</td>
<td>5.0</td>
<td>27.7</td>
</tr>
<tr>
<td>4</td>
<td>Bagels or English muffins</td>
<td>4.5</td>
<td>32.2</td>
</tr>
<tr>
<td>5</td>
<td>Squash, cauliflower, okra, cooked peppers</td>
<td>4.3</td>
<td>36.6</td>
</tr>
<tr>
<td>6</td>
<td>Cold cereals</td>
<td>3.1</td>
<td>39.7</td>
</tr>
<tr>
<td>7</td>
<td>Spinach</td>
<td>2.6</td>
<td>42.3</td>
</tr>
<tr>
<td>8</td>
<td>Milk</td>
<td>2.6</td>
<td>44.8</td>
</tr>
<tr>
<td>9</td>
<td>Spaghetti with meat sauce</td>
<td>2.5</td>
<td>47.4</td>
</tr>
<tr>
<td>10</td>
<td>Broccoli</td>
<td>2.5</td>
<td>49.8</td>
</tr>
<tr>
<td>11</td>
<td>Pizza</td>
<td>2.4</td>
<td>52.3</td>
</tr>
<tr>
<td>12</td>
<td>Oranges</td>
<td>2.3</td>
<td>54.5</td>
</tr>
<tr>
<td>13</td>
<td>White bread</td>
<td>2.1</td>
<td>56.6</td>
</tr>
<tr>
<td>14</td>
<td>Breakfast egg sandwich</td>
<td>2.0</td>
<td>58.7</td>
</tr>
<tr>
<td>15</td>
<td>100% Whole wheat bread</td>
<td>1.8</td>
<td>60.5</td>
</tr>
<tr>
<td>16</td>
<td>Eggs</td>
<td>1.5</td>
<td>61.9</td>
</tr>
<tr>
<td>17</td>
<td>Biscuits</td>
<td>1.5</td>
<td>63.4</td>
</tr>
<tr>
<td>18</td>
<td>Yogurt</td>
<td>1.4</td>
<td>64.8</td>
</tr>
<tr>
<td>19</td>
<td>Coffee and hot tea</td>
<td>1.4</td>
<td>66.2</td>
</tr>
<tr>
<td>20</td>
<td>Egg noodles, pasta salad, sopa seca</td>
<td>1.4</td>
<td>67.6</td>
</tr>
<tr>
<td>21</td>
<td>Bananas</td>
<td>1.4</td>
<td>68.9</td>
</tr>
<tr>
<td>22</td>
<td>Nuts</td>
<td>1.3</td>
<td>70.3</td>
</tr>
<tr>
<td>23</td>
<td>Beans (pinto, black) baked or in chili</td>
<td>1.3</td>
<td>71.6</td>
</tr>
<tr>
<td>24</td>
<td>Cooked cereal</td>
<td>1.3</td>
<td>72.9</td>
</tr>
<tr>
<td>25</td>
<td>Crackers</td>
<td>1.2</td>
<td>74.1</td>
</tr>
<tr>
<td>26</td>
<td>Power/energy bars</td>
<td>1.0</td>
<td>75.2</td>
</tr>
<tr>
<td>27</td>
<td>Macaroni and cheese</td>
<td>1.0</td>
<td>76.2</td>
</tr>
<tr>
<td>28</td>
<td>Meatless spaghetti</td>
<td>1.0</td>
<td>77.2</td>
</tr>
<tr>
<td>29</td>
<td>Hamburger, hotdog, submarine buns</td>
<td>1.0</td>
<td>78.1</td>
</tr>
<tr>
<td>30</td>
<td>Strawberries</td>
<td>0.8</td>
<td>79.0</td>
</tr>
<tr>
<td>31</td>
<td>Pancakes</td>
<td>0.8</td>
<td>79.8</td>
</tr>
<tr>
<td>32</td>
<td>Corn</td>
<td>0.8</td>
<td>80.5</td>
</tr>
<tr>
<td>33</td>
<td>Chicken dishes (stew, noodles, salad, Chinese chicken dishes)</td>
<td>0.7</td>
<td>81.3</td>
</tr>
<tr>
<td>34</td>
<td>Breakfast bars (cereal/granola bars)</td>
<td>0.7</td>
<td>82.0</td>
</tr>
<tr>
<td>35</td>
<td>Tacos</td>
<td>0.7</td>
<td>82.6</td>
</tr>
<tr>
<td>36</td>
<td>Peanut butter</td>
<td>0.6</td>
<td>83.3</td>
</tr>
<tr>
<td>37</td>
<td>Soup (chicken noodle, cream, ramen, instant noodle)</td>
<td>0.6</td>
<td>83.9</td>
</tr>
<tr>
<td>38</td>
<td>Refried beans</td>
<td>0.6</td>
<td>84.5</td>
</tr>
<tr>
<td>39</td>
<td>Apple, grape, or pineapple juice or fruit smoothies</td>
<td>0.6</td>
<td>85.1</td>
</tr>
<tr>
<td>40</td>
<td>Liver</td>
<td>0.6</td>
<td>85.7</td>
</tr>
<tr>
<td>41</td>
<td>Iced tea, bottled, with sugar</td>
<td>0.6</td>
<td>86.3</td>
</tr>
<tr>
<td>42</td>
<td>Green beans</td>
<td>0.6</td>
<td>86.9</td>
</tr>
<tr>
<td>43</td>
<td>Greens (collards, turnip greens, mustard greens)</td>
<td>0.6</td>
<td>87.4</td>
</tr>
<tr>
<td>44</td>
<td>Tofu</td>
<td>0.6</td>
<td>88.0</td>
</tr>
<tr>
<td>45</td>
<td>Tomatoes</td>
<td>0.5</td>
<td>88.5</td>
</tr>
<tr>
<td>46</td>
<td>Cheese</td>
<td>0.5</td>
<td>89.0</td>
</tr>
<tr>
<td>47</td>
<td>Carrots</td>
<td>0.5</td>
<td>89.5</td>
</tr>
<tr>
<td>48</td>
<td>Corn tortillas and cornbread</td>
<td>0.5</td>
<td>89.9</td>
</tr>
<tr>
<td>49</td>
<td>Salty snacks (potato chips, tortilla chips, popcorn)</td>
<td>0.4</td>
<td>90.4</td>
</tr>
<tr>
<td>50</td>
<td>Grapes, plums, honeydew or mango</td>
<td>0.4</td>
<td>90.8</td>
</tr>
</tbody>
</table>

1 Data are from the FFQ, $n = 339$. Results are expressed as μg of folate and have not been adjusted to account for differences in the bioavailability of folic acid and naturally occurring folates (1).
Rifas-Shiman et al. (51) measured the change in food and nutrient intakes using the Willett FFQ between the first and second trimesters of pregnancy in the Project Viva cohort and noted low-to-modest Pearson correlation coefficients for folate, vitamin B-12, and vitamin B-6 between the first and second trimester of pregnancy (r = 0.48, 0.46, and 0.32, respectively).

The top 2 contributors of total dietary folate intakes in early pregnancy were green salad and orange juice, providing 14.8% and 7.9% of total intakes, respectively. The most important contributors of folate for women were fruits and vegetables as well as fortified foods, whereas for vitamin B-6 and vitamin B-12 they were fruits and vegetables and dairy products.

### TABLE 6 Major contributors of vitamin B-6 in early pregnancy

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
<th>Total vitamin B-6, %</th>
<th>Cumulative vitamin B-6, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Vegetarian stew and soups</td>
<td>10.9</td>
<td>10.9</td>
</tr>
<tr>
<td>2</td>
<td>Bananas</td>
<td>5.8</td>
<td>16.7</td>
</tr>
<tr>
<td>3</td>
<td>Milk</td>
<td>4.7</td>
<td>21.5</td>
</tr>
<tr>
<td>4</td>
<td>Cold cereals</td>
<td>4.5</td>
<td>26.0</td>
</tr>
<tr>
<td>5</td>
<td>Squash, cauliflower, okra, cooked peppers</td>
<td>4.1</td>
<td>30.1</td>
</tr>
<tr>
<td>6</td>
<td>Real orange juice</td>
<td>3.4</td>
<td>33.5</td>
</tr>
<tr>
<td>7</td>
<td>Green salad</td>
<td>2.8</td>
<td>36.3</td>
</tr>
<tr>
<td>8</td>
<td>Apple, grape, or, pineapple juice or fruit smoothies</td>
<td>2.3</td>
<td>38.5</td>
</tr>
<tr>
<td>9</td>
<td>French fries</td>
<td>2.2</td>
<td>40.8</td>
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<tr>
<td>10</td>
<td>Potatoes (mashed, boiled, baked, salad)</td>
<td>1.9</td>
<td>42.7</td>
</tr>
<tr>
<td>11</td>
<td>Chicken dishes [stew, noodles, salad, Chinese chicken dishes]</td>
<td>1.8</td>
<td>44.5</td>
</tr>
<tr>
<td>12</td>
<td>100% Whole wheat bread</td>
<td>1.8</td>
<td>46.2</td>
</tr>
<tr>
<td>13</td>
<td>Spaghetti with meat sauce</td>
<td>1.6</td>
<td>47.8</td>
</tr>
<tr>
<td>14</td>
<td>Rice</td>
<td>1.6</td>
<td>49.4</td>
</tr>
<tr>
<td>15</td>
<td>Eggs</td>
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<td>50.7</td>
</tr>
<tr>
<td>16</td>
<td>Beef (fat trimmed off)</td>
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<td>52.1</td>
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<tr>
<td>17</td>
<td>Fish (not fried)</td>
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<tr>
<td>18</td>
<td>Breakfast egg sandwich</td>
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<td>54.7</td>
</tr>
<tr>
<td>19</td>
<td>Roasted/broiled chicken or turkey (no skin)</td>
<td>1.3</td>
<td>55.9</td>
</tr>
<tr>
<td>20</td>
<td>Yogurt</td>
<td>1.3</td>
<td>57.2</td>
</tr>
<tr>
<td>21</td>
<td>Breakfast bars (cereal/granola bars)</td>
<td>1.2</td>
<td>58.4</td>
</tr>
<tr>
<td>22</td>
<td>Power /energy bars</td>
<td>1.2</td>
<td>59.6</td>
</tr>
<tr>
<td>23</td>
<td>Salty snacks (potato chips, tortilla chips, popcorn)</td>
<td>1.2</td>
<td>60.8</td>
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<tr>
<td>24</td>
<td>Grapes, plums, honeydew, or mango</td>
<td>1.2</td>
<td>62.0</td>
</tr>
<tr>
<td>25</td>
<td>Broccoli</td>
<td>1.2</td>
<td>63.2</td>
</tr>
<tr>
<td>26</td>
<td>Tuna</td>
<td>1.2</td>
<td>64.3</td>
</tr>
<tr>
<td>27</td>
<td>Oranges</td>
<td>1.1</td>
<td>65.5</td>
</tr>
<tr>
<td>28</td>
<td>Nuts</td>
<td>1.1</td>
<td>66.6</td>
</tr>
<tr>
<td>29</td>
<td>Cooked cereal</td>
<td>1.1</td>
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</tr>
<tr>
<td>30</td>
<td>Pizza</td>
<td>1.1</td>
<td>68.8</td>
</tr>
<tr>
<td>31</td>
<td>Carrots</td>
<td>1.0</td>
<td>69.8</td>
</tr>
<tr>
<td>32</td>
<td>Apples, pears</td>
<td>1.0</td>
<td>70.7</td>
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<tr>
<td>33</td>
<td>Pancakes</td>
<td>1.0</td>
<td>71.7</td>
</tr>
<tr>
<td>34</td>
<td>Beef or pork dishes (beef stew, pot pie, corned beef hash, Hamburger Helper)</td>
<td>0.9</td>
<td>72.7</td>
</tr>
<tr>
<td>35</td>
<td>Peanut butter</td>
<td>0.9</td>
<td>73.5</td>
</tr>
<tr>
<td>36</td>
<td>Spinach</td>
<td>0.9</td>
<td>74.4</td>
</tr>
<tr>
<td>37</td>
<td>Low-fat breakfast bars (cereal/granola bars)</td>
<td>0.8</td>
<td>75.2</td>
</tr>
<tr>
<td>38</td>
<td>Cheese</td>
<td>0.8</td>
<td>76.0</td>
</tr>
<tr>
<td>39</td>
<td>Meat substitutes</td>
<td>0.8</td>
<td>76.8</td>
</tr>
<tr>
<td>40</td>
<td>Sweet potato</td>
<td>0.7</td>
<td>77.5</td>
</tr>
<tr>
<td>41</td>
<td>Cheeseburger</td>
<td>0.7</td>
<td>78.3</td>
</tr>
<tr>
<td>42</td>
<td>Roasted/broiled chicken or turkey (skin on)</td>
<td>0.7</td>
<td>79.0</td>
</tr>
<tr>
<td>43</td>
<td>Steak, roast beef, beef in sandwiches/frozen dinners</td>
<td>0.7</td>
<td>79.7</td>
</tr>
<tr>
<td>44</td>
<td>Tomatoes</td>
<td>0.7</td>
<td>80.3</td>
</tr>
<tr>
<td>45</td>
<td>Tacos</td>
<td>0.7</td>
<td>81.0</td>
</tr>
<tr>
<td>46</td>
<td>Fried fish</td>
<td>0.6</td>
<td>81.6</td>
</tr>
<tr>
<td>47</td>
<td>Pork (fat trimmed)</td>
<td>0.6</td>
<td>82.3</td>
</tr>
<tr>
<td>48</td>
<td>Bagels, English muffins</td>
<td>0.6</td>
<td>82.9</td>
</tr>
<tr>
<td>49</td>
<td>Canned fruit</td>
<td>0.6</td>
<td>83.5</td>
</tr>
<tr>
<td>50</td>
<td>Tomato juice</td>
<td>0.6</td>
<td>84.1</td>
</tr>
</tbody>
</table>

1 Data are from the FFQ, n = 339.
and eggs, respectively. Our data emphasize the importance of eating a balanced diet from all food groups in order to obtain essential one-carbon nutrients from diet alone. Our findings also reflect the important role that fortification plays in supplying adequate folate.

There are a few limitations in this study related to the dietary assessment tool. Although the FFQ is commonly used in epidemiologic research to measure dietary intake because of ease of administration, 24-h recalls or 3-d weighed-food records provide a more accurate estimate of nutrient intakes. Available

### TABLE 7  
Major contributors of vitamin B-12 in early pregnancy

<table>
<thead>
<tr>
<th>Rank</th>
<th>Description</th>
<th>Total vitamin B-12, %</th>
<th>Cumulative vitamin B-12, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Milk</td>
<td>21.0</td>
<td>21.0</td>
</tr>
<tr>
<td>2</td>
<td>Vegetarian stew and soups</td>
<td>7.6</td>
<td>28.5</td>
</tr>
<tr>
<td>3</td>
<td>Fish (not fried)</td>
<td>6.1</td>
<td>34.6</td>
</tr>
<tr>
<td>4</td>
<td>Yogurt</td>
<td>5.8</td>
<td>40.4</td>
</tr>
<tr>
<td>5</td>
<td>Cheese</td>
<td>5.1</td>
<td>45.5</td>
</tr>
<tr>
<td>6</td>
<td>Liver</td>
<td>4.7</td>
<td>50.2</td>
</tr>
<tr>
<td>7</td>
<td>Eggs</td>
<td>4.0</td>
<td>54.2</td>
</tr>
<tr>
<td>8</td>
<td>Shellfish</td>
<td>3.1</td>
<td>57.4</td>
</tr>
<tr>
<td>9</td>
<td>Spaghetti with meat sauce</td>
<td>3.1</td>
<td>60.4</td>
</tr>
<tr>
<td>10</td>
<td>Breakfast egg sandwich</td>
<td>2.8</td>
<td>63.2</td>
</tr>
<tr>
<td>11</td>
<td>Beef (fat trimmed off)</td>
<td>2.8</td>
<td>66.0</td>
</tr>
<tr>
<td>12</td>
<td>Tuna</td>
<td>2.4</td>
<td>68.4</td>
</tr>
<tr>
<td>13</td>
<td>Fried fish</td>
<td>2.3</td>
<td>70.7</td>
</tr>
<tr>
<td>14</td>
<td>Cheeseburger</td>
<td>2.3</td>
<td>73.0</td>
</tr>
<tr>
<td>15</td>
<td>Beef or pork dishes (beef stew, pot pie, corned beef hash, Hamburger Helper)</td>
<td>1.7</td>
<td>74.7</td>
</tr>
<tr>
<td>16</td>
<td>Veal, lamb, or deer meat</td>
<td>1.6</td>
<td>76.3</td>
</tr>
<tr>
<td>17</td>
<td>Oysters</td>
<td>1.5</td>
<td>77.8</td>
</tr>
<tr>
<td>18</td>
<td>Steak, roast beef, beef in sandwiches/frozen dinners</td>
<td>1.4</td>
<td>79.3</td>
</tr>
<tr>
<td>19</td>
<td>Pizza</td>
<td>1.4</td>
<td>80.7</td>
</tr>
<tr>
<td>20</td>
<td>Power/energy bars</td>
<td>1.4</td>
<td>82.0</td>
</tr>
<tr>
<td>21</td>
<td>Meat loaf</td>
<td>1.2</td>
<td>83.3</td>
</tr>
<tr>
<td>22</td>
<td>Soup (chicken noodle, cream, ramen, instant soup)</td>
<td>1.2</td>
<td>84.5</td>
</tr>
<tr>
<td>23</td>
<td>Hamburgers</td>
<td>1.1</td>
<td>85.6</td>
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<tr>
<td>24</td>
<td>Tacos</td>
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<td>86.5</td>
</tr>
<tr>
<td>25</td>
<td>Pancakes</td>
<td>0.8</td>
<td>87.3</td>
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<tr>
<td>26</td>
<td>Hot dogs</td>
<td>0.8</td>
<td>88.0</td>
</tr>
<tr>
<td>27</td>
<td>Lunch meats (bologna, ham, turkey)</td>
<td>0.8</td>
<td>88.8</td>
</tr>
<tr>
<td>28</td>
<td>Menudo, pozole, caldo de res, sanococho, ajiaco</td>
<td>0.8</td>
<td>89.6</td>
</tr>
<tr>
<td>29</td>
<td>Ribs</td>
<td>0.7</td>
<td>90.3</td>
</tr>
<tr>
<td>30</td>
<td>Beef (fat not trimmed)</td>
<td>0.6</td>
<td>90.9</td>
</tr>
<tr>
<td>31</td>
<td>Low-fat cheese</td>
<td>0.6</td>
<td>91.5</td>
</tr>
<tr>
<td>32</td>
<td>Meat substitutes</td>
<td>0.6</td>
<td>92.1</td>
</tr>
<tr>
<td>33</td>
<td>Ice cream</td>
<td>0.6</td>
<td>92.7</td>
</tr>
<tr>
<td>34</td>
<td>Chicken dishes [stew, noodles, salad, Chinese chicken dishes]</td>
<td>0.5</td>
<td>93.2</td>
</tr>
<tr>
<td>35</td>
<td>Macaroni and cheese</td>
<td>0.5</td>
<td>93.6</td>
</tr>
<tr>
<td>36</td>
<td>Breakfast sausage</td>
<td>0.4</td>
<td>94.1</td>
</tr>
<tr>
<td>37</td>
<td>Pork (fat trimmed)</td>
<td>0.4</td>
<td>94.5</td>
</tr>
<tr>
<td>38</td>
<td>Roasted/broiled chicken or turkey (no skin)</td>
<td>0.4</td>
<td>94.8</td>
</tr>
<tr>
<td>39</td>
<td>Bacon</td>
<td>0.3</td>
<td>95.2</td>
</tr>
<tr>
<td>40</td>
<td>Biscuits</td>
<td>0.3</td>
<td>95.5</td>
</tr>
<tr>
<td>41</td>
<td>Pork</td>
<td>0.3</td>
<td>95.8</td>
</tr>
<tr>
<td>42</td>
<td>Pigs feet</td>
<td>0.3</td>
<td>96.0</td>
</tr>
<tr>
<td>43</td>
<td>Bagels, English muffins</td>
<td>0.2</td>
<td>96.3</td>
</tr>
<tr>
<td>44</td>
<td>Low-carb breakfast bars (cereal/granola bars)</td>
<td>0.2</td>
<td>96.5</td>
</tr>
<tr>
<td>45</td>
<td>Pinto beans, black beans, chili with beans, baked beans</td>
<td>0.2</td>
<td>96.7</td>
</tr>
<tr>
<td>46</td>
<td>Roast chicken (with skin on)</td>
<td>0.2</td>
<td>96.9</td>
</tr>
<tr>
<td>47</td>
<td>Cream or half &amp; half</td>
<td>0.2</td>
<td>97.1</td>
</tr>
<tr>
<td>48</td>
<td>Chocolate candy</td>
<td>0.2</td>
<td>97.2</td>
</tr>
<tr>
<td>49</td>
<td>Diet shakes (Slim-Fast)</td>
<td>0.2</td>
<td>97.4</td>
</tr>
<tr>
<td>50</td>
<td>Fried chicken</td>
<td>0.2</td>
<td>97.6</td>
</tr>
</tbody>
</table>

1 Data from the FFQ, n = 339.
evidence suggests that the FFQ likely overestimates dietary intake of one-carbon nutrients (52). Also, although the education level of participants in this study reflect that reported for the city of Toronto, it is much higher compared with that obtained nationally, where, e.g., 22% of women hold a university degree (53). Therefore, generalizability of study findings to women nationally is uncertain.

In conclusion, this study demonstrates that prenatal supplements are a substantial source of folic acid, vitamin B-6, and vitamin B-12 during pregnancy in a sample of Canadian women. Without prenatal supplements many women would not have consumed quantities of folate and vitamin B-6 consistent with expert recommendations for a healthy pregnancy. The dose of folic acid (1000 μg) used in prenatal supplements, however, needs to be reconsidered, given that it is well above that recommended for NTD prevention and concern of unknown consequences of high intakes on long-term health outcomes in offspring. Finally, given the important role of choline in a healthy pregnancy and the seemingly low dietary intakes reported here, further research on the benefits and risks of including choline in a prenatal supplement is warranted.

Acknowledgments

HB, Y-IK, and DLO designed the research; SPM, LP, and AL conducted the research; HB and AYL contributed to participant recruitment; SPM analyzed the data; RC contributed to the data analysis; SPM wrote the paper; Y-IK and DLO critically revised the manuscript for important intellectual content; and HB, AYL, and RC contributed to the revision of the manuscript. All authors read and approved the final manuscript.

References


