A Three-Day Weighed Food Record and a Semiquantitative Food-Frequency Questionnaire Are Valid Measures for Assessing the Folate and Vitamin B-12 Intakes of Women Aged 16 to 19 Years

Timothy J. Green,* O. Brian Allen† and Deborah L. O’Connor**

ABSTRACT The purpose of this study was to validate a food-frequency questionnaire (FFQ) and a 3-d weighed food record (3d-WFR) by comparing nutrient intakes estimated using these methods with serum folate, RBC folate and serum vitamin B-12 concentrations in 105 females aged 16–19 y. During an early morning clinic visit, subjects completed a self-administered, 116-item FFQ, blood was collected and they were trained to complete a 3d-WFR. Folate intakes as determined by the 3d-WFR (\( r = 0.65, P < 0.01 \)) exhibited a stronger association with serum folate than did intakes from the FFQ (\( r = 0.48, P < 0.01 \)) (\( P = 0.017 \)). The correlations between folate intakes and RBC folate as determined by the FFQ (\( r = 0.42, P < 0.01 \)) and 3d-WFR (\( r = 0.50, P < 0.01 \)) methods did not differ. Vitamin B-12 intakes showed only a modest association with serum vitamin B-12 when supplement users were included in the analyses (FFQ, \( r = 0.25, P < 0.05 \); 3d-WFR, \( r = 0.32, P < 0.05 \)). After excluding supplement users from the analyses, the relationship between vitamin B-12 intakes as determined by FFQ and serum vitamin B-12 was no longer significant. Median daily folate intakes (346 vs. 212 \( \mu g \)) and vitamin B-12 (4.9 vs. 1.9 \( \mu g \)) estimated from the FFQ were higher than those obtained from the 3d-WFR. In sum, these data suggest that both the FFQ and 3d-WFR are valid measures of assessing the folate intake of young women, and both appear to be useful in determining vitamin B-12 intake when supplemental users are included. The markedly different conclusions about absolute folate and vitamin B-12 intakes obtained using these two dietary methodologies should be taken into consideration when making recommendations about optimal folate intakes in relation to disease prevention.

KEY WORDS: • young women • folate • vitamin B-12 • dietary assessment

Two recent trials, one coordinated by the British Medical Research Council (MRC Vitamin Study Research Group 1991) and the other conducted in conjunction with the Hungarian Family Planning Committee (Czeizel and Dudas 1992), provide compelling evidence that periconceptional folic acid supplementation reduces the number of pregnancies affected by neural tube defects (NTD). These studies confirmed a series of earlier case-control and cohort studies that showed a protective effect of supplemental folic acid on the incidence of NTD (Picciano et al. 1994). Despite the well-characterized relationship between periconceptional vitamin supplement use and NTD, the association between dietary folate intake and NTD has not been extensively studied. Data from the few available studies suggest, however, that this relationship is less remarkable (Bower and Stanley 1989, Brown et al. 1997, Cuskelly et al. 1996, Daly et al. 1995, Milunsky et al. 1989, Werler et al. 1993).

The weak association between dietary folate intake and the incidence of NTD may in fact reflect the difficulty in estimating individual folate intakes rather than a lack of a protective effect of dietary folate per se. Researchers examining the relationship between maternal dietary folate intake and the incidence of NTD have relied almost exclusively on food-frequency questionnaires (FFQ) to obtain estimates of usual folate intake during the periconceptional period (Bower and Stanley 1989, Daly et al. 1995, Milunsky et al. 1989, Werler et al. 1993). Food-frequency questionnaires are an attractive method in epidemiologic studies because of their low respondent burden and ease of administration (Willett 1990). The use of FFQ in estimating nutrient intake is based on the frequency with which a fixed list of foods of predetermined portion sizes is consumed over an extended period of time. This method relies heavily on memory, and the questions posed to respondents are open to interpretation (Willett 1990).

Another approach commonly employed to determine nutrient intake is the use of weighed food records. In contrast to FFQ, weighed food records allow more precise determination of portion sizes, do not rely on memory and are not limited

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2 Abbreviations used: 3d-WFR, 3-d weighed food record; FFQ, food-frequency questionnaire; NTD, neural tube defect; RNI, Canadian Recommended Nutrient Intakes.
to selection from a predetermined list of foods. Weighed food records are not very practical in large epidemiologic studies, however, because they require extensive participant training, have a high respondent burden and require lengthy data entry by trained personnel (Willett 1990). A larger concern is that food records may cause participants to alter their food intake and may not be representative of the respondents’ usual dietary intake (Gibson 1990).

Food-frequency questionnaires have been validated for determining folate intake in a variety of populations in the United States including the following: ranchers and volunteers from South Dakota and Wyoming (Longnecker et al. 1993), male health professionals (Rimm et al. 1992) and men and women aged 40 y and older (Jacques et al. 1993, Munger et al. 1992). However, to our knowledge, no studies have validated the use of a FFQ in a population of young women. Young women, in particular, are at risk of low folate intakes and suboptimal folate status as a result of poor dietary habits along with self-imposed restriction of energy secondary to concerns about weight gain (Bailey 1990a). Further, pregnancy, which places heavy demands on folate supplies, is a possibility in this population.

The purpose of this study was to estimate intakes of folate and vitamin B-12 in a group of young women (16–19 y of age) by using a semiquantitative FFQ and a 3-d weighed food record (3d-WFR). In addition, the validity of a FFQ and 3d-WFR in estimating usual intakes of folate and vitamin B-12 was assessed by correlating folate and vitamin B-12 intakes derived using these two dietary measures with biochemical indices. Further, the ability of the FFQ and the 3d-WFR to classify participants’ nutrient intakes correctly into quartiles of blood vitamin levels was determined.

**MATERIALS AND METHODS**

**Study population.** A sample of 105 adolescent female volunteers aged 16–19 y was recruited from September 1994 to March of 1995 from Southern Ontario, Canada, via publicity in local newspapers, universities, community colleges, shopping malls and other commercial areas frequented by adolescents. Exclusion criteria included the use of drugs known to interfere with folate metabolism and the presence of chronic disease. In addition, pregnant females or females who had a pregnancy lasting more than 20 wks in the year before the scheduled clinic visit were also excluded. Informed written consent was obtained from each participant after the purpose, significance and the protocol of the study were fully explained. The research protocol was approved by the University of Guelph Human Ethics Committee.

**Biochemical assessment.** Participants attended an early morning clinic visit after an overnight fast. Blood was collected via venipuncture from participants into evacuated containers with and without heparin. Hematocrits were determined on freshly collected heparinized blood. For the RBC folate assay, two 100-µL aliquots of heparinized whole blood were diluted with 1.0 mL of 4 g/L ascorbate solution to prevent the oxidation of folate. Plasma from heparinized containers and serum from containers with no anticoagulant were separated from whole blood by centrifugation (620 x g for 20 min at 3°C). Blood samples were stored at −75°C until analyzed for folate and vitamin B-12 concentrations.

Concentrations of serum folate and vitamin B-12 were measured using a dual isotope kit (Quantaphase Folate/B-12 Radioassy, Bio-Rad Laboratories, Mississauga, Canada). The accuracy of these radioassay methods was checked through serial replication of three levels of control sera (Lyphocheck, Bio-Rad Laboratories, Mississauga, Canada). All control sera fell within the manufacturer’s stated limits. The interassay coefficient of variation for serum folate and vitamin B-12 was 6.2 and 6.4%, respectively. At the time these analyses were performed, there was widespread concern regarding the use of radioassays to analyze blood folates (Gunter et al. 1996, Sauерlisch 1995). As demonstrated by Gunter et al. (1996), we found in our laboratory that analysis of serum samples with the use of either the microbiological method or radioassay with the newer Quanta Phase Folate/B-12 kit yielded virtually identical folate concentrations.

In contrast, the two methods yielded markedly different results for RBC folate concentrations. Hence, whole blood folate and heparinized plasma folate concentrations (used for determination of RBC folate) were determined using the microtrit technique described by Tamura (1958) with Lactobacillus casei (ATCC 7469) as the test microorganism. The interassay coefficient of variation for the microtrit technique was 6.7% based upon repeated measurements of a pooled serum sample.

**Dietary assessment.** After providing a blood sample, participants completed a self-administered 116-item semiquantitative FFQ developed by Willett et al. (1985 and 1988). The questionnaire was designed to assess usual intake over the previous year. Where possible, the portion sizes used in the questionnaire were based on the typical or natural portion consumed (e.g., a slice of bread, one egg, one cup of coffee). When a typical or natural portion size was not obvious, a commonly used portion size was selected (e.g., one cup rice). For the purposes of this study, portion sizes provided with the FFQ were not adjusted for the age or gender of subjects. The reproducibility (precision) of various forms of this questionnaire has been determined in a variety of adult populations, and correlations between repeated FFQ for folate intake have ranged from 0.57 to 0.87 (Longnecker et al. 1993, Munger et al. 1992, Rimm et al. 1992). Similarly, vitamin B-12 intakes have ranged from 0.39 to 0.87 (Longnecker et al. 1993, Munger et al. 1992, Rimm et al. 1992). The nutrient database used to calculate nutrient intakes from this FFQ was derived primarily from information from the Consumer and Food Economic Institute (1976–1991) compiled by the USDA with additional published data and information from food manufacturers (Willett et al. 1985). Because Canadian cold breakfast cereals are fortified with considerably lower levels of folate and vitamin B-12 than those in the U.S., the intakes of these vitamins derived from the FFQ were modified to reflect these differences. Nutrient values for cold breakfast cereals were obtained from Health and Welfare Canada (1988).

During the week after the clinic visit, a 3d-WFR was completed by each participant. Care was taken to ensure that there was proportional distribution of week and weekend days for the dietary records among subjects. All participants were provided with an electronic digital scale (Soehnle, CMS Weighing Equipment, London, UK) and received detailed instructions on how to accurately weigh the food and beverage consumed and washed out each week. Nutrient intakes were calculated using the Department of Family Studies Nutrient Intake System (Sabry et al. 1982). Most of the food composition values in the database were from the Consumer and Food Economic Institute (1976–1991). The folate and vitamin values for cereals and grains were modified by information from Health and Welfare Canada (1988) to incorporate the differences in Canadian fortification laws for folate and vitamin B-12. Additional values for certain food items were obtained from Holland et al. (1991). There were no missing values for any folate or vitamin B-12-containing foods in the database.

Supplement information obtained from the FFQ and the 3d-WFR was not used; rather, participants were asked to bring to the clinic visits any nutritional supplements they were currently taking. Information collected from supplement containers and a self-administered questionnaire completed by each participant included the type of supplement used, the brand name, the dosage, average use during the previous year and the frequency of use during the week before the survey. Average daily intakes of supplemental folate and vitamin B-12 were calculated from the responses and were added to the participants’ dietary intakes of these vitamins for both the FFQ and 3d-WFR estimates.

**Statistical analysis.** Statistical analyses were performed by using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS) Version 6, SAS Institute, Cary, NC. A probability level of 5% was chosen as the level of significance. Biochemical indices and folate intakes (FFQ and 3d-WFR) were normalized using logarithmic transformations; vitamin B-12 intakes (FFQ and 3d-WFR) were normalized using a square root transformation. 7 tests were used to compare folate and vitamin B-12 intakes as esti-
DIETARY METHODS TO PREDICT FOLATE AND VITAMIN B-12 STATUS

RESULTS

The mean age of the participants was 18.5 ± 0.1 y (mean ± SEM). Fourteen, 19, 29 and 43 of the young women were 16, 17, 18 and 19 y of age, respectively. Ninety-five of the participants were Caucasian, one was Black, and nine were Asian. Of the 105 participants, 61 lived at home with one or both parents, 39 lived with friends or in a university dormitory, three lived with a boyfriend and two lived alone. At the time of the survey, 64 of the participants were in high school or had completed high school and 41 were in university or college.

Median energy and nutrient intakes expressed on an absolute and a 4.2 MJ (1000 kcal) basis are presented in Table 1. There was relatively poor agreement between median folate and vitamin B-12 intakes as assessed by FFQ vs. the 3d-WFR. Considering all young women in the analyses (i.e., both supplement users and nonusers), the median intake for folate determined by the FFQ was 1.5 times that determined by the 3d-WFR (P < 0.001). Similarly, the median vitamin B-12 intake as determined from the FFQ was 2.5 times that determined from the 3d-WFR (P < 0.001). The median (range) intake of supplemental folic acid and vitamin B-12 in this sample was 5 µg (1.3–34.3) and 200 µg (21–1000) per day.

Based on the 3d-WFR data, 12.4% (13 of 105) and 17.5% (18 of 103) of participants had folate and vitamin B-12 intakes, respectively, less than two thirds of the Canadian Recommended Nutrient Intakes (RNI) (Health and Welfare Canada 1990). Similarly, based on the FFQ, only 2.8% (3 of 105) and 1.0% (1 of 103) had folate and vitamin B-12 intakes, respectively, less than two thirds of the RNI. The RNI for folate (3.1 µg folate/kg body weight or ~180–190 µg/d) is less than half of subsequent folate recommendations for women of childbearing potential to reduce their risk of having a pregnancy affected by NTD (Centers for Disease Control 1992, Health and Welfare Canada 1995). Approximately 90% (94 of 105) and 63% (66 of 105) of participants had folate intakes < 400 µg/d, based on 3d-WFR and FFQ estimates, respectively.

Median biochemical levels are presented in Table 2. Using a cut-off value of 6.7 nmol/L for serum folate and 317 nmol/L for RBC folate, 15.7% (16 of 102) and 3.8% (4 of 104) of

### TABLE 1

Quartiles of energy, folate, and vitamin B-12 intake as determined by a food-frequency questionnaire (FFQ) and 3-d weighed food record (3d-WFR) in a group of women aged 16–19 y

<table>
<thead>
<tr>
<th>Variable</th>
<th>n²</th>
<th>Absolute intake</th>
<th>FFQ</th>
<th>3d-WFR</th>
<th>Intake/4.2 MJ (1000 kcal)</th>
<th>FFQ</th>
<th>3d-WFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (g)</td>
<td>8.3 (6.5, 10.6)³</td>
<td>7.5 (6.2, 9.3)</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Supplement nonusers</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Folate, µg</td>
<td>82</td>
<td>289 (218, 400)a</td>
<td>187 (143, 258)</td>
<td>146 (114, 146)a</td>
<td>102 (87, 163)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B-12, µg</td>
<td>81</td>
<td>4.4 (3.4, 7.0)a</td>
<td>1.7 (0.7, 2.4)</td>
<td>2.3 (1.6, 3.5)b</td>
<td>0.8 (0.4, 1.3)</td>
<td></td>
<td></td>
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<tr>
<td>Supplement users</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folate, µg</td>
<td>22</td>
<td>572 (415, 665)a</td>
<td>386 (324, 501)</td>
<td>269 (213, 362)a</td>
<td>209 (159, 267)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B-12, µg</td>
<td>22</td>
<td>11.4 (7.5, 13.9)a</td>
<td>7.4 (5.7, 7.9)</td>
<td>5.0 (4.0, 9.4)a</td>
<td>4.4 (2.8, 9.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplement users + nonusers</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folate, µg</td>
<td>104</td>
<td>346 (229, 494)a</td>
<td>215 (155, 301)</td>
<td>165 (122, 217)a</td>
<td>112 (87, 163)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B-12, µg</td>
<td>103</td>
<td>4.9 (3.6, 10.0)a</td>
<td>1.9 (1.0, 3.7)</td>
<td>2.6 (1.7, 4.3)</td>
<td>1.0 (0.6, 2.0)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ Nutrient intake estimates included supplemental sources of vitamins for supplement users.
² Nutrient intakes for subjects were calculated only if there was a corresponding blood index for that nutrient (e.g., serum vitamin B-12 for vitamin B-12 intake and either serum folate or RBC folate for folate intake).
³ Median (1st, 3rd quartile).
⁴ Significantly different from 3d-WFR, P < 0.001.
⁵ Significantly different from 3d-WFR, P = 0.006.
participants had blood folate levels indicative of folate deficiency, respectively (Sauberlich 1995). Only 2.0% (2 of 100) of participants had both serum and RBC folate levels indicative of folate deficiency. Of the participants, 0 and 3.9% (4 of 103) had serum vitamin B-12 concentrations in the indeterminate (118-148 pmol/L) and deficient range (<118 pmol/L), respectively. Supplement users had higher serum folate, RBC folate and vitamin B-12 concentrations than supplement non-users.

The correlations between folate intakes and serum and RBC folate concentrations are summarized in Table 3. When supplement users were included in these analyses, folate intakes as determined by the 3d-WFR (adjusted \( r = 0.65, P < 0.01 \)) showed a higher correlation (\( P = 0.017 \)) with serum folate than did intakes from the FFQ (\( r = 0.48, P < 0.01 \)). Excluding supplement users from the statistical analyses decreased the association between folate intakes as determined by both dietary methods and serum folate concentrations (3d-WFR, \( r = 0.46, P < 0.01 \); FFQ, \( r = 0.38, P < 0.01 \)). In this case, the strength of the correlation between folate intakes concentrations as determined by 3d-WFR or FFQ and serum folate concentrations did not differ.

The correlations between folate intakes and RBC folate concentrations as determined by both 3d-WFR and FFQ intake methods were \( r = 0.50 (P < 0.01) \) and \( r = 0.42 (P < 0.01) \), respectively, (no significant difference between methods). After excluding supplement users from these analyses, the association between folate intakes estimated by using the FFQ and RBC folate concentrations remained significant (\( r = 0.25, P = 0.03 \)); however, the association between folate intakes as determined by 3d-WFR and RBC folate concentrations was significant only after adjustment for the ratio of intra- to intersubject variation in folate intakes (\( r = 0.23, P = 0.01 \)).

Vitamin B-12 intake as determined by either dietary method showed only a modest association with serum vitamin B-12 concentrations when supplement users were included in the analyses (3d-WFR, \( r = 0.32, P < 0.01 \); FFQ, \( r = 0.25, P < 0.05 \), i.e., no significant difference between methods). Excluding supplement users did not appreciably change the association between vitamin B-12 intakes estimated from the 3d-WFR and serum vitamin B-12 concentrations (\( r = 0.38, P < 0.01 \)); however, the relationship between vitamin B-12 intakes as determined by FFQ and serum vitamin B-12 was no longer significant (\( r = 0.19, P = 0.09 \)).

Adjusting for energy and/or age did not significantly improve the associations between dietary intakes and biochemical indices (data not shown). However, adjustment for the ratio of intra- to intersubject variation improved the correlations for the 3d-WFR especially when supplement users were excluded. For example, this adjustment improved the correlation between folate intakes as determined by 3d-WFR and RBC folate from 0.18 to 0.23 such that this relationship reached significance (\( P < 0.05 \)). The ratio of intra- to intersubject variation (i.e., variance ratio) for folate and vitamin B-12 intake excluding supplement users was 2.36 and 2.77, respectively. The inclusion of supplement users reduced these ratios to 0.94 and 0.27, respectively.

The ability of the dietary methods to classify individuals into the correct quartile of blood vitamin concentrations is shown in Table 4. The FFQ and 3d-WFR performed comparably in this regard. Regardless of dietary methodology, at least 75% of folate intakes were either correctly or closely classified when intakes from supplements were included in the analyses. Removing supplement users generally decreased the number of correctly classified individuals, and the correct classification of folate intakes (determined by 3d-WFR) as evaluated by RBC folate concentrations was no longer significant. Only when intake values were determined from 3d-WFR and supple-

**TABLE 2**

<table>
<thead>
<tr>
<th>Biochemical indicators</th>
<th>n</th>
<th>Supplement nonusers</th>
<th>Supplement users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serum folate, nmol/L</td>
<td>102</td>
<td>9.1 (7.0, 12.5)(^{1}A)</td>
<td>20.4 (11.5, 27.0)(^{1}A)</td>
</tr>
<tr>
<td>RBC folate, nmol/L</td>
<td>104</td>
<td>626 (487, 863)</td>
<td>1138 (862, 1371)(^{1}A)</td>
</tr>
<tr>
<td>Serum B-12, pmol/L</td>
<td>103</td>
<td>281 (223, 337)</td>
<td>349 (248, 451)(^{1}B)</td>
</tr>
</tbody>
</table>

\(^{1}\) Median (1st, 3rd quartile).
\(^{2}\) Significantly different from supplement nonusers, \( P < 0.001 \).
\(^{3}\) Significantly different from supplement nonusers, \( P < 0.05 \).

**TABLE 3**

<table>
<thead>
<tr>
<th>Independent variable</th>
<th>Serum folate</th>
<th>RBC folate</th>
<th>Serum vitamin B-12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( r )</td>
<td>( P )-value</td>
<td>( n )</td>
</tr>
<tr>
<td>Supplement nonusers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folate intake (FFQ)</td>
<td>0.38</td>
<td>&lt;0.01</td>
<td>81</td>
</tr>
<tr>
<td>Folate intake (3d-WFR)</td>
<td>0.46</td>
<td>&lt;0.01</td>
<td>81</td>
</tr>
<tr>
<td>Vitamin B-12 intake (FFQ)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Vitamin B-12 intake (3d-WFR)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supplement users + nonusers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folate intake (FFQ)</td>
<td>0.48(^{B})</td>
<td>&lt;0.01</td>
<td>102</td>
</tr>
<tr>
<td>Folate intake (3d-WFR)</td>
<td>0.65(^{B})</td>
<td>&lt;0.01</td>
<td>102</td>
</tr>
<tr>
<td>Vitamin B-12 intake (FFQ)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vitamin B-12 intake (3d-WFR)</td>
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</table>

\(^{1}\) The large intrasubject variance for nutrient intake tended to attenuate the correlation between nutrient intakes derived from the 3d-WFR and biochemical indices. Hence, the correlation coefficients between the nutrient intake as determined from the 3d-WFR and biochemical indices were adjusted to take this into account.

\(^{2}\) Unlike superscripts denote a significant difference between the strength of the correlations between nutrient intakes and biochemical indices as estimated by FFQ vs. 3d-WFR.
TABLE 4
Percentage of participants correctly, closely or misclassified into quartiles of folate and vitamin B-12 intake as determined by a 3-d weighed food record or a food-frequency questionnaire compared with classification by biochemical indices

<table>
<thead>
<tr>
<th>Variable</th>
<th>3-d weighed food record</th>
<th>Food-frequency questionnaire</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correctly classified</td>
<td>Closely classified</td>
</tr>
<tr>
<td>Including supplement users</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Serum folate</td>
<td>102</td>
<td>43</td>
</tr>
<tr>
<td>RBC folate</td>
<td>104</td>
<td>44</td>
</tr>
<tr>
<td>Serum vitamin B-12</td>
<td>103</td>
<td>42</td>
</tr>
<tr>
<td>Excluding supplement users</td>
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<td></td>
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<tr>
<td>Serum folate</td>
<td>81</td>
<td>30</td>
</tr>
<tr>
<td>RBC folate</td>
<td>82</td>
<td>23</td>
</tr>
<tr>
<td>Serum vitamin B-12</td>
<td>81</td>
<td>32</td>
</tr>
</tbody>
</table>

1 Percentage of participants misclassified by one quartile.
2 Percentage of participants misclassified by two or more quartiles.
3 A P-value < 0.05 indicates that there is a significant association between nutrient intake estimates and the appropriate blood nutrient concentration.

DISCUSSION

Results from this study suggest that both the FFQ and 3d-WFR are valid measures for assessing the folate intakes of young women aged 16–19 y. Using serum folate concentration as the sole biochemical criterion, it appeared that the 3d-WFR was superior to the FFQ as a tool to predict the folate intakes of young women (P = 0.017). The correlation coefficient between folate intakes estimated using the 3d-WFR and serum folate was 0.65 (adjusted for the ratio of intraclass subject variation) vs. 0.48 for the FFQ. Garry et al. (1984) reported a correlation of 0.49 (unadjusted) between folate intake as determined by 3d-WFR and plasma folate concentrations in a group of elderly men and women (n = 270) participating in the New Mexico Aging Process Study. Using a FFQ, Jacques et al. (1993) reported a correlation of r = 0.60 (energy, sex and age adjusted) between folate intakes and plasma folate concentrations in a group of 139 adults aged 40–83 y.

However, when RBC folate concentration was used as the biochemical outcome criterion, the FFQ and the 3d-WFR appeared to perform equally well in predicting folate intakes. Correlations between folate intakes determined with the use of the FFQ and 3d-WFR and RBC folate concentrations were 0.42 and 0.50, respectively. A similar correlation of 0.55 was observed between RBC folate concentrations determined in 1987 and folate intakes assessed via a FFQ administered in 1980 to a subsample of adult women who participated in the Nurses’ Health Study (Giovannucci et al. 1993). A similar correlation of 0.49 (unadjusted) was observed between folate intake as determined by a 3d-WFR and RBC folate concentrations (Garry et al. 1984). In a small group of elderly British subjects, a correlation of 0.51 (unadjusted) was observed between folate intakes as determined by 1 y of continuous diet records (n = 19) and RBC folate concentrations (Bates et al. 1982). In contrast, no correlation was observed between folate intakes as determined by food records and RBC folate in another British study (Bingham et al. 1995).

The finding in this study that folate intakes as determined by the 3d-WFR correlated better with serum folate than did folate intakes determined by FFQ is not unexpected. Serum folate is influenced by recent changes in folate intake; it is also indicative of the folate status at the time the blood sample is collected and may not always reflect folate stores (Bailey 1990b). In this study, the 3d-WFR were collected at the time of blood sampling and reflect nutrient intakes at that time. In contrast, the FFQ is designed to assess usual nutrient intake over the previous year which may or may not represent very recent dietary intake. Had the 3d-WFR been collected before blood sampling, the correlation between folate intake as estimated by 3d-WFR and serum folate might have improved.

Given the relatively long lifespan of red blood cells, it is unlikely that the timing of the 3d-WFR relative to the blood draw influenced the strength of this correlation.

Results from this study also suggest that both the FFQ and the 3d-WFR are valid measures of assessing the vitamin B-12 intakes of young women aged 16–19 y when both supplement users and nonusers were included in the analyses; however, the strength of the association between nutrient intakes as determined by either dietary methodology on blood values was less impressive than for folate. The correlation between vitamin B-12 intakes as determined by the FFQ (r = 0.25) and a 3d-WFR (r = 0.32) and serum vitamin B-12 were similar. In the New Mexico Aging Process Study, a correlation of 0.45 was observed between vitamin B-12 intake (including supplement users) determined from a 3-d food record and plasma cobalamin concentrations (Garry et al. 1984). Our results for the FFQ are consistent with those of Jacques et al. (1993), who observed a correlation (age, sex and energy adjusted) of 0.35 between vitamin B-12 intakes estimated from a FFQ and serum vitamin B-12 concentrations.

Although most associations remained significant, excluding supplement users generally attenuated the correlations between folate or vitamin B-12 intakes estimated by either of the dietary intake methods and their respective biochemical indices. This was expected because including supplement users increased the range of both vitamin intakes and vitamin concentrations in blood, thereby improving the correlation between the two.

In examining the correlations between dietary intakes and blood indices, it must be acknowledged that nutrient levels in the blood may be affected by factors other than the total intake of any given nutrient. For example, blood folate levels may be

mental vitamin B-12 intakes were included in the analyses were vitamin B-12 intakes correctly or closely classified to their respective quartile of serum vitamin B-12 more often than would be expected by chance.
influenced by the form of the folate ingested (supplemental vs. dietary) (Halsted 1990), smoking (Senti and Pilch 1985), chronic alcohol consumption (Herbert 1990) and certain prescription drugs (Roe 1990).

There were generally fair to good correlations between nutrient intakes and biochemical indices using either the FFQ or 3d-WFR, whereas estimates of absolute intake differed markedly. Median daily intakes for folate (346 vs. 212 µg) and vitamin B-12 (4.9 vs. 1.9 µg) estimated from the FFQ were much higher than those obtained from the 3d-WFR. There are several attractive and common explanations for this observation. First, use of 3d-WFR may have caused study participants to alter and underreport their usual dietary intake (Willett 1990). Second, the list of foods in the FFQ used in this study was designed for an American adult population and, consequently, contains foods most discriminating for this population (Willett 1990). Snack foods are known to contribute studies (Willett 1990). Although both methods appear to be study was designed for an American adult population and, make it a more attractive method than the 3d-WFR for the determination of usual folate intake in most epidemiologic studies (Willett 1990). Although both methods appear to be useful in determining vitamin B-12 intake when supplement users are included, the poor correlation between vitamin B-12 intake determined from a FFQ and serum vitamin B-12 suggests that the FFQ is not valid for the determination of vitamin B-12 intake from food alone in this population. Finally, these findings indicate that markedly different conclusions about absolute folate and vitamin B-12 intakes may be obtained depending on the dietary methodology employed. Given that these estimates of intake in relation to blood indices or desirable health outcomes (e.g., reduced risk of a NTD-affected pregnancy or cardiovascular disease) are often used to develop public policy recommendations, one must be mindful that the dietary instrument used may over- or underestimate actual nutrient intake.

**LITERATURE CITED**


