Cardiovascular disease risk factors and diet of Fulani pastoralists of northern Nigeria[1–3]

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ABSTRACT

Background: The Fulani of northern Nigeria are seminomadic pastoralists who consume a diet rich in saturated fats, do not use tobacco, are lean, and have an active lifestyle. Little is known about their serum lipid profiles and corresponding risk of cardiovascular disease.

Objective: We measured serum lipid, homocysteine, folate, and vitamin B-12 concentrations in Fulani men and women and assessed the nutrient content of their diet.

Design: Blood samples from 42 men (18–64 y old) and 79 women (15–77 y old) living in the Jos Plateau of Nigeria were analyzed for cholesterol (total, HDL, and LDL), triacylglycerol, homocysteine, folate, and vitamin B-12 serum concentrations. Body composition was determined by bioelectrical impedance analysis. Dietary information was obtained with use of a 7-d dietary recall and a food-frequency questionnaire. Results were compared with US referent ranges.

Results: The mean energy content of the Fulani diet was relatively low (men, 6980 kJ; women, 6213 kJ) and the mean protein content was high (men, 20% of energy; women, 16% of energy). Nearly one-half of energy was provided by fat, and one-half of that was derived from saturated fatty acids. The diet provided marginal to adequate amounts of vitamins B-12, B-6, and C but only one-third of the US recommended dietary allowance for folate. The mean total cholesterol, HDL-cholesterol, and triacylglycerol concentrations of Fulani adults were within the referent ranges; the mean LDL-cholesterol concentration of Fulani adults below the range; and the mean serum homocysteine concentration of Fulani men above the range. Homocysteine and folate concentrations were inversely correlated for both men and women.

Conclusions: Despite a diet high in saturated fat, Fulani adults have a lipid profile indicative of a low risk of cardiovascular disease. This finding is likely due to their high activity level and their low total energy intake. *Am J Clin Nutr* 2001;74:730–6.

KEY WORDS Cardiovascular disease risk factors, serum lipids, LDL cholesterol, HDL cholesterol, homocysteine, serum folate, Fulani, Nigeria, food-frequency questionnaire, dietary recall

INTRODUCTION

For nearly 50 y it has been widely accepted that high-fat diets, particularly those that contain large quantities of saturated fatty acids, raise blood cholesterol concentrations and predispose individuals to cardiovascular disease (CVD) (1–8). Another serum variable with dietary implications, high homocysteine concentration, has shown promise as a predictor of atherosclerosis in the coronary, cerebral, and peripheral vasculature (9–13). Elevated homocysteine concentrations are indicative of folate and vitamin B-12 deficiencies as well (14). Other factors, including cigarette smoking, physical activity level, and body composition, also contribute substantially to coronary risk profiles (15).

Much of the primary literature on CVD risk factors is based on studies conducted in economically advanced countries and among relatively sedentary populations; few published reports exist of the blood concentrations of specific risk factors for CVD in nomadic pastoralists. Nearly 25 y ago Murray et al (16), in their study of nomadic Turkana, found the serum concentrations of cholesterol (total, HDL, and LDL) and triacylglycerol to be within the normal ranges defined for healthy adults in North America and Europe, even though the diets of these East African pastoralists contained considerable quantities of meat, dairy products, and blood derived from their herd animals (17).

The Fulani of the Jos Plateau, a mountainous state in northern Nigeria, are seminomadic pastoralists whose culture and economy are centered on cattle. After having conducted several studies of the Fulani in which we focused mainly on the health and diets of mothers and children (18–23), it is our impression that the diet of the Fulani of the Jos Plateau contains relatively large amounts of fat and that much of this fat is derived from dairy products and cooking oils such as palm oil and butter oil (23), which are high in saturated fatty acids. Such a diet might be expected to adversely affect an individual's blood lipid profile and to increase one's risk

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of CVD. However, other aspects of the nomadic lifestyle of the Fulani might mitigate the hypercholesterolemic effects of a diet rich in saturated fatty acids: smoking and alcohol consumption are rare, the Fulani lead lives that require vigorous physical activity, and the people tend to be lean throughout their lives. In this report we describe our investigation of the relations between diet, body composition, and serum lipid and homocysteine concentrations in Fulani living in the Jos Plateau.

SUBJECTS AND METHODS

Subjects

This study was carried out in 4 Fulani hamlets (Tum, Fwil, Vweng, and Chugwi) with a total adult population of 600–650. These hamlets are near the village of Kaduna-Vom, which is 40 km south of the state capital Jos, itself centered in the Jos Plateau 2200 m above sea level. All of the subjects were members of the Fulani ethnic group, seminomadic pastoralists whose main occupation is cattle rearing. Traditionally, the men of the hamlets, the younger men in particular, are constantly moving in search of pasture and water for their cattle. The women remain close to their respective hamlets, where they tend to the children, gather firewood and water, cultivate subsistence gardens, and process cow milk into dairy products such as cheese and butter oil (23).

Participation in our study was open to all inhabitants of the 4 hamlets who had no obvious health problems. None of the study subjects were taking medications for malaria or other infectious disease. Informed consent was obtained verbally from each subject after the study and its requirements were explained in Fulbe or Hausa by a medical personnel fluent in the language. Information and blood samples were obtained from subjects in July through August of 1999. This study was approved by the Human Research Review Committee of the University of New Mexico School of Medicine (Albuquerque) and by the Ethics Review Committee of the Jos University Teaching Hospital (JUTH; Jos, Nigeria).

Anthropometric measurements

The weight of each subject was measured with a battery-operated scale accurate to 0.5 kg and height was measured with use of a portable stadiometer. We calculated body mass index (BMI) as weight (in kg) divided by height squared (in m). Midupper arm circumference was measured with use of a tape measure (Creative Health Products, Plymouth, MI) and triceps skinfold thickness with a body caliper (Caliper Company, Inc, Carson City, NV). Fat-free mass and body fat were estimated by bioelectrical impedance analysis conducted with use of a portable analyzer (RJL Systems, Inc, Detroit) as described elsewhere (24). Reactance and resistance values, weight, height, and self-reported age and sex were used to calculate fat-free mass and body fat by using the software provided by the manufacturer. Blood pressure was measured with a nylon cuff and latex inflation system (Prestige Medical, Inc, Northridge, CA).

Biochemical analysis

Blood samples were obtained once from each subject by venipuncture, and the samples were allowed to clot at room temperature for 45 min before being centrifuged (1200 × *g*, 10 min, 22°C) to separate the serum. Samples were then portioned into cryovials and stored at −40 °C until they were transported frozen to Albuquerque, NM, for analysis.

We measured serum total cholesterol concentrations by the endpoint colorimetry method of Allain et al (25) with use of a Vitros 950 analyzer (Ortho Diagnostics, Rochester, NY). Serum HDL-cholesterol concentrations were measured with use of Kodak Vitros cholesterol slides and a Vitros 250 analyzer (Ortho Diagnostics; 26). Serum LDL-cholesterol concentrations were calculated by using the equation LDL cholesterol = total cholesterol – (HDL cholesterol + triacylglycerol/5). We measured serum triacylglycerol concentrations by the method of Spayd et al (27) with a Vitros analyzer clinical chemistry slide and a Vitros 950 analyzer (Ortho Diagnostics).

Serum homocysteine concentrations were measured with the IMx homocysteine assay kit (Abbott Laboratories, Columbus, OH). Because folate and vitamin B-12 are involved in homocysteine metabolism, we were also interested in the relations that might exist between these 2 water-soluble vitamins and homocysteine. Serum folate and vitamin B-12 concentrations were measured immunologically by competitive magnetic separation assays, with use of kits purchased from Technicon (Tarrytown, NY).

Serum total antioxidant capacity was estimated by using the method of Miller et al (28). In this assay 2,2′-azino-di-(3-ethylbenzthiazoline-6-sulfonic acid) ($ABTS^{\bullet+}$) is incubated with metmyoglobin and hydrogen peroxide to produce a radical cation that has a relatively stable blue-green color. The addition of antioxidants or reductants contained in a serum sample to this reaction medium suppresses the radical cation and color production. For calibration, we used Trolox (Randox Laboratories, San Diego), a water-soluble analog of vitamin E.

The mean concentrations of each serum variable were calculated for men and for women and were evaluated against published referent ranges: Rifai et al (29) for total cholesterol and triacylglycerol concentrations for African Americans; Burtis and Ashwood (30) for HDL cholesterol, LDL cholesterol, folate, and vitamin B-12 concentrations for the general US population; and Ueland et al (31) for homocysteine concentration for US whites. No appropriate referent range was available for total antioxidant capacity.

Dietary analysis

Dietary information was collected by a JUTH dietitian (MW) from a subset of the main study cohort. The assessment included a 7-d dietary recall, a food-frequency questionnaire (FFQ), and several personal and lifestyle-related questions useful in determining nutritional status. Interviews were conducted by trained persons in the language most comfortable for the subject (Fulbe, Hausa, or English). The dietary analysis included all macronutrients and selected micronutrients relevant to cardiovascular health. Although a 7-d recall may be inaccurate when diets are highly variable, the Fulani diet is consistent throughout the year and among individuals because of the Fulani's reliance on a limited number of locally available food items.

The nutrient analysis was carried out by using the 7-d dietary recalls and applicable data from the FFQ. We analyzed the data with FOOD PROCESSOR nutrient analysis software (version 7.2; ESHA Research, Salem, OR). Nutrient composition was determined from foods already reported in the FOOD PROCESSOR database and from other foods added to this database, using information from the US Department of Agriculture nutrient database for standard reference, release 13 (32) and a food-composition

TABLE 1
Anthropometric characteristics of the Fulani study cohort[1]

Characteristic	Men (n = 42)	Women (n = 79)
Age (y)	33.9 ± 12.5	32.0 ± 13.0
Weight (kg)	57.5 ± 8.8	50.6 ± 8.0[2]
Height (m)	1.69 ± 0.07	1.59 ± 0.06[2]
BMI (kg/m^2)	20.0 ± 2.2	20.2 ± 3.0
MUAC (cm)	24.0 ± 2.3	22.6 ± 2.5[3]
TSF (mm)	7.6 ± 3.8	13.8 ± 5.8[2]
FFM (%)	87.3 ± 4.6	71.5 ± 7.7[2]
Body fat (%)	12.7 ± 4.6	28.5 ± 7.7[2]
Systolic BP (mm Hg)	120 ± 16	118 ± 20
Diastolic BP (mm Hg)	74 ± 10	77 ± 13

[1] $\bar{x}$ ± SD. MUAC, midupper arm circumference; TSF, triceps skinfold thickness; FFM, fat-free mass; BP, blood pressure.

[2,3] Significantly different from men (two-sample t test): [2] $P < 0.001$, [3] $P = 0.003$.

table for use in Africa (33). Because neither the 7-d dietary recall nor the FFQ included exact serving portions, a standard portion size for each food was established by the JUTH dietitian from her direct observations and used throughout the analysis. Standard Fulani recipes for mixed foods reported on dietary records were obtained from the JUTH dietitian and entered into the FOOD PROCESSOR program for analysis as well.

After the dietary analysis was completed, each subject's actual nutrient intakes were compared with US recommended dietary allowances (RDA) for those nutrients for moderately active persons of similar sex, age, and size as that subject (34). Mean intakes were then determined for individual nutrients and compared with these referent values.

Statistical analysis

We analyzed our data to determine whether there were statistically significant correlations between the age or anthropometric characteristics of the Fulani subjects and the concentration of any of the biochemical variables we measured in their blood serum. The 2-sample t test was used to identify statistically significant differences between the men and women. Descriptive statistics, group comparisons, and correlations were made with use of NUMBER CRUNCHER statistical software (version 6; NCSS, Kaysville, UT). P values <0.05 were considered statistically significant.

RESULTS

Cohort characteristics

The study cohort consisted of 42 Fulani men aged 18–64 y ($\bar{x}$: 33.9 y) and 79 Fulani women aged 15–77 y ($\bar{x}$: 32.0 y) (**Table 1**). The homogeneity of the culture among the hamlets indicates the study participants were representative of the Fulani population of the Jos Plateau. The proportion of study subjects aged >40 y was greater among men than women, perhaps because many of the younger Fulani men were away from the hamlets herding their cattle. The men were significantly heavier and taller than the women, but the mean BMI of the 2 sexes was nearly identical and statistically indistinguishable. The mean midupper arm circumference was significantly higher among the men. The women had considerably more body fat than men did, as evidenced by a higher mean triceps skinfold thickness, a lower percentage of fat-free mass, and a higher percentage of body fat.

Mean serum concentrations

The mean serum total cholesterol concentration of Fulani men and women was identical at 3.50 mmol/L, a value on the low side of the referent range for African Americans (**Table 2**) as well as various other US racial and ethnic groups (29). The mean concentration of HDL cholesterol was significantly higher in the Fulani women than in the men. For both sexes, however, mean concentrations of LDL cholesterol were not significantly different and fell below the lower limit of the LDL-cholesterol referent range for whites. The mean serum triacylglycerol concentration was significantly higher in the men than in the women.

The mean serum homocysteine concentration in both the Fulani men and women was relatively high (Table 2). In fact, for the men, the mean homocysteine concentration exceeded the upper limit of the referent range for whites. The mean serum homocysteine concentration of the men was about 40% higher than that in the women.

The mean serum folate concentrations of the men and women were not significantly different, but fell near the lower end of the referent range of values reported for the general US population. The mean serum vitamin B-12 concentrations of the Fulani men and women were also at the lower end of the referent range of values reported for the general US population. The mean serum vitamin B-12 concentration of the men was significantly higher than that of the women.

TABLE 2
Serum concentrations of variables related to the risk of cardiovascular disease in the Fulani study cohort

Variable	Men (n = 42)	Women (n = 79)	Referent range (5th–95th percentile)[1]
Total cholesterol (mmol/L)	3.50 ± 0.80[2]	3.50 ± 0.73	3.42–6.55
HDL cholesterol (mmol/L)	0.88 ± 0.27	1.07 ± 0.27[3]	0.73–1.63
LDL cholesterol (mmol/L)	1.84 ± 0.70	1.88 ± 0.52	2.02–4.90
Triacylglycerol (mmol/L)	1.62 ± 0.89	1.19 ± 0.54[3]	0.43–2.53
Homocysteine (μmol/L)	14.7 ± 6.2	10.8 ± 4.3[3]	4.5–12.4
Folate (nmol/L)	9.4 ± 4.3	9.2 ± 4.1	3.6–27.2
Vitamin B-12 (pmol/L)	260 ± 163	175 ± 118[3]	148–626
Total antioxidant capacity (mmol/L)	1.06 ± 0.11	0.98 ± 0.12[3]	—

[1] Sources for referent ranges are Rifai et al (29) for total cholesterol and triacylglycerol for African Americans; Burtis and Ashwood (30) for HDL cholesterol, LDL cholesterol, folate, and vitamin B-12 for the general US population; and Ueland et al (31) for homocysteine for US whites. No appropriate referent range was available for total antioxidant capacity.

[2] $\bar{x}$ ± SD.

[3] Significantly different from men, $P < 0.001$ (two-sample t test).

TABLE 3
Estimated daily energy and nutrient intakes of the Fulani study cohort[1]

Energy or nutrient intake	Men (n = 22) Dietary intake	Men Referent[2]	Men Percentage of referent	Women (n = 73) Dietary intake	Women Referent[2]	Women Percentage of referent
			%			%
Energy (kJ)	6980 ± 1106[3]	9924	70	6213 ± 892	8330	75
Protein						
(g)	85 ± 19	43	198	62 ± 14	41	151
(% of energy)	20 ± 0.03	15	133	16 ± 0.03	15	107
Carbohydrate						
(g)	137 ± 21	349	39	138 ± 22	293	47
(% of energy)	33 ± 0.07	55	30	36 ± 0.05	55	65
Fat						
(g)	93 ± 27	80	116	81 ± 18	67	120
(% of energy)	48 ± 0.08	30	160	47 ± 0.07	30	156
Saturated fat						
(g)	46 ± 15	24	192	40 ± 10	20	200
(% of fat)	50[4]	33	152	50	33	152
(% of energy)	25	10	250	24	10	240
Cholesterol (mg)	232 ± 85	300	77	147 ± 45	300	49
Vitamin B-6 (mg)	1.2 ± 0.3	1.4	87	0.85 ± 0.3	1.3	66
Vitamin B-12 (μg)	7.0 ± 1.8	2.4	287	4.7 ± 1.3	2.4	197
Folate (μg)	134 ± 21	400	33	126 ± 15	400	31
Vitamin C (mg)	52 ± 7	90	58	47 ± 6.0	75	63
Vitamin A (RE)	789 ± 157	1000	79	721 ± 189	800	90
Vitamin E (TE)	11 ± 3.4	15	73	12 ± 3.0	15	80
Selenium (μg)	57 ± 13	55	104	41 ± 9	55	75
Iron (mg)	15 ± 5.6	10	153	11 ± 5.0	15	77
Calcium (mg)	935 ± 293	1050	89	871 ± 328	1052	83

[1] RE, retinol equivalent; TE, α-tocopherol equivalent.
[2] US recommended dietary allowance for moderately active persons of similar sex, age, and size (34).
[3] $\bar{x}$ ± SD.
[4] $\bar{x}$.

The mean serum total antioxidant capacity was slightly but significantly higher in the Fulani men than in the women (Table 2). The means for both sexes appeared to be at the low end of the range of values we previously observed in the sera of Nigerian women and their breast-fed infants (35) and the values Miller et al (28) observed in premature neonates.

Dietary analysis

Food records were obtained from 22 men and 73 women of the complete study cohort. Dietary analysis revealed a relatively low-energy diet, with an estimated mean daily energy intake of 6980 kJ for men (70% of the US RDA) and 6213 kJ for women (75% of the US RDA) (**Table 3**).

Protein provided an estimated 20% of energy intake for men and 16% for women, and intake was 198% above the referent range for men and 151% above the referent range for women. The major sources of protein in the Fulani diet were meat (the primary source) and milk, which together provided 82% of total protein for men and 74% for women (data not shown). All subjects consumed meat several times a week, and all but one woman drank milk. Fish was eaten in small quantities ≥1 time/wk by 53% of the men and 60% of the women.

The estimated mean carbohydrate intake accounted for one-third of the cohort's daily energy intake. These values were much lower than the US RDA (39% lower for men, 47% lower for women).

Fat supplied 47–48% of the estimated mean daily energy intake of the Fulani study participants; fully half of the energy from fat was derived from saturated fatty acids. In contrast, the US RDA is 30% of energy from fat and 23–33% of fat from saturated fatty acids. Mean cholesterol intake was well under the US RDA, at 77% of the amount recommended for men and 49% that for women. Milk and other dairy products (eg, butter oil) supplied an estimated 28–29% of total energy for men and women (data not shown). The main sources of saturated fatty acids were dairy products and red palm oil.

Of the 3 vitamins thought to be most critical in maintaining serum homocysteine concentration, mean daily intake of vitamin B-12 appeared to be more than adequate for both men and women (287% and 197% of the US RDA), whereas intakes of folate (33% and 31%) and vitamin B-6 (87% and 66%) were low. For both sexes, the Fulani diet supplied ≥73% of the US RDA for the fat-soluble antioxidants vitamins A and E and for selenium, iron, and calcium. The percentage of the water-soluble antioxidant vitamin C was fairly low, at 58% for men and 63% for women.

Correlations between anthropometric and serum variables

Except for folate and homocysteine concentrations, no significant correlations were found between age, percentage of fat-free mass, percentage of body fat, or BMI and the concentrations of any of the lipids or vitamin B-12 in serum. In women, there was a slight, but nonsignificant, increase in serum folate concentration with increasing age (**Figure 1**). However, the correlation between serum homocysteine and age in the women was significant. When we plotted the serum homocysteine concentration versus the serum folate concentration for the Fulani women, a significant and strong negative correlation was observed (**Figure 2**).

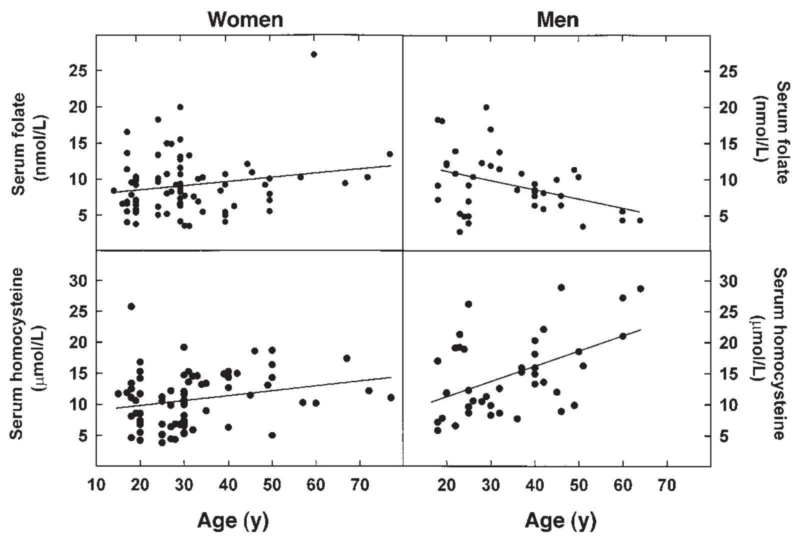

FIGURE 1. The relation between age of Fulani women and serum concentration of folate ($r = 0.19$, $P = 0.10$) or homocysteine ($r = 0.23$, $P = 0.04$) and age of the Fulani men and serum concentration of folate ($r = -0.39$, $P = 0.013$) or homocysteine ($r = 0.50$, $P < 0.001$).

When a similar analysis was performed for the Fulani males, a different picture emerged: with increasing age, serum folate concentrations decreased (Figure 1) whereas serum homocysteine concentrations increased (Figure 1). As was seen for the Fulani women, in men, the serum homocysteine concentration was strongly and negatively correlated with the serum folate concentration (Figure 2).

DISCUSSION

Four major findings resulted from our study of the Fulani of the Jos Plateau. First, the mean cholesterol (total, HDL, and LDL) and triacylglycerol concentrations in the Fulani men and women were favorable with respect to the risk of CVD. Specifically, mean total cholesterol, HDL-cholesterol, and triacylglycerol concentrations were within the range of values considered acceptable for African Americans (29) or the general US population (30), and the mean concentration of LDL cholesterol—widely regarded as the most important harbinger of CVD in humans—actually fell below the LDL referent range for the general US population (30) and 30–40% lower than the LDL-cholesterol concentrations reported by Bunker et al (36) for the 1407 male and female civil servants they studied in southern Nigeria. Neither Bunker et al nor we observed any statistically significant relations between BMI and the concentration of any of the serum lipids in subjects, who had uniformly low BMIs (mean BMI < 22).

The mean serum cholesterol concentrations of Fulani men and women, who consumed diets high in fat and saturated fatty acids, were low compared with the ranges seen in US populations. This finding is in accord with observations reported by Murray et al (16) and Nelson et al (1). Murray et al (16) studied 2 populations living near the village of Diffa in eastern Niger. The nomadic population consumed a diet high in saturated fat and the sedentary population consumed a high-carbohydrate diet of equivalent low-energy content (each population had an average BMI of 18); each group had equally low serum cholesterol and triacylglycerol concentrations. In a crossover study involving 11 persons fed a high-fat diet (39% of energy from fat) or a low-fat diet (22% of energy from fat) of nearly identical fatty acid composition for 50 d, Nelson et al (1) observed that serum concentrations of total, HDL, and LDL cholesterol were essentially the same for persons consuming either diet and that the serum triacylglycerol concentration was actually lower among persons fed the high-fat diet. These studies and our own findings with the Fulani do not support the dogma of the past 50 y that high-fat diets necessarily raise cholesterol concentrations (2–5). It may be that the low total energy intake of the Fulani adults we studied (range: 6192–7018 kJ), together with their healthy lifestyle, in some way mitigates the hypercholesterolemic effects of their high-fat diet. Genetic factors unique to the Fulani may also help account for why their diet does not result in elevated total or LDL-cholesterol concentrations.

Our second major finding was that the prevalence of hypertension, an independent risk factor for CVD (37), among the Fulani men and women in our study was low compared with

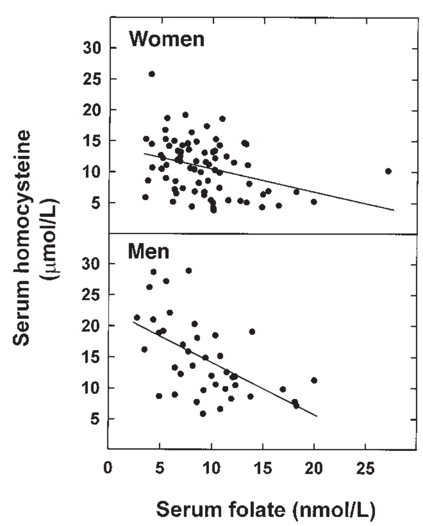

FIGURE 2. The relation between serum concentrations of folate and homocysteine among Fulani women ($r = -0.33$, $P < 0.002$) and men ($r = -0.56$, $P = 0.001$).

other Nigerian populations (38, 39). The relatively low prevalence may be due to the lower average age of the subjects we studied [33 y in our study compared with 61 y (38) and 52 y (39)], although age is not a known risk factor for hypertension.

In terms of lipid profile and blood pressure, these observations *1*) indicate that the Fulani population we studied in the Jos Plateau is at low risk of CVD and *2*) support our hypothesis that the low energy intake, active lifestyle, and rural existence of these semi-nomadic people override whatever negative effects their diets high in fat and saturated fatty acids might have on their risk of CVD. Counter to the generally favorable serum lipid profiles and low blood pressures of our Fulani cohort, however, is the third major set of findings of our study: relative to Western populations, the mean serum homocysteine concentration of the Fulani men was high (especially those of older men) and their mean total antioxidant capacity seemed low (which was age independent). These indexes should be of concern because elevated homocysteine concentration and antioxidant deficiency are risk factors for CVD (9–12).

The fourth major finding of our cross-sectional study was that, among Fulani men but not among Fulani women, serum folate concentration declined significantly as age increased. The men's dietary intake of folate could not account for the decline in serum folate concentration with increasing age because folate intake was not correlated with age. In addition, folate consumption was similar in men and women at all ages. We do not know why the serum concentration declined with age in men but not women.

Although dietary folate intake was similar among men and women, and although serum folate concentration declined in both sexes as serum homocysteine concentration increased, the mean homocysteine concentration was significantly lower in Fulani women than in Fulani men. Several other studies showed that women tend to have lower fasting serum homocysteine concentrations than do men, and it was speculated that the lower risk of CVD among premenopausal women may be related to their lower homocysteine concentration (40, 41). A recent study by Fukagawa et al (13) provided a partial explanation for the difference in homocysteine concentration: a higher rate of homocysteine remethylation in women than in men.

Future research should provide answers to some of the questions raised by our study. For example, why is the mean serum concentration of vitamin B-12 among Fulani men nearly 50% higher than that among Fulani women? Perhaps the difference is due to the vitamin B-12 dietary intake of the women being 67% that of the men, which in turn may be due to the lower intake of protein by the women. Why is the serum total antioxidant capacity of Fulani men and women low compared with other populations we have studied (RH Glew, DJ VanderJagt, unpublished observations, 1999)? We do not know the mean or range of serum concentrations of the various antioxidants in the Fulani or the dietary sources of these antioxidants, although we know that the mean Fulani dietary vitamin C intake is less than two-thirds of the US RDA. How might the serum folate concentration of the Fulani in general, and the older men in particular, be increased using locally available resources? Would improved folate status reduce the mean serum homocysteine concentration in this population?

Finally, and most important, information regarding the cause of death in seminomadic and nomadic Fulani is sparse. To place our biochemical findings in proper clinical perspective, future studies should gather information by sex about Fulani mortality rates and causes of death. For example, the very low serum cholesterol concentrations may predispose Fulani to hemorrhagic stroke, especially among those who have high blood pressure (42). In addition, the male Fulani offer a rare opportunity to investigate the contribution of high serum homocysteine concentration to risk of CVD because the men are free of most of the other well-established risk factors for CVD: they do not smoke, are lean, are very active physically, and have favorable serum lipid profiles.

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