Effects of a Low-Fat Vegan Diet and a Step II Diet on Macro- and Micronutrient Intakes in Overweight Postmenopausal Women

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OBJECTIVE: This study investigated the nutrient intake of overweight postmenopausal women assigned to a low-fat vegan diet or a Step II diet.

METHODS: Fifty-nine overweight (body mass index, 26 to 44 kg/m^2) postmenopausal women were randomly assigned to a self-selected low-fat vegan or a National Cholesterol Education Program Step II diet in a 14-wk controlled trial on weight loss and metabolism. Nutrient intake, which was measured per 1000 kcal, was the main outcome measure. Statistical analyses included within-group and between-group *t* tests examining changes associated with each diet.

RESULTS: Consumption of a low-fat vegan diet was associated with greater decreases in fat, saturated fat, protein, and cholesterol intakes and greater increases in carbohydrate, fiber, β-carotene, and total vitamin A intakes than was a Step II diet. The low-fat vegan group also increased thiamin, vitamin B6, and magnesium intakes more than the Step II group, and both groups increased folic acid, vitamin C, and potassium intakes. If considering only food sources of micronutrients, the low-fat vegan group decreased vitamin D, vitamin B12, calcium, selenium, phosphorous, and zinc intakes compared with baseline. However, with incidental supplements included, decreases were evident only in phosphorous and selenium intakes. No micronutrient decreases were found in the Step II group.

CONCLUSIONS: Individuals on a low-fat vegan or Step II diet should take steps to meet the recommended intakes of vitamin D, vitamin K, folic acid, calcium, magnesium, and zinc. Individuals on a low-fat vegan diet should also ensure adequate intakes of vitamin B12, phosphorous, and selenium. *Nutrition* 2004;20: 738–746. ©Elsevier Inc. 2004

KEY WORDS: body weight, diet, energy intake, nutrition assessment, obesity, postmenopause, vegetarianism

INTRODUCTION

Vegetarian and vegan diets are increasingly studied for the prevention, management, or treatment of heart disease,[1–3] diabetes,[4,5] hypertension,[1,6,7] cancer, and other chronic diseases.[8–10] When well planned, such diets are nutritionally adequate[11] and are generally higher in carbohydrate and fiber and lower in fat, saturated fat, cholesterol, protein, and energy than are omnivorous diets.[12–18] Although a few studies have compared the micronutrient contents of vegetarian and omnivorous diets,[15–17,19–22] with some showing increased nutrient density with vegetarian diets[19,23] and others raising questions about nutrient intakes for the long term,[20,22,24] only very limited data are available on the nutrient content of low-fat vegan diets, despite their increased use in clinical and research settings.[16,17]

This study examined how a change from an omnivorous diet to a low-fat vegan diet affects nutrient intake and fruit and vegetable consumption as compared with the National Cholesterol Education Program Step II diet, hereafter referred to as the Step II diet.[25] It was part of a study examining the effects of a low-fat vegan diet on body weight, with the Step II diet as a control. The Step II diet is a low-fat diet (≤30% kcal as fat) developed to treat hypercholesterolemia. The Step II diet significantly decreased serum concentrations of low-density lipoprotein cholesterol, apolipoprotein A-IV, and triacylglycerol-rich lipoproteins in comparison with diets typical in the United States.[26,27]

The Step II[26,27] and low-fat vegan[1–10] diets are used in clinical settings to prevent and treat a variety of chronic diseases, but there is little available information on the effect these diets have on nutrient intake. We therefore examined the changes in nutrient intake associated with the Step II and low-fat vegan diets.

MATERIALS AND METHODS

Subjects

Sixty-four overweight postmenopausal women (body mass index [BMI], 26 to 44 kg/m^2) were recruited through newspaper advertisements for a 14-wk trial comparing the effects of a low-fat vegan diet with those of a Step II diet on body weight, resting metabolic rate (RMR), thermic effect of food (TEF), and nutrient intake. Volunteers were excluded if they had been diagnosed with

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TABLE I.

SAMPLE VEGAN MENU*

Breakfast	Lunch	Snack	Dinner
Bran flakes with enriched soy milk	Barley vegetable soup	Apple	Vegetable burrito with black beans, broccoli, carrots, cauliflower, and mushrooms
Banana	Soy hotdog with mustard		Brown rice
Whole wheat toast with jam	Green salad with fat-free vinaigrette		Fruit salad
Orange juice, calcium fortified	Vegan low-fat animal crackers		Chocolate pudding made with rice milk

* Nutritional analysis: energy, 1538 kcal; carbohydrate, 306 g (72% of calories); fat, 17 g (10% as calories); protein, 66 g (18% as calories); fiber, 41 g; cholesterol, 0 mg; vitamin A, 2920 RE; vitamin C, 341 mg; calcium, 962 mg; iron, 16 mg.

diabetes mellitus or any other endocrine condition that would affect body weight; were taking estrogen or any other medications that could affect weight, blood pressure, serum glucose, or lipid concentrations; had a history of alcohol abuse; had used tobacco within the previous 6 mo; had a menstrual period in the preceding 12 mo; or had an unstable medical status. The Georgetown University institutional review board approved the study, and informed consent was obtained from volunteers before enrollment. Monetary compensation of $100 was provided for completion of all pre- and postintervention measures.

Study Design

This study was completed in two successive replications. Volunteers were randomly assigned, by using a computer-generated random number table, to a low-fat vegan diet or the Step II diet for 14 wk. Participants were asked not to alter their exercise habits during the intervention period, and activity was measured at baseline and at 14-wk with Bouchard's 3-Day Physical Activity Record for 24-h intervals on two weekdays and one weekend day on the same schedule as the 3-d dietary record. Participants were not constrained with regard to their use of vitamin or mineral supplements. However, subjects on the vegan diet were asked to take supplemental vitamin B12, such as any common multivitamin that contains at least 2 μg of vitamin B12, if they chose to continue the diet after the 14-wk intervention.

Dietary Intake

The low-fat vegan diet was designed to provide approximately 10% of energy from fat, 15% from protein, and 75% from carbohydrate and consisted of grains, vegetables, legumes, and fruits, with no limit on energy intake or portions. Participants were asked to exclude animal products, added oils, high-fat processed foods, avocados, olives, nuts, nut butters, and seeds because these foods are typically calorie dense. Participants following the Step II diet were asked to limit their total fat intake to no more than 60 g/d or no more than 30% of energy (saturated fat $<$ 7%, polyunsaturated fat $\leq$ 10%, and monounsaturated fat $\leq$ 15% of energy) and cholesterol to less than 200 mg/d. The Step II diet was designed to provide approximately 15% of energy from protein and 55% from carbohydrate.

Participants in both groups were encouraged to eat to satiety. There was no specified limit on energy intake or any attempt to maintain isocaloric intake between the two groups. Throughout the 14-wk intervention, weekly 1-h meetings were held separately for each group and provided participants with group support, nutritional information about their assigned diets, and cooking instructions. The Step II participants learned to identify and limit fat-rich foods and learned cooking and shopping methods for limiting fat intake. The vegan participants were guided to consume a diet very low in fat consisting largely of whole-plant foods including fresh fruits, vegetables, salads with fat-free dressings, and simple grain and bean dishes prepared without added fat. Fat-free cooking techniques and careful label reading were also taught. Participants were allowed to eat whatever they liked within the constraints of their prescribed diets. Nutritional instruction did not emphasize single micro- or macronutrients but rather provided information on sources of all nutrients.

Both groups received a list of allowable food groups and suitable choices in each food group. For example, the Step II group was instructed on low-fat choices from the meat, dairy, vegetable, fruit, and grain groups. The vegan group was given examples of low-fat vegetable protein sources, fruits, vegetables, and grains. In practice, this led the vegan group to base meals around beans (e.g., pinto, black, and kidney beans), low-fat soy foods (e.g., low-fat tofu, soy meat analogs, and soymilk), grains (e.g., rice, pasta, quinoa, barley, and oats), vegetables, and fruit. Typically, the recommended Step II diet translated into 6 oz (170 g) of lean meat, two to three servings (490 to 735 g) of low-fat dairy products, two to three servings (200 to 300 g) of vegetables, two servings (200 g) of fruit, and five to six servings (200 to 240 g) of grains. The recommended vegan diet translated into one to two servings (150 to 300 g) of beans, one to two servings (85 to 170 g) of soy foods, three servings (300 g) of vegetables, three servings (300 g) of fruit, and five to six servings (200 to 240 g) of grains. A typical vegan menu is presented in Table I.

For body weight, TEF, and RMR measurements, participants were asked to report to the Women's Exercise Research Center laboratory of George Washington University within 60 min of waking and after a 12-h fast. TEF was measured after participants consumed a liquid test meal consisting of two cans of Boost Plus (Novartis Medical Health, Inc., Fremont, MI USA). Weight, TEF, and RMR were measured at baseline and at 14 wk by an exercise physiologist who used the same equipment at both determinations. Body weight was determined and recorded by a researcher with a digital scale accurate to 0.1 kg while participants wore undergarments or a swimming suit. After 30 min of quiet supine rest in a dimly lit room, pulse, respiratory rate, and body temperature were measured. RMR was then measured for 30 min through indirect calorimetry (Sensormedics V_{max} System, Yorba Linda, CA, USA) using a ventilated hood system.

Participants were instructed on how to keep a weighed, 3-d dietary record, including food and supplement use, and were provided with food scales. A practice dietary record was completed before the start of the assigned diet and reviewed during an individual meeting with a registered dietitian. Participants then completed baseline (before dietary change) and 14-wk (during the assigned diet) dietary records during two weekdays and one weekend day for a total of 6 d. Participants were encouraged to attach recipes for mixed dishes so each individual food ingredient and amount could be entered. Most vegan products eaten by subjects were included in the Nutritionist V database. For the exceptions, the research dietitian used the nutritional label and ingredients list

TABLE II.

BASELINE DEMOGRAPHIC CHARACTERISTICS*

	Vegan group (n = 29)		Step II group (n = 30)	
	Baseline	14 wk	Baseline	14 wk
Mean age (y)	57.4 ± 4.8		55.6 ± 6.5	
Age range (y)	47–71		44–73	
Race				
White, non-Hispanic	22		17	
Black, non-Hispanic	7		12	
White, Hispanic	0		1	
Education				
High school	1		2	
Partial college	5		9	
College graduate	14		10	
Advanced degree	9		9	
Body weight (kg)†	89.3 ± 13.4	83.5 ± 13.5†	86.1 ± 12.1	82.3 ± 12†
BMI (kg/m^2)†	33.6 ± 5.2	31.5 ± 5.3†	32.6 ± 3.3	31.2 ± 3.5†
RMR (kcal/d)	1441 ± 204	1289 ± 197†	1392 ± 169	1291 ± 141†
Ratio of reported energy intake (kcal) to RMR	1774:1441	1408:1289	1762:1392	1424:1291

* Mean ± standard deviation.
† Significance of differences in within-group comparison, $P < 0.001$.
BMI, body mass index; RMR, resting metabolic rate

of foods that were not included in the database to find an approximate match. Each record was reviewed for completeness, and any questions about the record were discussed with the subject.

Fruit and vegetable intakes were also specifically examined. A registered dietitian, using Nutritionist V 2.0 for Windows 98 (First DataBank Inc., Hearst Corporation, San Bruno, CA, USA), analyzed dietary records with and without supplements, in addition to fruit and vegetable intakes. In addition to the 3-d dietary records, dietary compliance was assessed through 24-h food recalls that were administered three times during the study but were not subjected to statistical tests. These food recalls offered the research dietitian an opportunity to identify the rare problems with compliance with the diets (generally due to a lack of knowledge or understanding about a specific food) and offer information and encouragement to help the participant to comply fully. The participant was considered non-compliant if two consecutive food recalls showed that she was not following the assigned diet or if her final 3-d food record showed she was not following the assigned diet. Serum lipids were also measured and will be reported in another report, when long-term data are available.

Statistical Methods

Data were analyzed with SAS 8.2 (SAS Institute, Inc., Cary, NC, USA). Two sets of statistical analyses were conducted on nutrient intake. The first examined the similarity of the low-fat vegan diet and the Step II diet groups at baseline after random assignment. The second set of analyses examined changes associated with each diet. For each participant, 14-wk data were subtracted from baseline data to determine the magnitude of change for each measure. Between-subjects t tests were calculated on these change values to determine whether the changes associated with the low-fat vegan diet were greater than the corresponding changes associated with the Step II diet. In addition, for each diet group, paired comparison t tests were calculated to determine whether the mean change from baseline to 14 wk was significantly different from zero. Because energy intake was significantly lower for both groups at 14 wk as compared with baseline, dietary data were presented as nutrient intake per 4.19 MJ (1000 kcal). All tests were conducted with an α level of 0.05.

RESULTS

Fifty-nine volunteers completed the study. Participant characteristics are listed in Table II. Of the 64 volunteers who met the participation criteria, one participant in the low-fat vegan group did not begin the diet, and two others dropped out during the trial. Two participants in the Step II group also dropped out during the study. All statistical analyses were performed on subjects who completed the study. There were no significant demographic differences between groups or between subjects who completed and did not complete the study. A series of between-subjects t tests was calculated for each baseline measurement. These tests established that there were no significant differences between groups at baseline, including baseline weight and macro- and micronutrient intakes between groups.

Within-group comparisons showed that the low-fat vegan group significantly increased reported intakes of carbohydrate, fiber, sugar, total vitamin A, β-carotene, thiamin, vitamin B6, folic acid, vitamin C, magnesium, and potassium and decreased reported intakes of protein, fat, saturated fat, monounsaturated fat, polyunsaturated fat, cholesterol, vitamin D, vitamin B12, calcium, phosphorous, selenium, and zinc per 4.19 MJ (1000 kcal). The Step II group increased mean reported intakes of carbohydrate, fiber, sugar, folate, vitamin C, and potassium and decreased fat, saturated fat, monounsaturated fat, and cholesterol intakes (Tables III to V).

Between-group comparisons showed that the low-fat vegan group decreased intakes of protein, fat, saturated fat, monounsaturated fat, polyunsaturated fat, cholesterol, caffeine, vitamin B12, and phosphorous and increased intakes of carbohydrate, fiber, total vitamin A, and β-carotene to a greater degree than did the Step II group (Tables III to V).

At baseline, 8 (28%) of the 29 participants in the vegan group and 8 (27%) of the 30 Step II group participants were taking

TABLE III.

ESTIMATED MEAN MACRONUTRIENT INTAKE PER 4.19 MJ (1000 KCAL) OF WOMEN ON VEGAN AND STEP II DIETS*

	Vegan group (n = 29)		Step II group (n = 30)		Change between groups† (P)
	Baseline	14 wk	Baseline	14 wk	
Energy (MJ/d)	7.42 ± 2.39	5.89 ± 1.78‖	7.37 ± 1.77	5.96 ± 1.5‡	NS
Protein					
Grams per 4.19 MJ (1000 kcal)	41 ± 10	30 ± 5‡	43 ± 8	47 ± 12	<0.001
% Total energy	16 ± 4	12 ± 2‡	17 ± 3	18 ± 5	<0.001
Carbohydrate					
Grams per 4.19 MJ (1000 kcal)	133 ± 23	195 ± 15‡	133 ± 20	154 ± 22‡	<0.001
% Total energy	53 ± 9	78 ± 6‡	53 ± 8	62 ± 9‡	<0.001
Fat					
Grams per 4.19 MJ (1000 kcal)	34 ± 9	13 ± 5‡	33 ± 8	22 ± 7‡	<0.001
% Total energy	30 ± 8	11 ± 4‡	29 ± 7	20 ± 6‡	<0.001
Saturated fat (g)	11 ± 5	2 ± 2‡	10 ± 3	6 ± 3‡	<0.001
MUFA (g)	10 ± 3	3 ± 2‡	10 ± 3	6 ± 3‡	<0.001
PUFA (g)	6 ± 2	3 ± 2‡	6 ± 3	5 ± 3	<0.05
Cholesterol (mg)	131 ± 62	12 ± 24‡	131 ± 62	84 ± 58‡	<0.001
Fiber (g)	12 ± 4	22 ± 7‡	11 ± 4	14 ± 5‡	<0.001
Sugar (g)	46 ± 15	62 ± 17‡	51 ± 17	59 ± 19§	NS
Caffeine (mg)	138 ± 118	121 ± 78	93 ± 82	124 ± 129	<0.05
Alcohol (g)	2.0 ± 5.0	2.1 ± 4.7	2.0 ± 4.0	2.7 ± 5.5	NS

* Mean ± standard deviation. Six days of dietary intake were investigated. Baseline is before the diet intervention and 14 weeks is during the diet intervention.
† For each participant, 14-wk data were subtracted from baseline data to determine the magnitude of change for each measure. Significance of change in nutrient intake was measured between the vegan and Step II groups.
‡ $P < 0.001$, within-group comparison.
§ $P < 0.05$, within-group comparison.
‖ $P < 0.01$, within-group comparison.
MUFA, monounsaturated fatty acid; NS, not significant; PUFA, polyunsaturated fatty acid.

multivitamin-mineral supplements. At 14 wk, these figures were seven (24%) and seven (23%), respectively. At baseline, seven (25%) vegan participants and five (17%) Step II participants were taking a calcium supplement. At 14 wk, these figures were four (14%) and four (13%), respectively. Only three participants at baseline and one at 14 wk were taking single-nutrient supplements other than calcium.

With supplements included, within-group analyses indicated increases in total vitamin A, β-carotene, magnesium, and potassium intakes and decreases in phosphorous and selenium intakes in the vegan group. The Step II group increased intakes of folate, vitamin C, and potassium. Between-group analyses showed that the vegan group increased total vitamin A, β-carotene, potassium, and magnesium intakes and decreased phosphorous intake to a greater degree than the respective changes in the Step II group (Tables IV and V).

The vegan group increased fruit consumption from a mean of 2.0 to 3.1 daily servings (200 to 310 g; $P < 0.01$) and vegetable intake from 1.6 to 2.6 daily servings (160 to 260 g; $P < 0.05$). The Step II group increased fruit intake from a mean of 2.1 to 3.2 daily servings (210 to 320 g; $P < 0.05$) but did not significantly change vegetable intake.

Total supplemented vitamin and mineral intakes in relation to dietary reference intakes and recommended dietary allowances were examined (Table VI). These values were assessed to fully understand the effect these dietary changes had on compliance with current dietary recommendations. At baseline, fewer than 50% of participants in each group met the recommended intakes for vitamin D, vitamin K, folic acid, calcium, and magnesium. At 14 wk, fewer than 50% of participants in each group met the recommended intakes for vitamin D, vitamin K, folic acid, calcium, magnesium, and zinc. In addition, at 14 wk, fewer than 50% of vegan participants met the recommended intakes for vitamin B12, phosphorous, and selenium.

The 3-d dietary records (at baseline and 14 wk) and periodic 24-h food recalls showed a high degree of compliance, and no participant was dropped from the study due to non-compliance. There were no significant differences between baseline activity levels and 14-wk activity levels in either group according to the activity records. The TEF results were reported elsewhere (American Diabetes Association Conference, June 2002). Body weight was also examined. The vegan group lost significantly more weight than the Step II group ($P < 0.05$; Table II).

DISCUSSION

The adoption of a low-fat vegan diet or a Step II diet resulted in major changes in nutrient intake. Among the macronutrients, protein, saturated fat, total fat, and cholesterol intakes decreased, whereas carbohydrate and fiber intakes increased (cholesterol intake reported for the low-fat vegan group was mainly artifactual and probably overestimated due to the absence in the Nutritionist V database of vegan versions of some common foods). These changes were greater than those in the Step II group and were similar to differences reported in previous studies of vegan diets.[13,14,18,28] Fat intake in the vegan group decreased to levels seen in other studies using a low-fat vegetarian diet.[3] Dramatic decreases in fat intake were achieved through weekly education sessions that aided the participants in adhering to the respective diets. Protein intake also decreased in the vegan group. Although the vegan group's protein intake dropped, the average intake of

TABLE IV.

ESTIMATED MEAN VITAMIN INTAKE PER 4.19 MJ (1000 KCAL) OF WOMEN ON VEGAN AND STEP II DIETS*

	Vegan group (n = 29)		Step II group (n = 30)		Change between groups† (P)
	Baseline	14 wk	Baseline	14 wk	
Total vitamin A (RE)‡					
Food	696 ± 499	1239 ± 1113#	941 ± 918	859 ± 463	<0.05
Food + supplements	850 ± 556	1405 ± 1107¶	985 ± 626	1019 ± 557	<0.05
β-Carotene (μg)					
Food	380 ± 588	1042 ± 1324¶	427 ± 823	453 ± 563	<0.05
Food + supplements	568 ± 755	1230 ± 1358¶	443 ± 493	595 ± 700	<0.05
Vitamin D (μg)					
Food	1.1 ± 0.8	0.7 ± 0.9#	1.9 ± 4.1	1.6 ± 2.3	NS
Food + supplements	2.9 ± 3.5	2.9 ± 4.9	3.5 ± 5.1	3.2 ± 3.9	NS
Vitamin E (ATE)§					
Food	3.0 ± 1.1	2.7 ± 1.2	4.5 ± 6.6	5.6 ± 12.4	NS
Food + supplements	21.1 ± 47.9	24.3 ± 62.3	15.3 ± 26.0	16.4 ± 36.3	NS
Vitamin K (μg)					
Food	47.2 ± 57.9	62.4 ± 66.5	42.7 ± 39.3	64.2 ± 58.6	NS
Food + supplements	52.8 ± 60.1	67.6 ± 74.3	42.9 ± 40.7	68.2 ± 57.8	NS
Thiamin (mg)					
Food	0.8 ± 0.2	1.2 ± 0.4‖	1.3 ± 2.9	1.1 ± 0.5	NS
Food + supplements	2.1 ± 4.4	1.5 ± 0.7	2.2 ± 5.1	2.1 ± 4.5	NS
Riboflavin (mg)					
Food	0.8 ± 0.2	0.8 ± 0.2	1.4 ± 3.0	1.0 ± 0.3	NS
Food + supplements	2.1 ± 4.5	1.1 ± 0.6	2.4 ± 5.2	2.0 ± 4.4	NS
Niacin (mg)					
Food	10.5 ± 3.6	9.5 ± 2.2	12.2 ± 9.5	13.4 ± 4.9	NS
Food + supplements	18.1 ± 25.4	12.8 ± 6.9	15.3 ± 10.9	16.8 ± 8.8	NS
Vitamin B6 (mg)					
Food	0.9 ± 0.4	1.0 ± 0.3#	1.2 ± 2.8	1.3 ± 0.5	NS
Food + supplements	4.7 ± 13.1	4.9 ± 19.1	6.5 ± 22.7	9.2 ± 37.8	NS
Vitamin B12 (μg)					
Food	1.9 ± 1.4	0.7 ± 0.8‖	2.2 ± 1.8	1.9 ± 1.4	<0.05
Food + supplements	16.8 ± 62.0	20.1 ± 95.5	4.4 ± 6.0	4.1 ± 6.0	NS
Folate (μg)					
Food	176 ± 88	261 ± 108¶	161 ± 65	217 ± 82‖	NS
Food + supplements	260 ± 213	342 ± 216	209 ± 124	267 ± 152¶	NS
Vitamin C (mg)					
Food	66 ± 41	124 ± 60‖	76 ± 47	114 ± 54‖	NS
Food + supplements	148 ± 273	161 ± 122	109 ± 91	144 ± 97#	NS

* Mean ± Standard deviation. Six days of dietary intake were investigated. Baseline is before the diet intervention and 14 wk is during the diet intervention.

† For each participant, 14-wk data were subtracted from baseline data to determine the magnitude of change for each measure. Significance of change in nutrient intake was measured between the vegan and Step II groups.

‡ Although the new DRI for vitamin A is in RAEs, the total vitamin A intake measured in this study is reported in REs because Nutritionist V does not report in RAEs. It includes retinol and carotenoid intakes.

§ Nutritionist V software does not differentiate between the various forms of α-tocopherol; so, in the present study, vitamin E was recorded in ATEs. Current DRIs for vitamin E are in milligrams.

‖ $P < 0.001$, within-group comparison.

\# $P < 0.05$, within-group comparison.

¶ $P < 0.01$, within-group comparison.

ATE, α-tocopherol equivalent; DRI, dietary reference intake; NS, not significant; RAE, retinol activity equivalent; RE, retinol equivalent.

41 g (12% of kilocalories) at 14 wk remained within the dietary reference intake range of 40 to 52 g/d. This range was calculated by using the dietary reference intake of 0.8 g/kg of body weight, the average height of participants (163 cm), and their calculated ideal body weight of 50 to 65 kg (BMI, 18.8 to 24.5 kg/m^2), not actual body weight, as is appropriate for overweight individuals.[29] Studies examining the protein intake of vegans and vegetarians have found similar results, with both groups consuming adequate protein.[19,23]

Decreased intakes of saturated fat and cholesterol have been shown to decrease the risk of heart disease.[30,31] High fiber intake has been associated with decreased risks of diabetes,[32] cancer,[33,34] and heart disease.[35] In comparison with the Step II diet, the overall macronutrient pattern in the vegan group more closely approximated that associated with improvements in cardiovascular disease,[3] diabetes,[4,5] and hypertension[7] in clinical trials and with a lower risk of cancer in epidemiologic studies.[8–10]

Notable non-supplemented micronutrient changes in the vegan group included increases in total vitamin A, β-carotene, thiamin, vitamin B6, folic acid, vitamin C, magnesium, and potassium intakes and decreases in vitamin D, vitamin B12, calcium, phos-

TABLE V.

ESTIMATED MEAN MINERAL INTAKE PER 4.19 MJ (1000 KCAL) OF WOMEN ON VEGAN AND STEP II DIETS*

	Vegan group (n = 29)		Step II group (n = 30)		Change between groups† (P)
	Baseline	14 wk	Baseline	14 wk	
Calcium (mg)					
Food	392 ± 146	314 ± 108§	463 ± 365	430 ± 202	NS
Food + supplements	494 ± 241	409 ± 245	556 ± 402	530 ± 299	NS
Iron (mg)					
Food	9.5 ± 4.7	11.0 ± 3.4	8.3 ± 3.0	9.1 ± 2.7	NS
Food + supplements	11.7 ± 7.6	13.3 ± 5.9	10.3 ± 5.3	11.2 ± 6.1	NS
Magnesium (mg)					
Food	151 ± 47	172 ± 53§	153 ± 146	161 ± 63	NS
Food + supplements	167 ± 62	206 ± 106§	174 ± 153	185 ± 93	NS
Phosphorous (mg)					
Food	586 ± 125	448 ± 111‡	550 ± 125	555 ± 150	<0.001
Food + supplements	608 ± 145	495 ± 176‖	559 ± 137	580 ± 162	<0.05
Potassium (mg)					
Food	1506 ± 461	1804 ± 514‖	1463 ± 370	1760 ± 372‡	NS
Food + supplements	1543 ± 513	1841 ± 559§	1483 ± 380	1765 ± 383‡	NS
Selenium (mg)					
Food	0.05 ± 0.06	0.03 ± 0.02§	0.04 ± 0.03	0.24 ± 1.07	NS
Food + supplements	0.07 ± 0.09	0.03 ± 0.02§	0.05 ± 0.03	0.24 ± 1.07	NS
Sodium (mg)	1375 ± 372	1491 ± 499	1565 ± 547	1473 ± 534	NS
Zinc (mg)					
Food	4.6 ± 1.9	3.4 ± 1.1‡	6.0 ± 6.8	4.5 ± 2.4	NS
Food + supplements	6.8 ± 4.2	5.8 ± 4.8	8.3 ± 7.6	6.6 ± 4.8	NS

* Mean ± standard deviation. Six days of dietary intake were investigated. Baseline is before the diet intervention and 14 wk is during the diet intervention.
† For each participant, 14 wk data were subtracted from baseline data to determine the magnitude of change for each measure. Significance of change in nutrient intake was measured between the vegan and Step II groups.
‡ $P < 0.001$, within-group comparison.
§ $P < 0.05$, within-group comparison.
‖ $P < 0.01$, within-group comparison.
NS, not significant.

phorous, selenium, and zinc intakes. In the Step II group, there were increases in non-supplemented micronutrient intakes of folic acid, vitamin C, and potassium, with no significant decreases in non-supplemented intakes of the other nutrients studied.

Compared with omnivores, vegetarians tend to have higher intakes and serum concentrations of β-carotene[36] and total vitamin A.[23,36] Vegans and vegetarians typically have lower intakes of vitamin D,[14,37] higher intakes of vitamin E,[17,23,38] and higher vitamin E serum concentrations[21,24] compared with non-vegetarians. In the current study, there were no significant differences between or within groups in vitamin E intake, probably due to the limitation of added vegetable oils and nuts in both groups.

The vegan group had a significant increase in thiamin intake but no change in riboflavin or niacin intakes. Studies have found similar results regarding thiamin when comparing vegan or vegetarian diets with omnivorous diets,[23,38,39] but results on niacin intake and serum concentrations have been variable.[14,38,40] Folic acid is critical for healthful pregnancies[41,42] and plays a role in decreasing serum homocysteine concentrations, a factor of potential importance in the prevention of cardiovascular disease[43] and Alzheimer's disease.[44] Folic acid intakes increased for the vegan group, a finding consistent with most studies,[16,17,39] and for the Step II group. Vegans and vegetarians, in general, have higher intakes and serum levels of vitamin C than do individuals consuming omnivorous diets.[12,16,17,21]

Calcium intake has usually, but not always, been reported to be lower among vegans than among omnivores.[37,45,46] However, we found no significant difference in the changes between groups, reflecting the low baseline calcium intake of both groups and the vegan group's use of leafy greens and fortified foods such as soymilk and orange juice. Although we found no significant difference between groups with regard to iron intake, previous studies have shown vegetarians and vegans to have higher[38,46,47] or lower[19,20] intakes. Two studies have reported that vegans are no more likely than omnivores to have low serum ferritin stores, although females are at greater risk of below-normal ferritin values regardless of diet.[16,48] Prior studies have reported that vegetarians and vegans have a lower or higher intake of selenium than omnivores.[28,36,46] Because selenium may be protective against some cancers, it would be important for vegans following a low-fat vegan diet to be aware of selenium-rich foods. Previous findings on zinc intake and serum concentrations among vegetarians have also been variable.[18–20,36,38,45–49]

The reported supplement use in this study was much lower than expected, given other studies reporting that more than 50% of adults in the United States use vitamin or mineral supplements.[50] Because supplementation was neither encouraged nor discouraged in this study, we did not expect a change in supplement usage between baseline and 14 wk.

An advantage of the present study is its applicability outside the research setting, because the participants in this study prepared their own meals or ate at restaurants with minimal monitoring (weekly meetings). The study also has limitations. Because nutrient intake was analyzed only at baseline and at 14 wk, it may not

TABLE VI.

PERCENTAGE OF PARTICIPANTS MEETING THE DRI OR RDA FOR PROTEIN, VITAMINS, AND MINERALS

	Vegan group (n = 29)				Step II group (n = 30)			
	Baseline		14 wk		Baseline		14 wk	
Nutrient	SP	NSP	SP	NSP	SP	NSP	SP	NSP
Protein*	90		55		100		97	
Vitamins†								
Total vitamin A	72	41	79	55	80	50	77	60
Vitamin D	21	0	21	0	30	3	27	7
Vitamin K	28	38	35	45	30	47	47	50
Thiamin	76	72	90	83	73	60	83	80
Riboflavin	66	69	69	59	80	70	80	73
Niacin	76	72	45	31	83	73	83	77
Vitamin B6	55	45	52	45	70	53	77	60
Vitamin B12	72	66	34	14	73	67	53	40
Folic Acid	31	14	45	34	30	13	23	7
Vitamin C	86	76	90	86	87	80	93	87
Minerals								
Calcium	17	7	7	0	30	13	16	13
Iron	97	86	97	93	93	87	100	67
Magnesium	31	21	14	14	30	20	13	7
Phosphorous	79	76	31	28	73	77	60	53
Potassium	69	72	76	76	80	77	73	73
Selenium	79	0	28	0	77	0	73	0
Zinc	59	21	24	0	60	23	33	7

* Protein based on a DRI of 0.8 g/kg of ideal body weight. Ideal body weight for this group, based on the average height of 163 cm, would be 50 to 65 kg (body mass index, 18.8 to 24.5 kg/m^2). Therefore, the DRI for protein intake of 0.8 g/kg would be 40 to 52 g/d.

† Nutritionist V software does not differentiate between the various forms of α-tocopherol; so, in the present study, vitamin E was recorded in α-tocopherol equivalents. Current DRIs for vitamin E are in milligrams.

DRI, dietary reference intake; NSP, non-supplemented; RDA, recommended dietary allowance; SP, supplemented

be representative of consumption patterns over the entire 14-wk period. A total of 6 d of dietary intake was recorded, and, although that was likely enough time to accurately assess macronutrient intake, it may have been too short for an accurate overall micronutrient intake profile. It may be difficult to assess selenium intake because nutrient analysis programs do not account for potentially large regional variations in the selenium content of soil (and, hence, of food crops).[51] In addition, the food records were analyzed by a research dietitian, which could have influenced participants in their reporting of "desirable" or "undesirable" foods.

Under-reporting of dietary intake, particularly for food items that may seem nutritionally undesirable, is common in individuals with higher BMIs.[52] The study participants were selected to have high BMIs. At baseline, the ratios of energy intake to RMR, a proxy for the validity measurements of the ratio of energy intake to energy expenditure, were 1.23 and 1.27 for the vegan and Step II participants, respectively. These values are consistent with the ratio of energy intake to basal energy expenditure of 1.24 reported from the Third National Health and Nutrition Examination Survey for women in the second BMI tertile (mean BMI, 25.7) who answered "yes" to the question, "Are you currently trying to lose weight?".[53] However, these values fall into the range of cutoff values for low energy reporters (<0.9 to <1.28) from papers reviewed by Livingstone and Black[54] and, therefore, indicate that some level of under-reporting did occur. If activity is taken into account and the standard Goldberg cutoff physical activity level of 1.55 is used to calculate total energy expenditure, then the baseline estimated ratios of energy intake to energy expenditure are 0.79 and 0.82 for the vegan and Step II participants, respectively. When using this physical activity level and assuming weight stability, the average estimated level of under-reporting of caloric intake was about 20% in both groups.[54]

This is an issue in any study relying on self-reported dietary intake. However, under-reporting most likely occurred at baseline and at 14-wk, so the degree of change in caloric intake should be accurate. Moreover, although energy intake tends to be underestimated by individuals with higher BMIs, it appears to be underestimated to the same degree in vegans and omnivores.[55] Further, we chose to use a 3-d food record over a food-frequency questionnaire because studies have shown that 3-d food records have a high degree of validity, especially in populations following a low-fat dietary intervention program.[56] This study, as any study of non-institutionalized individuals, relied on self-reports for assessing nutrient intakes. The 3-d diet records and the periodic 24-h food recalls showed a high degree of compliance, and no participant was dropped from the study due to non-compliance. Evidence of compliance in this study comes not only from the diet records and food recalls but also from objective changes in body weight reported here and changes in serum cholesterol and insulin sensitivity to be reported elsewhere. Although both groups participated concurrently, there was no attempt to isolate the effects of seasonal variation on nutrient intake. The present study was a short-term intervention. Investigation of the long-term sustainability and compliance of the low-fat vegan and Step II diets and resultant weight loss is currently underway.

There are clearly many ways to implement low-fat vegan diets. Because these diets are defined by what they omit (added fats or animal-derived foods) rather than by what they include, they could emphasize grain products, vegetables, fruit, or legumes. Each of these food groups would have its own effects on nutrient intake, especially for micronutrients. Low-fat vegan diets emphasizing green leafy vegetables, beans, and vitamins D- and B12-fortified whole grain cereals would likely have increased intakes of vitamin D, calcium, phosphorous, and zinc, whereas vegan diets emphasizing nuts and seeds would likely increase selenium. Similarly, the use of unrefined grain products increases fiber intake, whereas the use of refined grains decreases it. Emphasizing beans, meat alternates, nuts, seeds, some whole grains, and vegetables would result in higher protein intakes, whereas the use of fruit, beverages, and refined grains would result in lower protein consumption. Our intervention group showed the nutrient effects not of vegan diets generally but of one set of low-fat vegan dietary guidelines on the nutrient intake of free-living participants interpreting and implementing these guidelines. Other guidelines would be expected to lead to very different protein and micronutrient profiles.

Research has shown that a diet deriving 10% of calories from fat facilitates weight loss, control of blood pressure, and reversal of atherosclerosis.[1,3,4] However, the recommendation of any therapeutic diet must be accompanied by attention to nutritional adequacy. Although there is some debate as to whether increasing carbohydrate intake and decreasing fat intake increases triacylglycerol and glucose levels, most research has shown that low-fat, high-carbohydrate diets result in substantial reductions in body weight. This in turn produces beneficial results on insulin resistance and triacylglycerol formation.[57] However, people following a very low-fat diet should incorporate regular physical exercise into their lifestyle to prevent increases in triacylglycerol and glucose levels.[58]

The results of this study show that the adoption of a low-fat vegan diet improves several aspects of macronutrient intakes, provided that adequate attention is paid to micronutrient-rich foods. This would also apply to other low-fat or reduced-calorie diets. A dietitian or other nutritional professional can provide important guidance to individuals implementing weight-loss programs. The present study is useful because it helps us to better understand the effects therapeutic low-fat vegan or Step II diets have on overall nutrient intake.

Overall, a change from an omnivorous diet to a low-fat vegan diet led to greater reductions in fat, saturated fat, and cholesterol intakes than those reported for the Step II diet. The vegan group increased nutrient density from baseline for total vitamin A, β-carotene, thiamin, vitamin B6, folate, vitamin C, magnesium, and potassium. Nutrient density decreased for protein, vitamin D, vitamin B12, calcium, phosphorous, selenium, and zinc on an non-supplemented low-fat vegan diet. To increase intakes of these nutrients, people following a low-fat vegan diet should emphasize legumes and whole grains for protein; supplemental sources of vitamin D and B12, such as fortified cereals and soymilk to increase vitamin D and B12 intakes; leafy greens, beans, and fortified soymilks and juices to increase calcium intake; and whole, unrefined grains, nuts, and seeds to increase phosphorous, selenium, and zinc intakes. However, the use of self-selected supplements in the present study attenuated many of these reductions. The Step II diet increased folate, vitamin C, and potassium intakes, and there were no significant decreases in micronutrient intakes.

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