Serum and red blood cell folate concentrations, race, and education: findings from the third National Health and Nutrition Examination Survey[1,2]

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ABSTRACT

Background: Little is known about the relations between race or ethnicity, educational attainment, and serum and red blood cell folate concentrations.

Objective: We examined the relation between educational attainment and serum and red blood cell folate concentrations in 8457 white, African American, and Mexican American men and women aged ≥17 y.

Design: We performed a cross-sectional analysis using data from Phase 1 of the third National health and Nutrition Examination Survey (1988–1991).

Results: White men had significantly higher adjusted serum and red blood cell folate concentrations (16.9 and 502.6 nmol/L, respectively) than did African American men (15.6 and 423.3 nmol/L, respectively) or Mexican American men (16.0 and 457.0 nmol/L, respectively); white women had significantly higher concentrations (18.4 and 515.9 nmol/L, respectively) than did African American women (16.3 and 415.4 nmol/L, respectively) or Mexican American women (15.9 and 455.7 nmol/L, respectively). For the entire sample, rank correlation coefficients between educational attainment and serum and red blood cell folate were 0.11 and 0.12, respectively, and were larger in white participants than in other participants. No significant linear trends between adjusted serum or red blood cell folate and educational attainment were found. Among participants with >12 y of education, the mean adjusted concentrations of serum folate were 15% and 18% lower and those of red blood cell were 18% and 22% lower in African American men and women than in white men and women, respectively.

Conclusions: African Americans and Mexican Americans could benefit most from public health programs to boost folate intakes by encouraging increased intake of folate-rich foods and vitamin supplements. *Am J Clin Nutr* 1999;69:476–81.

KEY WORDS Education, ethnic group, folic acid, health surveys, third National Health and Nutrition Examination Survey, NHANES III, African Americans, Mexican Americans

INTRODUCTION

Because of the beneficial effects of folate in preventing neural tube defects (1, 2), and perhaps cardiovascular disease (3) and selected cancers (4), current knowledge about serum and red blood cell concentrations of folate in the US population is of considerable interest. Previous analyses of the second National Health and Nutrition Examination Survey (NHANES II) data from adults showed that serum and red blood cell folate concentrations increased with increasing age (5). Although the percentage of participants with low serum folate concentrations, defined as <6.8 nmol/L (3 ng/mL), differed according to smoking status, supplement use, aspirin use, education, poverty income ratio, race, pregnancy, and parity, none of these differences were statistically significant. Small sample size may be partly responsible for the failure to find statistically significant differences. Furthermore, the proportion of participants with low serum and red blood cell folate concentrations did not differ according to medication use or use of oral contraceptives. However, folate data were only obtained from a relatively small sample of NHANES II participants, and 2 different assays were used, making interpretation difficult.

If public health interventions to increase folate consumption in the United States are to be effective, the populations with the greatest need for folate must be identified. Therefore, we examined data from Phase 1 of NHANES III, collected in 1988–1991, to explore racial or ethnic and educational differences in serum and red blood cell folate concentrations. Because educational attainment is often linked to better nutritional practices, we were interested in whether education was associated with folate concentrations in the sexes and racial or ethnic groups and whether any racial or ethnic differences in folate concentrations would be a function of educational attainment.

SUBJECTS AND METHODS

Subjects

To obtain information about the health of the US population, a population sample is periodically asked to participate in an

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NHANES. The latest in this series of health surveys, NHANES III, was started in 1988 and completed in 1994. Interviews were conducted in the participants' homes and at the conclusion of the interviews blood pressure measurements were taken. Participants were asked to appear at a mobile examination center on a subsequent date, where they completed additional questionnaires, had blood drawn, and underwent a series of examinations. Participants who were unable for health reasons or unwilling to attend the examination centers were offered a limited home examination. For this analysis we included only data from the first phase, conducted during 1988–1991, because data for serum cotinine, a measure of exposure to tobacco, were available for only this phase. Using a multistage, stratified sampling design, NHANES III included a representative sample of the noninstitutionalized US population. Details of the plan and operation of NHANES III have been published (6).

Methods

For Phase 1 of NHANES III, serum and red blood cell folate concentrations were measured by using a radioassay (Quanta-Phase I; Bio-Rad Laboratories, Hercules, CA) (7). A detailed discussion of the methods used to measure folate concentrations in NHANES III was published (8). Because standards for the Quanta-Phase I kit were calibrated erroneously, a correction factor was applied to the original folate values. Raiten and Fisher (8) discussed this issue in detail.

Variables included in this analysis included age, race or ethnicity (white, African American, or Mexican American), educational attainment, serum cotinine concentration, body mass index, alcohol use, dietary folate (from a single 24-h recall), vitamin and mineral supplement use during the previous 24 h, fruit and vegetable consumption, cereal intake, pregnancy status, and use of oral contraceptives or hormone replacement therapy. Persons of Hispanic origin were not included in the white or African American groups. Serum cotinine concentration was determined by using an enzyme-linked immunoassay (STC Diagnostics, Bethlehem, PA). Frequency of alcohol use, fruit and vegetable consumption, and cereal intake during the previous month were obtained from a food-frequency questionnaire. Portion sizes were not included in the questionnaire. We summed up the responses to the questions on fruit and vegetable intake and dichotomized this variable into < 150 and ≥150 times/mo to correspond with the recommendation to consume 5 fruits and vegetables/d. Vitamin and mineral suplement use was determined with the question, Have

TABLE 1

Unadjusted baseline characteristics, by sex and race, of participants in phase I of the third National Health and Nutrition Examination Survey, 1988–1991[1]

Baseline characteristic	White	African American	Mexican American	P^2 W × AA	W × MA	AA × MA
Men						
Age (y)	43.2 ± 0.5 [1891]	39.1 ± 0.8 [1115]	34.4 ± 0.9 [1226]	< 0.001	< 0.001	0.001
Education (y)	12.7 ± 0.1 [1891]	11.3 ± 0.2 [1115]	9.0 ± 0.2 [1226]	< 0.001	< 0.001	< 0.001
Serum cotinine (μg/L)	103.4 ± 6.0 [1779]	124.6 ± 7.4 [968]	39.7 ± 4.1 [1142]	NS	< 0.001	< 0.001
Body mass index (kg/m^2)	26.2 ± 0.1 [1891]	26.1 ± 0.2 [1111]	26.3 ± 0.2 [1217]	NS	NS	NS
Alcohol use (drinks/mo)	13.1 ± 1.0 [1889]	13.1 ± 0.7 [1115]	10.3 ± 0.7 [1226]	NS	0.020	0.022
Dietary folate intake						
(μg/d)	342.9 ± 7.4 [1834]	287.2 ± 9.8 [1066]	344.8 ± 11.6 [1175]	0.001	NS	0.001
(μg · kJ^{-1} · d^{-1})	0.6 ± < 0.1 [1834]	0.5 ± < 0.1 [1066]	0.6 ± < 0.1 [1175]	0.001	NS	0.001
Vitamin and mineral use (% ± 1 SE)	19.7 ± 1.4 [1862]	11.9 ± 1.1 [1068]	10.3 ± 0.9 [1166]	< 0.001	< 0.001	NS
Fruit and vegetable intake (times/mo)	125.2 ± 2.1 [1891]	118.4 ± 2.7 [1115]	151.4 ± 1.9 [1226]	NS	< 0.001	< 0.001
Cereal intake (times/mo)	10.6 ± 0.3 [1887]	8.5 ± 0.4 [1115]	6.7 ± 0.2 [1226]	0.001	< 0.001	0.001
Serum folate (nmol/L)	13.2 ± 0.4 [1823]	10.1 ± 0.2 [990]	10.4 ± 0.3 [1171]	< 0.001	< 0.001	NS
Red blood cell folate (nmol/L)	439.3 ± 8.4 [1840]	325.9 ± 6.8 [1008]	364.3 ± 14.3 [1172]	< 0.001	< 0.001	0.019
Women						
Age (y)	45.2 ± 0.6 [1859]	40.1 ± 0.7 [1176]	36.6 ± 1.0 [1190]	< 0.001	< 0.001	0.010
Education (y)	12.5 ± 0.1 [1859]	11.8 ± 0.2 [1176]	9.0 ± 0.2 [1190]	0.004	< 0.001	< 0.001
Serum cotinine (μg/L)	68.9 ± 4.9 [1716]	89.1 ± 6.8 [1022]	19.5 ± 4.1 [1091]	0.025	< 0.001	< 0.001
Body mass index (kg/m^2)	25.7 ± 0.2 [1855]	27.8 ± 0.3 [1171]	27.3 ± 0.2 [1175]	< 0.001	< 0.001	NS
Alcohol use (drinks/mo)	5.8 ± 0.6 [1858]	3.9 ± 0.3 [1176]	2.2 ± 0.3 [1189]	0.011	< 0.001	< 0.001
Dietary folate intake						
(μg/d)	245.2 ± 4.5 [1807]	214.9 ± 6.6 [1132]	253.0 ± 10.3 [1165]	0.001	NS	0.005
(μg · kJ^{-1} · d^{-1})	0.6 ± < 0.1 [1807]	0.5 ± < 0.1 [1132]	0.6 ± < 0.1 [1165]	< 0.001	NS	0.002
Vitamin and mineral use (% ± 1 SE)	29.8 ± 1.7 [1824]	18.1 ± 1.0 [1134]	18.8 ± 2.2 [1147]	< 0.001	< 0.001	NS
Pregnant (% ± 1 SE)	5.2 ± 1.0 [775]	7.2 ± 1.1 [713]	9.8 ± 1.7 [793]	NS	0.038	NS
Oral contraceptive use by women aged 17–45 y (% ± 1 SE)	18.7 ± 1.6 [756]	19.8 ± 2.8 [693]	16.1 ± 1.4 [756]	NS	NS	NS
Hormone replacement therapy use by women aged ≥ 50 y (% ± 1 SE)	17.7 ± 1.5 [919]	8.1 ± 1.9 [369]	11.5 ± 2.8 [303]	0.001	NS	NS
Fruit and vegetable intake (times/mo)	137.8 ± 2.6 [1859]	122.5 ± 3.0 [1176]	155.8 ± 2.7 [1190]	0.001	< 0.001	< 0.001
Cereal intake (times/mo)	10.2 ± 0.3 [1858]	8.8 ± 0.3 [1176]	9.5 ± 0.5 [1189]	0.004	NS	NS
Serum folate (nmol/L)	16.4 ± 0.5 [1758]	11.8 ± 0.3 [1046]	12.0 ± 0.7 [1133]	< 0.001	< 0.001	NS
Red blood cell folate (nmol/L)	483.4 ± 9.7 [1776]	342.7 ± 8.6 [1053]	393.7 ± 21.1 [1138]	< 0.001	< 0.001	0.031

[1] $\bar{x}$ ± SE except where noted. *n* in brackets.

[2] W × AA, whites compared with African Americans; W × MA, whites compared with Mexican Americans; AA × MA, African Americans compared with Mexican Americans.

TABLE 2
Unadjusted and adjusted serum and red blood cell folate concentrations, by race, in women aged 17–49 y, participating in the third National Health and Nutrition Examination Survey, 1988–1991[1]

Folate concentration	White	African American	Mexican American	P^2 W × AA	P^2 W × MA	P^2 AA × MA
		nmol/L				
Unadjusted						
Serum	13.9 ± 0.5 [811]	10.8 ± 0.2 [684]	11.5 ± 0.8 [821]	<0.001	0.016	NS
Red blood cell	432.9 ± 12.3 [817]	320.9 ± 8.2 [688]	387.1 ± 22.5 [823]	<0.001	0.044	0.011
Adjusted[3]						
Serum	15.8 [786]	14.1 [647]	13.9 [750]	<0.001	0.007	NS
Red blood cell	463.9 [780]	369.2 [639]	419.0 [749]	<0.001	0.008	0.014

[1] $\bar{x}$ ± SE. *n* in brackets.
[2] W × AA, whites compared with African Americans; W × MA, whites compared with Mexican Americans; AA × MA, African Americans compared with Mexican Americans.
[3] Adjusted for age, serum cotinine concentration, body mass index, fruit and vegetable consumption, vitamin and mineral supplement use, cereal intake, and alcohol use.

you taken any vitamins or minerals during the past 24 h? Women who reported that they were taking birth control pills at the time of the interview were considered to be current users. We defined current users of hormone replacement therapy as women who reported that they were using estrogen or female hormones (pills, vaginal cream, suppositories, injections, or skin patches) at the time of the interview. Pregnancy status was determined from self-report or a positive urine pregnancy test.

Statistics

Rank correlation coefficients were obtained by calculating Pearson's correlation coefficients on the ranks of continuous variables. We used analysis of covariance to calculate mean serum and red blood cell folate concentrations that were age-adjusted and adjusted for various covariates using SAS (version 6.09; SAS Institute, Cary, NC). Differences in these adjusted means were tested in SUDAAN to account for the complex sampling design of the survey (9). We used the sampling weights of the participants of the medical examination component of the survey to calculate weighted estimates. A limitation of the SUDAAN software is its inability to adjust for multiple comparisons. We restricted analyses involving oral contraceptive use to women who were ≤45 y of age and analyses involving use of hormone replacement therapy to women who were ≥50 y of age.

RESULTS

Two thousand, two hundred seventy-one white men, 1223 African American men, 1394 Mexican American men, 2300 white women, 1303 African American women, and 1317 Mexican American women were interviewed during Phase 1 of NHANES III. Participants ranged in age from 17 to >90 y. Characteristics of participants who attended the medical examination clinic and form the basis of this report are presented in **Table 1**.

TABLE 3
Unadjusted rank correlation coefficients between serum and red blood cell folate concentrations and continuous covariates, by sex and race, of participants in the third National Health and Nutrition Examination Survey, 1988–1991

	Folate (nmol/L) White: Serum	White: Red blood cell	African American: Serum	African American: Red blood cell	Mexican American: Serum	Mexican American: Red blood cell
Men						
Age (y)	0.28	0.24	0.15	0.20	0.13	0.19
Education (y)	0.13	0.14	−0.06	−0.01	0.06	0.07
Serum cotinine (μg/L)	−0.27	−0.26	−0.15	−0.16	−0.16	−0.18
Body mass index (kg/m^2)	−0.01	0.07	−0.10	0.01	−0.05	0.07
Alcohol use (drinks/mo)	0.07	0.09	−0.04	−0.07	0.07	0.01
Dietary folate intake						
(μg/d)	0.29	0.24	0.23	0.17	0.19	0.11
($\mu g \cdot kJ^{-1} \cdot d^{-1}$)	0.42	0.35	0.33	0.25	0.22	0.13
Cereal intake (times/mo)	0.40	0.36	0.22	0.15	0.20	0.10
Women						
Age (y)	0.27	0.27	0.18	0.25	0.09	0.10
Education (y)	0.11	0.09	0.02	0.02	0.02	0.02
Serum cotinine (μg/L)	−0.31	−0.33	−0.17	−0.20	−0.21	−0.23
Body mass index (kg/m^2)	−0.09	0.01	−0.07	0.03	−0.10	0.03
Alcohol use (drinks/mo)	−0.02	−0.02	−0.05	−0.03	−0.08	−0.11
Dietary folate intake						
(μg/d)	0.34	0.32	0.28	0.25	0.23	0.20
($\mu g \cdot kJ^{-1} \cdot d^{-1}$)	0.40	0.35	0.37	0.31	0.26	0.15
Cereal intake (times/mo)	0.35	0.31	0.30	0.25	0.24	0.15

There were significant differences in age, educational attainment, serum cotinine concentration, alcohol intake, dietary folate intake, fruit and vegetable consumption, cereal consumption, and vitamin and mineral use among the 3 groups of men and women (Table 1). In addition, body mass index and hormone replacement therapy use differed significantly among the 3 groups of women. A larger percentage of Mexican American than white women were pregnant.

White men and women had higher concentrations of serum and red blood cell folate than did African American or Mexican American men and women (Table 1). Serum and red blood cell folate concentrations were lower in women aged 17–49 y (**Table 2**) than in the total sample of women (Table 1). White women had the highest concentrations of serum and red blood cell folate among the 3 race or ethnic groups.

Age, dietary folate consumption, cereal consumption, and serum cotinine concentration showed the largest correlation coefficients with serum and red blood cell folate concentrations in men and women (**Table 3**). Serum and red blood cell folate concentrations were higher in participants who consumed ≥150 fruits and vegetables/mo compared with those who did not, except in Mexican American women (**Table 4**). Significant differences in serum and red blood cell folate concentrations according to use of vitamin and mineral supplements were also evident. Generally, women who used hormone replacement therapy had higher serum and red blood cell folate concentrations than women who did not.

Women aged ≥50 y using hormone replacement therapy reported an average of 1.3 more years of education and were, as a group, 5.4 y younger than women not using hormone replacement therapy. To examine the issue of use of hormone replacement therapy further, we ran a multiple linear regression model with serum and red blood cell folate as dependent variables and age, race, education, and use of hormone replacement therapy as independent variables in women aged ≥50 y. Use of hormone replacement therapy was a borderline independent predictor of untransformed serum folate concentration ($P = 0.089$) and an independent predictor of log-transformed serum folate concentration ($P = 0.003$). Use of hormone replacement therapy remained an independent predictor of untransformed serum folate concentration ($P = 0.003$) and log-transformed serum folate concentration ($P < 0.001$).

After adjusting for age, serum cotinine concentration, body mass index, fruit and vegetable consumption, cereal intake, vitamin and mineral supplement use, and alcohol consumption, white men had higher serum and red blood cell folate concentrations than did African American or Mexican American men, and white women had higher serum and red blood cell concentrations than did African American or Mexican American women (**Tables 5 and 6**). When stratified by educational attainment, the differences in serum folate concentrations between white or Mexican American men and African American men were significant for those with >12 y of education; differences in red blood cell folate concentrations were significant among the 3 groups of men for most groups of men for most levels of education. The results among women were generally similar to the results among men.

Educational attainment was only weakly related to serum or red blood cell folate concentrations. Correlation coefficients

TABLE 4
Unadjusted serum and red blood cell folate concentrations by categorical variables, and by sex and race, of participants in the third National Health and Nutrition Examination Survey, 1988–1991[1]

	Folate concentration					
	White		African American		Mexican American	
	Serum	Red blood cell	Serum	Red blood cell	Serum	Red blood cell
	nmol/L					
Men						
Vitamin and mineral use						
Yes	21.5 ± 0.8[2]	590.6 ± 17.2[2]	16.7 ± 1.0[2]	440.0 ± 26.1[2]	14.7 ± 1.1[2]	451.3 ± 26.4[2]
No	11.3 ± 0.3	403.9 ± 6.7	9.2 ± 0.2	311.1 ± 7.0	9.9 ± 0.3	354.5 ± 13.3
Fruit and vegetable intake						
<150/mo	12.3 ± 0.3[2]	420.4 ± 8.9	9.8 ± 0.2[3]	318.8 ± 6.8	10.0 ± 0.4	358.7 ± 13.1
≥150/mo	15.4 ± 0.5	485.0 ± 10.7	10.9 ± 0.4	345.8 ± 9.7	10.7 ± 0.4	372.1 ± 16.4
Women						
Vitamin and mineral use						
Yes	26.3 ± 1.1[2]	639.5 ± 15.0[2]	18.9 ± 1.2[2]	461.6 ± 21.0[2]	19.5 ± 1.4[2]	493.4 ± 22.0[2]
No	12.3 ± 0.3	415.5 ± 8.9	10.0 ± 0.2	314.1 ± 8.7	10.2 ± 0.3	371.7 ± 19.8
Fruit and vegetable intake						
<150/mo	14.9 ± 0.3[2]	450.7 ± 9.7	11.3 ± 0.3[3]	328.4 ± 7.0	12.1 ± 0.7	395.1 ± 20.2
≥150/mo	19.1 ± 0.8	542.8 ± 12.7	13.3 ± 0.6	381.9 ± 18.0	11.9 ± 0.6	391.0 ± 23.3
Oral contraceptive use by women aged <45 y						
Yes	12.6 ± 0.7	403.9 ± 17.9	11.2 ± 0.9	301.3 ± 17.5	10.5 ± 0.5	375.7 ± 24.5
No	13.9 ± 0.6	428.1 ± 10.5	10.6 ± 0.2	323.1 ± 7.8	11.6 ± 0.9	389.9 ± 22.9
Hormone replacement therapy by women aged ≥50 y						
Yes	21.3 ± 1.3	605.0 ± 25.7[4]	19.4 ± 2.7[4]	506.6 ± 55.6[4]	16.5 ± 0.7[4]	558.2 ± 43.6[2]
No	20.3 ± 1.1	550.1 ± 17.1	13.7 ± 0.8	391.7 ± 12.8	13.7 ± 0.7	397.9 ± 17.2

[1] $\bar{x}$ ± SE.
[2–4] Significantly different from other category; [2] $P < 0.001$, [3] $0.001 \le P < 0.01$, [4] $0.01 \le P < 0.05$.

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TABLE 5
Mean adjusted serum folate concentrations by sex, race, and educational attainment of participants in the phase I of the National Health and Nutrition Examination Survey, 1988–1991[1]

Sex and educational attainment	Serum folate			P^2		
	White	African American	Mexican American	W × AA	W × MA	AA × MA
		nmol/L				
Men						
<9 y	16.2 [274]	15.1 [158]	15.4 [496]	NS	NS	NS
9–11 y	17.0 [292]	16.5 [234]	16.6 [245]	NS	NS	NS
12 y	17.0 [515]	15.9 [319]	16.2 [200]	0.004	NS	NS
>12 y	17.0 [670]	14.5 [222]	16.3 [145]	<0.001	NS	0.016
Total	16.9 [1751]	15.6 [933]	16.0 [1086]	<0.001	0.020	NS
Women						
<9 y	17.9 [234]	17.1 [140]	15.2 [445]	NS	0.005	NS
9–11 y	17.7 [269]	16.7 [215]	16.1 [209]	NS	NS	NS
12 y	17.9 [623]	16.1 [359]	17.0 [239]	0.029	NS	NS
>12 y	19.3 [556]	15.9 [271]	15.7 [146]	<0.001	0.001	NS
Total	18.4 [1682]	16.3 [985]	15.9 [1039]	<0.001	<0.001	NS

[1] Adjusted for age, serum cotinine concentration, body mass index, fruit and vegetable consumption, vitamin and mineral supplement use, cereal intake, and alcohol use. *n* in brackets.

[2] ANCOVA. W × A, whites compared with African Americans; W × MA, whites compared with Mexican Americans; AA × MA, African Americans compared with Mexican Americans.

between educational attainment and serum folate concentration and between educational attainment and red blood cell folate concentration were 0.11 and 0.12 for all participants, 0.12 and 0.15 for all men, and 0.11 and 0.10 for all women. White participants had larger correlation coefficients than other participants (Table 3). None of the results of the tests for linear trend for adjusted mean concentrations of serum or red blood cell folate by educational attainment were significant (Tables 5 and 6).

There was no evidence that the differences in serum and red blood cell folate concentrations between white men and women and African American and Mexican American men and women narrowed or disappeared at the highest levels of educational attainment (Tables 5 and 6). In men with >12 y of education, the mean adjusted concentration of serum folate was 15% lower and that of red blood cells was 22% lower in African Americans than in whites. In women with >12 y of education, the mean adjusted concentration of serum folate was 18% lower and that of red blood cell folate was 22% lower in African Americans than in whites.

DISCUSSION

These nationally representative results show that serum and red blood cell folate concentrations are not uniform across certain demographic groups. Folate concentrations are higher in whites than in African Americans or Mexican Americans in the United States. These differences are not fully explained by differences in age, education, serum cotinine concentration, body mass index, vitamin and mineral supplement use, fruit and vegetable consumption, cereal intake, or alcohol consumption.

In NHANES I, conducted in 1971–1975, serum folate concentrations were slightly higher in white participants (8.0 nmol/L) than in African American participants (7.5 nmol/L) but

TABLE 6
Mean adjusted red blood cell folate concentrations by sex, race, and educational attainment of participants in phase I of the third National Health and Nutrition Examination Survey, 1988–1991[1]

Sex and educational attainment	Red blood cell folate			P^2		
	White	African American	Mexican American	W × AA	W × MA	AA × MA
		nmol/L				
Men						
<9 y	470.3 [273]	407.7 [156]	445.9 [494]	0.003	NS	0.071
9–11 y	509.4 [292]	444.8 [233]	464.4 [244]	0.001	0.026	NS
12 y	491.4 [515]	429.8 [317]	464.0 [198]	<0.001	0.033	0.006
>12 y	512.8 [668]	399.4 [222]	469.6 [145]	<0.001	0.006	<0.001
Total	502.6 [1748]	423.3 [928]	457.0 [1081]	<0.001	0.002	0.023
Women						
<9 y	527.2 [232]	430.9 [139]	443.8 [443]	0.004	0.004	NS
9–11 y	492.1 [267]	413.0 [212]	467.1 [209]	<0.001	NS	0.007
12 y	505.2 [619]	413.0 [355]	459.0 [239]	<0.001	NS	NS
>12 y	532.6 [555]	413.0 [269]	472.1 [146]	<0.001	0.031	0.044
Total	515.9 [1673]	415.4 [975]	455.7 479 [1037]	<0.001	0.001	0.038

[1] Adjusted for age, serum cotinine concentration, body mass index, fruit and vegetable consumption, vitamin and mineral supplement use, cereal intake, and alcohol use. *n* in brackets.

[2] ANCOVA. W × AA, whites compared with African Americans; W × MA, whites compared with Mexican Americans; AA × MA, African Americans compared with Mexican Americans.

the difference was not significant (10). In NHANES II, conducted in 1976–1980, 16% of African American participants and 14% of white participants had serum folate concentrations < 6.8 nmol/L (3.0 μg/L) ($P > 0.05$) and 17% of African American participants and 7% of white participants had red blood cell folate concentrations < 317 nmol/L (140 μg/L) ($P < 0.01$) (5).

In this analysis, education was only weakly related to serum and red blood cell folate concentrations. This is consistent with previous reports from NHANES I, NHANES II, and the Hispanic Health and Nutrition Examination Survey, conducted from 1982 to 1984, that also failed to find strong positive relations between educational attainment and folate concentrations (5, 10, 11). Although education was not strongly related to folate concentrations in NHANES III for the entire sample, it was positively related to red blood cell folate concentration in white men and with serum folate concentration in Mexican American women. However, the size of the educational effect was at best moderate. At least one other study found education to be directly related to serum folate concentration (12).

Because vitamin supplement use and fruit and vegetable intake correlate with educational attainment (13), we anticipated that any differences in folate concentrations that might exist among racial or ethnic groups would narrow or disappear in people with higher educational attainment because health knowledge, purchasing power, and access to consumer goods all increase with education. However, this was not the case. In fact, the relative differences for adjusted concentrations of serum and red blood cell folate between whites and African Americans were the largest in the most-educated group. Reasons for this are not clear.

Serum and red blood cell folate concentrations reflect the balance of folate intake from diet and nutritional supplements, folate absorption, and folate excretion. In our analysis, we adjusted for differences in the frequency of intake of foods known to be rich in folate and for use of vitamin and mineral supplements. Nevertheless, after these and other adjustments, differences in serum and red blood cell folate concentrations between the racial or ethnic groups remained. It is possible that we did not fully adjust for differences in folate intake because of incorrect reporting of food intake on the food-frequency questionnaire. However, differences in folate absorption from the small intestine, increased utilization of folate during the course of some diseases, or differences in folate excretion could also contribute to the differences we described.

Some limitations of this study deserve mention. We were unable to adjust completely for dietary folate intake because this value was available from only a single 24-h dietary recall. Instead, we adjusted for the frequency of fruit and vegetable consumption and cereal intake—important sources of dietary folate—from the food-frequency questionnaire. Because detailed data for vitamin and mineral supplement use was not available, we had to rely on a single question about supplement use in the previous 24 h. Some of the analyses involved many comparisons. We did not attempt to adjust for multiple comparisons. Instead, we have presented the probability values so that readers can decide for themselves whether an adjustment is appropriate when they interpret the data.

Our results suggest that African Americans and Mexican Americans could benefit most from public health programs to boost folate intakes by encouraging increased intake of foods rich in folates and of vitamin supplements. Therefore, it is instructive to note that only ≈30% of white women, 18% of African American women, and 19% of Mexican American women reported using a vitamin and mineral supplement, which was one of the stronger predictors of folate concentrations, during the previous 24 h in NHANES III. Rates in men were even lower. The decision by the US Food and Drug Administration to require folate fortification of enriched cereal and grain products in the United States beginning in 1998 (14) may narrow racial differences in the future.

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