Strategies to Increase Vegetable or Reduce Energy and Fat Intake Induce Weight Loss in Adults

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For obese individuals seeking to optimize health and well-being, healthy dietary strategies are important. Vegetables and fruits contribute to a healthy diet, and increased consumption may cause weight reduction by displacing foods high in energy and fat. The objective of this study was to determine if advising high vegetable (8 servings) and moderate fruit (2–3 servings) consumption would result in weight reduction in obese individuals. We compared this to advising a more traditional strategy of reducing daily energy intake by 500 kcal (2.1 MJ)/d and limiting energy from fat to ≤25%. A randomized study design was used. Subjects (age 21–50 y, *n* = 30/group) received food (2 meals + 1 snack/d, 5 d/wk) and education (2 group lessons/wk plus individual consultations as requested) for the first 3 mo. Weight and body composition were measured at baseline and after 3, 12, and 18 mo. Fasting serum lipid panel, insulin, glucose, hematocrit, and C-reactive protein were measured at baseline, 3, and 12 mo. Both groups lost weight after 3 mo ($P = 0.0087$ for high vegetable diet and $P < 0.0001$ for energy reduction diet), and the energy and fat reduction diet resulted in lower weight over time ($P < 0.0001$, treatment effect). Total cholesterol and cholesterol:HDL decreased after 3 mo in both groups ($P \leq 0.0061$). Both strategies produced initial weight loss at 3 mo, but only the group following the caloric and fat reduction advice maintained weight loss at the 12- and 18-mo follow-up assessments. Nonetheless, the group following the high vegetable advice did not regain weight above baseline. In conclusion, traditional messages to reduce calories and fat are important, and increasing vegetable intake can assist individuals to maintain weight. Exp Biol Med 234:542–552, 2009

Key words: body composition; caloric restriction; obesity; vegetables; reducing diet; weight loss

Introduction

Due to concerns of negative health effects of obesity, strategies for optimizing health in obese individuals are needed. A potential dietary strategy is consumption of high amounts of vegetables and fruits (1, 2). Not only is it known that a diet high in vegetables and fruits can reduce the risk for cancer (3) and cardiovascular disease (4), improve bone health (5, 6), and reduce age-related cognitive decline (7), it may also result in weight loss (8–11). This may be due to a reduction in the energy density (kcal/g food) of the diet resulting in less energy consumed daily (11–14). Long-term maintenance of modest weight loss, as little as 10% of body weight, has been shown to be sufficient for reducing risk of multiple obesity-related medical complications, such as diabetes and cardiovascular disease (15, 16), sleep-disordered breathing (i.e., a condition characterized by either pauses in or shallow breathing during sleep) (17), and for improving overall physical and psychological health (18).

Several weight-loss studies of obese individuals have examined dietary strategies that include a focus on increasing vegetable and fruit consumption in addition to other goals such as a reduction in energy intake (8) or fat (11) or an increase in grains (19) or low-fat dairy products (20, 21). This study evaluated the impact of advising high vegetable consumption (≥8 servings/d) and moderate fruit consumption (2–3 servings/d), in the absence of other goals, on weight and body composition after 3, 12, and 18 mo and on serum chemistry values after 3 and 12 mo in obese individuals. The hypothesis of this study was that including high amounts of vegetables and moderate amounts of fruit would induce weight loss by causing a reduction in total

This research was supported by the National Research Initiative of the USDA Cooperative State Research, Education, and Extension Service, grant number 2003-35200-05377, and the Wisconsin Cranberry Board, Inc.

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Received October 2, 2008.
Accepted January 26, 2009.

DOI: 10.3181/0810-RM-293
1535-3702/09/2345-0542$15.00

energy and fat consumed daily, presumably by displacing foods higher in energy and fat from the diet. We predicted that subjects following this dietary advice would continue to lose weight long-term, because once incorporated as a routine part of the diet, high vegetable and fruit consumption would be more sustainable than counting calories and grams of fat from food labels.

Materials and Methods

Subjects. Subjects were recruited from the greater Madison, WI, area using posted flyers and newspaper and website advertisements seeking obese volunteers for a weight-loss study. Respondents were screened by telephone interview for major eligibility and then via medical history, physical activity questionnaire, and physical exam by the study medical doctors.

To be considered for the study, subjects had to be 19–50 y of age, have a BMI ≥30 but ≤40 kg/m^2, and be willing to visit the study kitchen twice per week during the first 16 wk of the study for food pick-up and group lessons. Exclusion criteria comprised aerobic exercise >90 min/wk, consumption of ≥5 servings vegetables and/or fruits per day, history of insulin treatment, history of drug or alcohol abuse, participation in other research studies that could confound results, plans to move away from the study area within 12 mo of the study start, pregnancy or lactation, serious medical or psychiatric illness, unwillingness or inability to discontinue use of supplements containing carotenoids, use of drugs that might affect weight loss, and weight change >3% of body weight during the 3 mo prior to recruitment. Only 1 member per household was eligible to participate.

Of the 77 people who completed screening (Fig. 1), 14 declined participation, and 3 were excluded, resulting in 60 subjects (16 males, 44 females). These 60 subjects were stratified by gender and BMI and randomized to either the high vegetable and modest fruit consumption (HiVeg) group or the energy- and fat-reduction diet (Reduction) group ($n =$ 30/group; 8 males/group). Of the randomized subjects, 78.3% were Caucasian, 8.3% were black or African American, 5% considered themselves Hispanic or Latino, 3.3% were Asian, and 5% were other or did not report their race or ethnicity. The majority of the subjects were married (51.7%), and 74.2% of those married had children; 45% were single, and 18.5% of single subjects had children. The remaining 2 subjects considered themselves partnered (e.g., engaged) with 1 of them having children. Subjects gave written informed consent. The Health Sciences Institutional Review Board at the University of Wisconsin School of Medicine and Public Health approved all aspects of this study.

Body composition was measured by air displacement plethysmography (BOD POD®, Life Measurements, Inc., Concord, CA) (22, 23). Weight was measured using the BOD POD® scale, which was tested with calibration weights each day of use. Height was measured at baseline using a wall-mounted stadiometer. All body composition and weight assessments were conducted by BOD POD® certified users.

Blood samples were drawn into sterile Vacutainer® tubes containing 5.4 mg K_2EDTA or serum separator gel (Becton Dickinson, NJ) after an overnight fast (at least 8 h). Samples sat for 10 min and then were centrifuged for 10 min at 4°C and 2410 × *g*. Serum was transferred to transportation tubes provided by the contract laboratory and stored on ice until analysis within 18 h for fasting serum triacylglycerols, total cholesterol, HDL cholesterol, VLDL cholesterol, LDL cholesterol (calculated by difference), cholesterol:HDL ratio, insulin, glucose, hematocrit, and C-reactive protein at the contract laboratory (Consultants Laboratory, Fond du Lac, WI).

Experimental Design. A randomized study design was used to compare the effects of the dietary strategies on weight, body composition, and serum chemistry profile. Primary outcomes of interest were change in weight, fat mass, fat-free mass, and absolute BMI. These were measured at baseline, 3, 12, and 18 mo. Secondary outcomes included fasting serum lipid panel (cholesterol, triacylglycerol, HDL, LDL, VLDL, cholesterol:HDL), insulin, glucose, hematocrit, and C-reactive protein, which were measured at baseline, 3, and 12 mo. Subjects were asked to report any adverse events throughout the trial.

Subjects randomized to the HiVeg group were educated about counting vegetable and fruit intake using the Food Guide Pyramid (24), where intake is described by the number of servings. The Food Guide Pyramid is a free and publicly available resource based on the *Dietary Guidelines for Americans, 5th Ed* (25), and was used because this study was initiated prior to, but concluded after, the release of the *Dietary Guidelines for Americans 2005, 6th Ed* (26) and *MyPyramid* (27). According to the Food Guide Pyramid, ½ cup raw or cooked vegetables, 1 cup raw leafy greens, or ¾ cup vegetable juice is equivalent to 1 serving of vegetables. For fruits, ½ cup of raw or cooked fruit and ¾ cup fruit juice equal 1 serving. HiVeg subjects had a daily goal of consuming 8 servings of vegetables and 2–3 servings of fruits. The HiVeg group was asked not to consume potato chips, fried vegetables, or fruit or vegetable juices to meet their goal. In the *post hoc* dietary analysis, however, fruits and vegetables were defined according to the updated *Dietary Guidelines for Americans 2005, 6th Ed* (26) and *MyPyramid* (27). Thus, potato chips, french-fried potatoes, 100% fruit juice, and 100% vegetable juice counted toward goals.

Subjects randomized to the Reduction group had two daily goals: reduce caloric intake by 500 kcal (2.1 MJ) from the estimated kcal needed for weight maintenance each day and consume <25% energy from fat. Daily kilocalories for weight maintenance were estimated by multiplying an individual's estimated resting energy expenditure (REE) by an individually appropriate activity factor. REE was

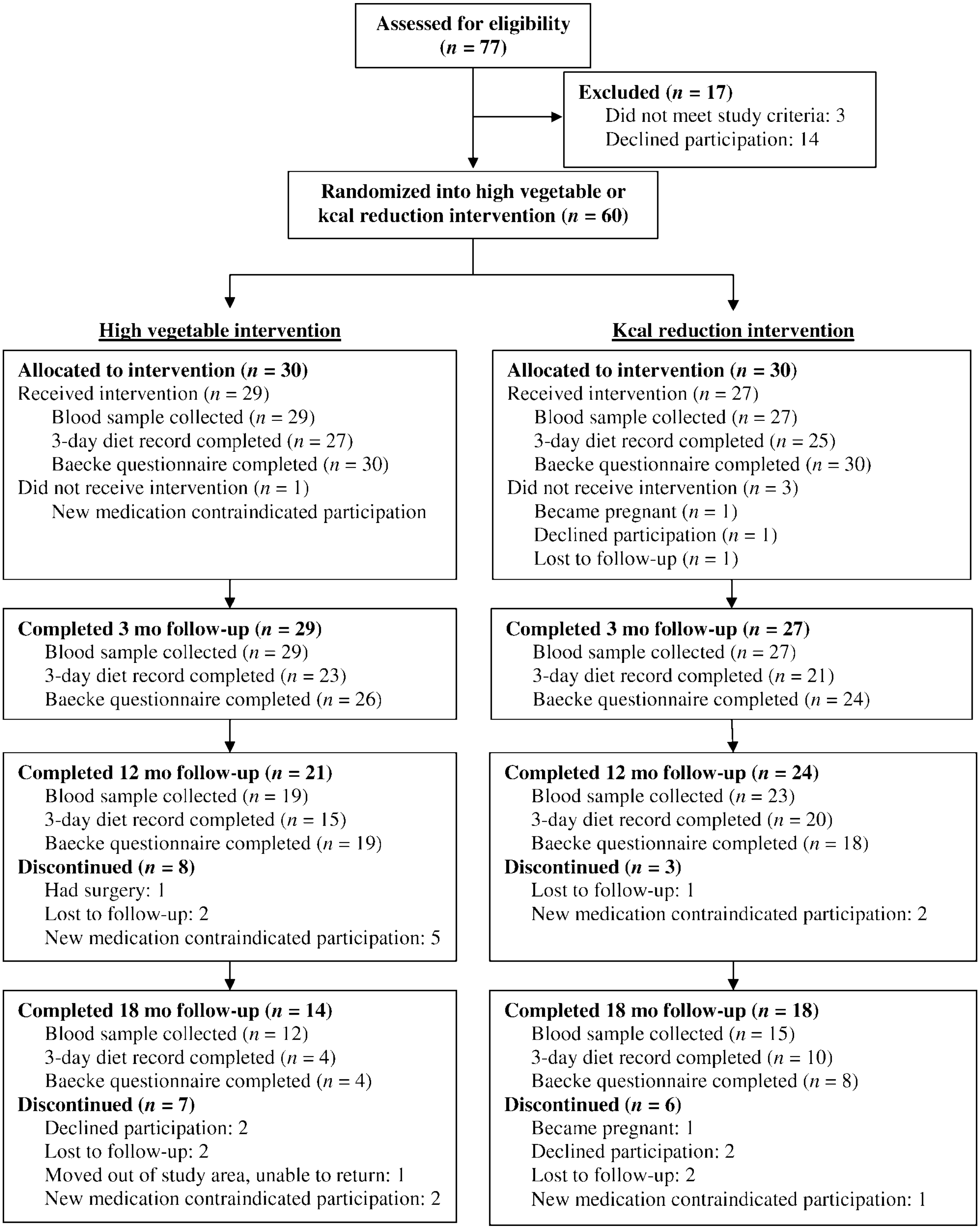

Figure 1. Subject progression through the trial. Obese individuals were recruited from Madison, WI, and surrounding areas. At baseline, male ($n = 16$) and female subjects ($n = 44$) were randomly assigned, stratified by gender and BMI, to a weight-loss intervention focused on including high amounts of vegetables and moderate amounts of fruit or restricting kilocalories and fat intake. Follow-up data were collected at 3, 12, and 18 mo. Subjects who were counted as completing a follow-up assessment had their weight and body composition measured. The number of subjects who also gave blood samples, completed 3-d diet records, and completed Baecke Physical Activity Questionnaires at each follow-up is shown. Reasons for discontinuation, when known, are listed.

Table 1. List of Foods Provided to Obese Subjects from Baseline to 4 mo[a]

Meal and foods provided
Breakfast
Fat-free milk, 8 oz (0.24 L)
Fruit,[b] 1 serving
Cereal,[b] 1 cup (0.24 L)
Muffin
Carrot muffin (3 d/wk)[c]
Pumpkin muffin (2 d/wk)[d]
Lunch
Lean Cuisine® entrée[b,e]
Fat-free milk, 8 oz (0.24 L)
Low fat or fat-free salad dressing,[b] 2 tablespoons (30 mL)
Vegetables
Raw vegetables[b,f,g] (Mondays)
Salad[h] + raw vegetables[b,f,i] (Tuesdays–Fridays)
Snack
Fat-free milk, 8 oz (0.24 L)
~60 kcal (0.25 MJ) snack[b,j]

[a] For the first 3 mo of the study, the menu was provided on weekdays (5 d/wk). For month 4 of the study, the menu was provided 2 weekdays per week.
[b] Indicates that subjects selected from offered options.
[c] Carrot muffins provided 1 or 0.5 serving vegetables to the HiVeg and Reduction groups, respectively.
[d] Pumpkin muffins provided 0.6 or 0.3 serving vegetables to the HiVeg and Reduction groups, respectively.
[e] Lean Cuisine® entrées provided 0.5–3 serving of vegetables; HiVeg subjects were always offered entrées with twice as many servings of vegetables as the entrées offered to Reduction subjects.
[f] Raw vegetable options included baby carrots, cauliflower, broccoli, snow peas, and tomatoes.
[g] On Mondays, 6 or 3 servings of raw vegetables were provided to the HiVeg and Reduction groups, respectively.
[h] On Tuesdays–Fridays, 2 or 1 servings of vegetables as a mixed-greens salad were provided to the HiVeg and Reduction groups, respectively.
[i] On Tuesdays–Fridays, 4 or 2 servings raw vegetables were provided to the HiVeg and Reduction groups, respectively.
[j] Snack options included 28 g soy nuts, 1 piece of fruit, or 14.5 g Baked Whole Grain Wheat Reduced Fat Triscuit® crackers, among others.

estimated using the equations by Mifflin et al. (28) which include height, weight, age, and gender. The activity factors used (1.3, 1.5, and 1.6 for very light, light, and moderate activity, respectively) were those recommended by the Institute of Medicine (29). A 500 kcal/d reduction was chosen to achieve a safe weight-loss rate of approximately 0.5 kg/wk. Caloric goals were modified weekly according to weight change for each subject.

Food, described in Table 1, was provided to subjects during the first 4 mo of the study to facilitate compliance. Although the food was intended for breakfast and lunch, subjects were free to consume it at anytime. Each day, 7–8 and 3.5–4 servings of vegetables were given to the HiVeg and Reduction groups, respectively. Both groups received 2 servings of fruit daily. Most vegetables were provided raw and subjects were encouraged to prepare them as they chose (e.g., consume raw, cooked, or use them in a recipe). To accommodate food preferences, subjects were allowed some choices. In general, choices were offered for frozen-meal entrées, vegetables, fruits, and snacks. When options were offered, the choices were nearly equivalent in type of food or macronutrients (e.g., contained the same number of vegetable servings, total energy, and/or fat). Food packaging and meal choices were similar between groups with the main difference being that the HiVeg group was given twice as many servings of vegetables as the Reduction group.

The trial comprised 4 phases. During Phase I (week 1–3), subjects were advised to transition from their usual eating habits to their assigned dietary strategy. Subjects were required to attend the morning educational sessions with members from the same treatment group 2 d/wk. Food was provided for weekdays (5 d/wk). Subjects were encouraged to ask for individual consultations if they desired additional assistance in achieving their dietary goals. For Phase II (week 4–12), subjects were asked to consistently meet their dietary goals. Subjects continued to have regular in-person education and support in the form of group education sessions (2 d/wk) and the optional individual consultations. Food was provided on weekdays (5 d/wk), and subjects were expected to adhere to their assigned dietary strategy on evenings and weekends. Phase III (month 4) was designed to transition subjects to following their dietary strategy independently. Food was provided only 2 d/wk. Group lessons were not offered, but subjects had the option to speak with researchers about any questions or concerns twice weekly when they picked up their study food. Individual consultations were still available upon request. Most individual consultations were accommodated informally after breakfast sessions in the mornings. During Phase IV (months 5–18), subjects were asked to follow their dietary strategy independently using the skills and knowledge obtained in the previous phases, but subjects could still request individual consultations. The coordinator provided support calls by telephone with gradually decreasing frequency (from weekly to monthly) from months 5 to 12.

It was not possible to blind subjects to their own treatment. However, the subjects were not aware of the other treatment by holding the morning educational sessions on different days, offering similar foods and education, and asking subjects not to discuss their diets with members of the other group. Similarly, it was not possible to blind researchers assisting with food distribution, giving dietary advice, or measuring body weight and composition. However, researchers and consultants who analyzed blood samples were unaware of the treatment assignments.

All subjects completed 3-d diet records (2 weekdays and 1 weekend day) at baseline, 3, 12, and 18 mo. These were analyzed for energy, fat, protein, fiber, vegetables, and fruit using Nutritionist Pro™ Version 3.1.0 (Axxya Systems; Stafford, TX, 2007).

Education. At the educational sessions, subjects were

Table 2. Baseline Characteristics by Treatment Group ($n = 30$/Group, Except Where Indicated)

	HiVeg[a]	Reduction[b]
Age (y)	30.7 ± 6.6[c,d]	36.4 ± 9.4
Male (*n*)	8	8
Body wt (kg)	94.2 ± 14.9	96.0 ± 17.1
Fat mass (kg)	40.0 ± 10.0[e]	39.8 ± 10.2[f]
Fat-free mass (kg)	54.0 ± 10.4[e]	56.4 ± 12.8[f]
BMI (kg/m^2)	33.7 ± 3.8	33.3 ± 3.5
Lifetime maximum body wt (kg)[g]	98.1 ± 17.0	103.2 ± 22.9
Calculated lifetime maximum BMI[h]	35.2 ± 4.5[e]	35.9 ± 5.9[f]
Age first overweight (y)[g]	12.8 ± 7.6[e]	15.2 ± 8.9
Maximum weight lost previously (kg)[g]	12.5 ± 7.9	16.6 ± 9.4[e]
No. of times lost 9.07 kg (20 lbs) or more[g]	1.4 ± 1.4[e]	1.8 ± 1.7[e]
No. of different weight-loss programs tried[g]	2.1 ± 1.3[e]	1.8 ± 1.4[e]
C-reactive protein (mg/L)	4.5 ± 3.2	8.0 ± 15.7
Insulin (pM)	79.0 ± 60.6	66.9 ± 31.9
Glucose (mM)	5.17 + 0.52	5.29 + 0.45
Hematocrit (vol/vol)	0.42 + 0.025	0.42 + 0.032

[a] HiVeg subjects followed a weight-loss strategy focused on including high amounts of vegetables and moderate amounts of fruit in the diet.
[b] Reduction subjects followed a weight-loss strategy focused on reducing energy and fat intake.
[c] Data are presented as means ± SD, for all such values. $P \leq 0.050$ is considered significant.
[d] Mean ages between groups are significantly different ($P = 0.0081$, *t* test).
[e] $n = 29$.
[f] $n = 27$.
[g] Self-reported answers were not verified by medical records.
[h] Calculated using reported lifetime maximum weight and assuming that height at time of maximum weight was not different from height measured at baseline.

taught strategies for meeting the goals of their diet, participated in lessons on nutrition and health, and received handouts. Both groups were taught to follow a healthy eating plan as described by the Food Guide Pyramid (24). All educational sessions and handouts were identical, except for those focused on how to count servings of vegetables and fruits (HiVeg) or kilocalories and fat grams (Reduction). Both groups were taught the same lessons about increasing physical activity. Recommendations included achieving 180 min/wk of aerobic activity and 270 weight-resistance exercise repetitions (e.g., arm curls) per week. All subjects were provided with pedometers and instructed on proper use (30), but pedometer use was optional. Subjects were asked to complete Baecke Physical Activity Questionnaires (31) at baseline, 3, 12, and 18 mo as a measure of changes in physical activity.

Statistical Analyses. Statistical analyses were performed using SAS software (version 9.1.3; SAS Institute, Cary, NC). Data are presented as means ± SD, and $P \leq 0.050$ is considered significant. The analysis was intention-to-treat. We chose not to use analytic approaches to reduce the effect of withdrawal (e.g., last-observation-carried-forward or multiple imputation for missing values); therefore, missing values were ignored by the statistical program.

Primary outcomes, secondary outcomes, 3-d diet records, and Baecke Physical Activity Scores were examined for main effects of treatment, time, and treatment × time using PROC MIXED to account for repeated measures. Age at baseline and age of overweight onset were included as fixed effects in all models. Baseline BMI was included as a fixed effect as appropriate. Gender was included as a fixed effect in models evaluating measures of physical activity. Changes within treatment groups were examined using PROC MIXED or adjusted *t* tests controlling for age at baseline, age of overweight onset, and baseline BMI (as appropriate).

Between-group differences in primary outcomes from baseline to 3 mo only were examined using adjusted *t* tests (primary outcomes) or Student's *t* tests (secondary outcomes). This short-term analysis was performed in order to understand the effects of the intensive 3-mo feeding and education intervention, when compliance was highly facilitated.

Results

Of the 60 randomized subjects, 56, 45, and 32 participated in the 3-, 12-, and 18-mo data collection points, respectively. Reasons for dropout, when known, are in Figure 1. There was an age difference between groups ($P = 0.0081$) after randomization; thus, age was controlled for in all statistical analyses. Groups did not differ in any other baseline characteristics (Table 2) or dietary intake (Table 3). Baseline characteristics of the subjects who completed the trial were not different from those who did not complete the trial (data not shown).

Weight and fat mass changed with treatment, but fat-free mass did not change (Fig. 2). BMIs also changed over time (Table 4). There were no significant treatment × time interactions or time effects for the primary outcomes. At 3 mo, after the conclusion of the intensive feeding and

Table 3. Analysis of 3-d Diet Records of Obese Subjects Following Two Dietary Strategies for Weight Loss

	HiVeg[a]	Reduction[b]	Effect	*P* value
Vegetable intake (servings/d)				
Baseline[c]	3.2 ± 1.8[d]	2.6 ± 1.4	Treatment × time	0.015
3 mo	6.6 ± 2.2[e,f]	3.6 ± 1.4	Treatment	<0.0001
12 mo	4.6 ± 1.9[e]	3.6 ± 2.0	Time	<0.0001
18 mo	4.6 ± 3.2	2.8 ± 1.2		
Fruit intake (servings/d)				
Baseline[c]	1.2 ± 1.4	1.4 ± 1.2	Treatment × time	0.73
3 mo	2.0 ± 1.2	1.6 ± 2.2	Treatment	0.75
12 mo	2.2 ± 3.2	2.0 ± 1.6	Time	0.052
18 mo	2.0 ± 1.8	2.0 ± 1.9		
Fat intake (g/d)				
Baseline[c]	87.2 ± 22.1	84.5 ± 37.4	Treatment × time	0.58
3 mo	61.7 ± 22.2[e]	44.0 ± 12.3[e]	Treatment	0.030
12 mo	66.9 ± 25.6[e]	55.1 ± 21.5[e]	Time	<0.0001
18 mo	48.1 ± 12.4[e]	38.0 ± 9.9[e]		
Energy intake (kcal/d)[g]				
Baseline[c]	2273 ± 582[d]	2009 ± 647	Treatment × time	0.84
3 mo	1923 ± 474[e,h]	1667 ± 269[e]	Treatment	0.15
12 mo	1874 ± 544[e]	1744 ± 458	Time	0.0001
18 mo	1556 ± 190[e]	1456 ± 284[e]		
% Energy from fat/d				
Baseline[c]	35.0 ± 6.4	37.3 ± 8.8	Treatment × time	0.093
3 mo	28.6 ± 6.0[e]	23.7 ± 4.5[e]	Treatment	0.036
12 mo	32.2 ± 7.7	28.9 ± 10.5[e]	Time	<0.0001
18 mo	28.0 ± 7.2	23.7 ± 6.0[e]		
Protein intake (g/d)				
Baseline[c]	84.6 ± 22.2	83.3 ± 26.8	Treatment × time	0.43
3 mo	78.1 ± 16.3	85.5 ± 13.4	Treatment	0.84
12 mo	82.3 ± 21.9	85.8 ± 26.4	Time	0.90
18 mo	87.7 ± 25.5	74.8 ± 17.8		
% Energy from protein/d				
Baseline[c]	15.3 ± 3.7	16.9 ± 2.9	Treatment × time	0.28
3 mo	17.1 ± 4.3	20.9 ± 4.0[e]	Treatment	0.33
12 mo	18.8 ± 7.5[e]	20.3 ± 5.8[e]	Time	0.0008
18 mo	22.3 ± 5.4[f]	20.6 ± 3.5[f]		
Fiber intake (g/d)				
Baseline[c]	17.5 ± 8.4	16.4 ± 6.6	Treatment × time	0.98
3 mo	24.7 ± 5.8[e]	22.9 ± 6.7[e]	Treatment	0.73
12 mo	20.5 ± 9.5	19.8 ± 8.3	Time	0.0004
18 mo	22.0 ± 7.9	19.8 ± 7.7		

[a] HiVeg subjects followed a weight-loss strategy focused on including high amounts of vegetables and moderate amounts of fruit in the diet. The numbers of dietary records analyzed were $n = 27$, 23, 15, and 4 for the baseline, 3-, 12-, and 18-mo time points, respectively.
[b] Reduction subjects followed a weight-loss strategy focused on reducing energy and fat intake. The numbers of dietary records analyzed were $n = 25$, 21, 20, and 10 for the baseline, 3-, 12-, and 18-mo time points, respectively.
[c] Baseline values are not different between groups.
[d] Data are presented as means ± SD, and $P \leq 0.050$ is considered significant.
[e] Values within a group that differed significantly from baseline as evidenced by a mixed effects model with repeated measures showing a significant effect of time.
[f] Values at that time point differed between groups as evidenced by a significant treatment × time interaction in a mixed effects model accounting for repeated measures.
[g] Energy data are reported in kilocalories because subjects in the Reduction group were advised to count kilocalories. 1 kcal = 4.18 kJ.
[h] Values differed between groups as evidenced by a *t* test, which was evaluated for energy data only.

education intervention, there was a difference between groups in change in weight, change in fat mass, and BMI ($P \leq 0.0011$).

Adjusted *t* tests were used to compare within-group changes from baseline to follow-up. In the HiVeg group, weight (Fig. 2a) and fat-mass (Fig. 2b) were lower than baseline at 3 mo ($P = 0.0087$ and $P = 0.0002$, respectively), while fat-free mass (Fig. 2c) increased from baseline at 3 mo

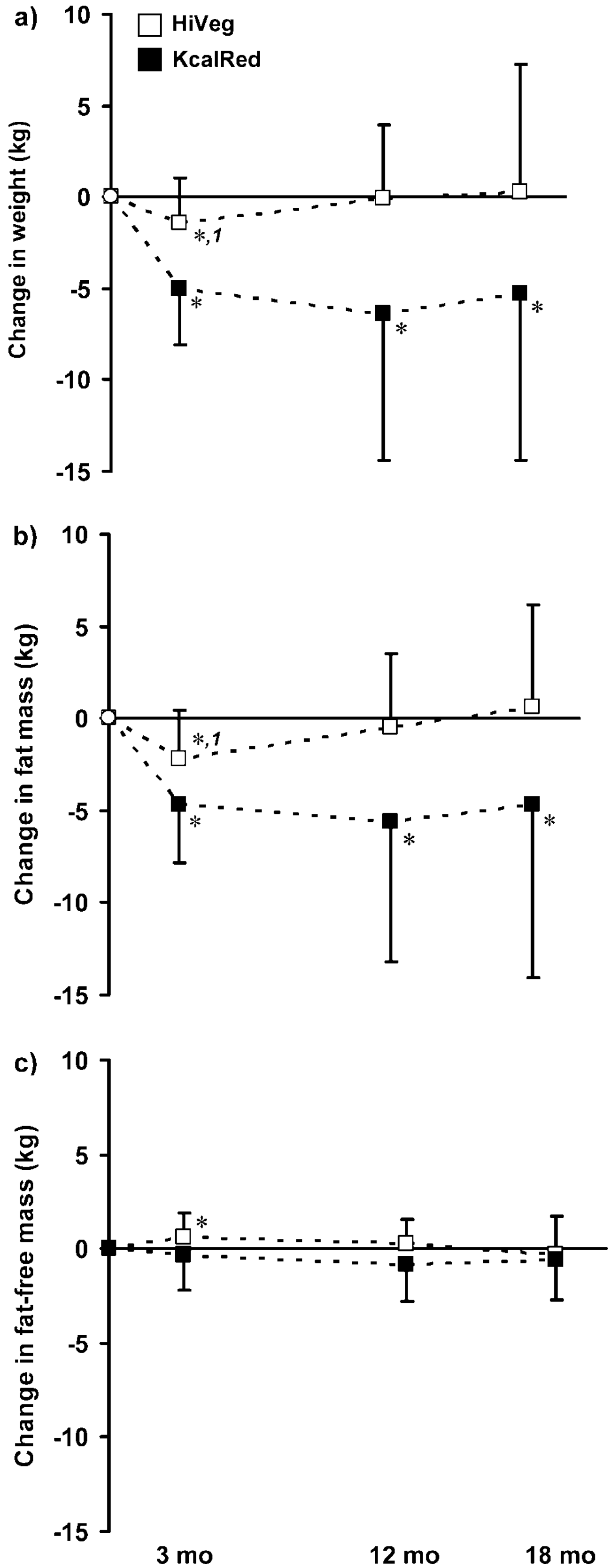

Figure 2. Change after 3, 12, and 18 mo in weight (**a**), fat mass (**b**) and fat-free mass (**c**) of obese subjects, stratified by gender and BMI, who were randomly assigned to a weight-loss intervention focused on including high amounts of vegetables and moderate amounts of fruit (□ HiVeg) or reducing energy and fat intake (■ KcalRed). Data are presented as means ± SD, and P values ≤ 0.050 are considered statistically significant. PROC MIXED assessment with age at baseline, baseline BMI, and age of overweight onset included as fixed effects in all models showed that treatment × time interactions did not exist ($P \geq 0.38$) nor did time have an effect ($P \geq 0.25$) on change in weight, fat mass, or fat-free mass. There were significant treatment effects on weight change and change in fat mass ($P <$ 0.0001, for both) but not change in fat-free mass ($P = 0.12$). Adjusted t tests controlling for age at baseline and age of overweight onset were used to compare changes from baseline within a group at each follow-up and to evaluate changes between groups at 3 mo. Within a group, significant changes from baseline are indicated with an asterisk (*). Differences in change as determined by adjusted t tests (controlling for age at baseline, baseline BMI, and age of overweight onset) between groups at 3 mo are indicated with the number *1*. For the Reduction group, $n = 27$, 24, 18, and 18 at baseline, 3, 12, and 18 mo, respectively. For the HiVeg group, $n = 29$, 21, 14, and 14 at baseline, 3, 12, and 18 mo, respectively.

Table 4. BMI Over Time of Obese Subjects Following Two Dietary Strategies for Weight Loss

	HiVeg[a]	Reduction[b]	Effect	*P* value
Baseline[c]	33.7 ± 3.8[d]	33.3 ± 3.5	Treatment × time	0.67
3 mo	33.3 ± 3.9[e,f]	31.7 ± 3.4[e,g]	Treatment	0.019
12 mo	33.3 ± 4.2	31.3 ± 4.3[e,g]	Time	0.41
18 mo	33.2 ± 4.1	31.7 ± 4.6[e,g]		

[a] HiVeg subjects followed a weight-loss strategy focused on including high amounts of vegetables and moderate amounts of fruit in the diet; $n = 29$, 21, 14, and 14 at baseline, 3, 12, and 18 mo, respectively.
[b] Reduction subjects followed a weight-loss strategy focused on reducing energy and fat intake; $n = 27$, 24, 18, and 18 at baseline, 3, 12, and 18 mo, respectively.
[c] Baseline values were not different between groups.
[d] Data are presented as means ± SD; $P \leq 0.05$ is considered significant.
[e] Values significantly different from baseline as shown by adjusted t tests, controlling for age at baseline and age of onset of overweight.
[f] Change from baseline significantly different between groups using adjusted t tests, controlling for age at baseline and age of onset of overweight.
[g] Values within a group that differed significantly from baseline as evidenced by a mixed effects model with repeated measures showing a significant effect of time.

($P = 0.0075$). BMI was lower than baseline at only 3 mo in the HiVeg group ($P = 0.014$, Table 4). The Reduction group decreased weight at 3 ($P < 0.0001$), 12 ($P = 0.0006$), and 18 mo ($P = 0.019$, Fig. 2a). Fat mass (Fig. 2b) was lower than baseline in the Reduction group at 3 ($P < 0.0001$) and 12 mo ($P = 0.0032$), and fat-free mass (Fig. 2c) did not differ from baseline at any follow-up ($P \geq 0.058$). Mean BMIs were lower than baseline at all 3 follow-ups in the Reduction group ($P \leq 0.045$, Table 4).

At baseline, serum chemistry variables did not differ between groups ($P \geq 0.25$, Tables 2 and 5), and mean values, except LDL cholesterol (Table 5), were within reference ranges. There were no significant treatment × time interactions or treatment effects. Cholesterol:HDL signifi-

Table 5. Lipid Profiles in Obese Subjects Following Two Dietary Strategies for Weight Loss

	HiVeg[a]	Reduction[b]
Total cholesterol (mM) [reference range: 3.88–5.15]		
Baseline[c]	5.06 ± 0.97[d]	4.99 ± 1.08
3 mo	4.62 ± 0.72[e]	4.47 ± 0.88[e]
12 mo	4.90 ± 0.75	4.75 ± 0.80
HDL (mM) [reference range: > 1.01]		
Baseline[c]	1.19 ± 0.39	1.21 ± 0.35
3 mo	1.13 ± 0.31	1.16 ± 0.30
12 mo	1.14 ± 0.31	1.16 ± 0.33
LDL (mM)[f] [reference range: < 2.59]		
Baseline[c]	3.33 ± 0.75	3.22 ± 0.85
3 mo	2.95 ± 0.62[e]	2.84 ± 0.70[e]
12 mo	3.27 ± 0.61	3.06 ± 0.74
VLDL (mM) [reference range: 0.08–0.83]		
Baseline[c]	0.54 ± 0.34	0.56 ± 0.32
3 mo	0.53 ± 0.25	0.47 ± 0.24[e]
12 mo	0.45 ± 0.17	0.52 ± 0.29
Triacylglycerols (mM) [reference range: 0.56–1.68]		
Baseline[c]	1.48 ± 0.93	1.54 ± 0.88
3 mo	1.56 ± 0.93	1.27 ± 0.64[e]
12 mo	1.45 ± 1.09	1.41 ± 0.79
Cholesterol:HDL[g] [reference range: 2.0–4.5]		
Baseline[c]	4.59 ± 1.31	4.31 ± 0.96
3 mo	4.36 ± 1.14[e]	4.03 ± 1.0[e]
12 mo	4.56 ± 1.27	4.38 ± 1.29

[a] HiVeg subjects followed a weight-loss strategy focused on including high amounts of vegetables and moderate amounts of fruit.
[b] Reduction subjects followed a weight-loss strategy focused on reducing energy and fat intake.
[c] Baseline values were not different between groups.
[d] Data are presented as means ± SD; $P \leq 0.050$ is considered significant.
[e] Values differed from baseline within a group as evidenced by Student's *t* test, which was evaluated for 3-mo data only.
[f] LDL cholesterol was calculated by difference.
[g] For all variables except cholesterol:HDL, there were no effects of treatment, time, or treatment × time ($P \geq 0.051$). A significant effect of time for cholesterol:HDL as evidenced by a mixed effects model accounting for repeated measures was found for cholesterol:HDL ($P = 0.022$).

cantly decreased with time (Table 5). Glucose decreased with time in the Reduction group and was 5.29 ± 0.45 at baseline and 4.96 ± 0.43 at 12 mo.

Looking at the short-term effects within the HiVeg group (3-mo data compared to baseline), total cholesterol, LDL, and cholesterol:HDL decreased ($P = 0.0001$, $P < 0.0001$, and $P = 0.0040$, respectively). Within the Reduction group, there was a decrease from baseline at 3 mo for hematocrit (0.42 ± 0.032 to 0.41 ± 0.031; $P = 0.029$), triacylglycerols ($P = 0.0030$), total cholesterol ($P = 0.0001$), LDL ($P = 0.0008$), VLDL ($P = 0.0031$), and cholesterol:HDL ($P = 0.0061$).

Reported vegetable consumption was higher than baseline at 3 ($P < 0.0001$) and 12 mo ($P = 0.044$) in the HiVeg group, but the mean servings of vegetables were significantly less than the goal of 8 ($P = 0.0026$, 3 mo; $P < 0.0001$, 12 mo; Table 3). Fruit consumption did not change from baseline and was never different from 2 servings ($P \geq 0.41$). Because mean vegetable consumption never met the 8-serving goal, we calculated the proportion of HiVeg subjects who returned 3-d diet records that reached (≥8 servings/d) or nearly reached (≥7 servings/d) the vegetable goal at each follow-up. At baseline, none of the HiVeg subjects consumed ≥7 servings vegetables per day. At 3 mo, when subjects were transitioning to following the dietary advice independently, 9 of 23 subjects (39.1%) consumed ≥7 servings vegetables per day, and 5 of those consumed 8 or more servings per day. At 12 and 18 mo, of those subjects that returned diet records, only 1 (6.7%) and 0 subjects, respectively, consumed ≥7 servings vegetables per day.

To determine if the HiVeg group also met the goals of the Reduction group, mean daily energy intake and percent daily energy from fat were evaluated. At all three follow-up times, mean energy consumed was significantly less than baseline ($P = 0.0089$, $P = 0.0036$, and $P = 0.0040$ for 3, 12, and 18 mo, respectively). These reductions were not different from a 500 kcal/d reduction from baseline ($P \geq 0.18$). There was a significant reduction in percent energy from fat at 3 mo only ($P = 0.0009$), but percent energy from fat was still >25% in the HiVeg group at that time ($P = 0.0092$).

At 3 and 18 mo but not at 12 mo, Reduction subjects were consuming significantly fewer kilocalories per day than at baseline ($P = 0.020$, 3 mo; $P = 0.077$, 12 mo; $P = 0.0044$, 18 mo). At both 3 and 18 mo, the mean reduction in kilocalories per day consumed was not different from a 500-kcal/d reduction from baseline ($P = 0.39$ and $P = 0.056$, respectively). The Reduction group successfully met the ≤25% daily energy from fat goal at all follow-ups ($P \geq 0.11$). Fat grams and percent energy from fat per day were significantly reduced from baseline at all follow-ups ($P \leq 0.0003$). Neither vegetable nor fruit consumption increased over time ($P = 0.056$ and $P = 0.11$, respectively) in the Reduction group. The fraction of Reduction subjects who reported eating ≥7 servings vegetables per day were as follows for baseline, 3, 12, and 18 mo: 0/25, 0/21, 2/20, and 0/10.

Daily energy consumed (Table 3) did not differ between the HiVeg and Reduction groups long-term. However, looking at the 3-mo follow-up, the Reduction group consumed fewer kilocalories per day than the HiVeg group ($P = 0.033$, Student's *t* test). The Reduction group also consumed fewer grams of fat and percent energy from fat per day (Table 3) than the HiVeg group as evidenced by significant treatment effects.

Main effects of treatment, time, and treatment × time were found for vegetable consumption (Table 3). Overall, HiVeg subjects consumed more vegetables than the Reduction subjects throughout the study, and at 3 mo, the HiVeg group had a greater increase in vegetable consumption from baseline than the Reduction group ($P = 0.025$). There were no main effects for fruit consumption. The percent energy from protein, grams of protein, and grams of fiber consumed per day did not differ between groups.

Groups did not differ at baseline for sport, non-sports leisure, or total activity indices as assessed by Baecke Physical Activity Questionnaires ($P \geq 0.12$, data not shown). A main effect of time ($P = 0.043$) but not treatment or treatment × time was found for the total activity score, indicating an overall change in physical activity over time (data not shown). There were no differences between groups in the change in scores from baseline to 3 mo ($P \geq 0.094$).

Within the Reduction group, the 3- and 12-mo mean total activity scores were higher than baseline ($P = 0.037$ and $P = 0.0009$, respectively), indicating total activity increased (data not shown). No other indices changed over time within either group ($P \geq 0.061$). The number of subjects who returned Baecke Physical Activity Questionnaires at baseline, 3, 12, and 18 mo were 30, 26, 19, and 4 for the HiVeg group and 30, 24, 18, and 8 for the Reduction group, respectively.

Discussion

This study examined weight loss over the short- and long-term in obese adults following a healthy eating plan focused on consuming high amounts of vegetables and moderate amounts of fruits or on reducing daily energy and fat intake. We hypothesized that including high amounts of vegetables and moderate amounts of fruits would induce weight loss by causing a decrease in total energy and fat consumed and that weight loss would continue long-term because eating high amounts of vegetables and fruits would be reasonable to maintain. Both energy and fat intake decreased in the HiVeg group, but not as low as observed in the Reduction group. Correspondingly, the increased vegetable and moderate amounts of fruits strategy was not as effective for weight loss as the more traditional energy and fat restriction diet. Subjects in the Reduction group lost more weight than the HiVeg group after 3 mo of an intensive food and education intervention and were able to maintain that weight loss long-term. These results indicate that simple messages such as "include 8 servings (or 4 cups) of vegetables daily" may not cause a change in diet sufficient to induce continued long-term weight loss. It should be noted, however, that consuming vegetables was not without benefit: HiVeg subjects' fat mass decreased, and fat-free mass increased after 3 mo. Additionally, subjects in both groups saw improved serum lipids after 3 mo of dietary change.

The greater weight loss in the Reduction group after 3 mo was attributed to differences in diet and physical activity between groups. At 3 mo, the Reduction group consumed fewer kilocalories and grams of fat daily (~250 fewer kcal/d [160 kcal from fat]) than the HiVeg group. The Reduction group increased their physical activity relative to baseline, and the HiVeg group did not. This improvement in activity may have contributed to increased weight loss in the Reduction group. We suggest that the reduction in fat mass and total weight was sustained in the Reduction group due to their continued lowered intake of fat and increase in physical activity from baseline over the long-term.

Although the energy intake of the HiVeg group did not differ from the Reduction group at 18 mo, not all participants returned food records. Returned records may not have reflected the entire group's intake which would explain why the HiVeg group did not continue to lose weight. Moreover, subjects tend to report less energy intake in 24-hr recalls than actual expenditure (32). Compared to baseline, vegetable intake was statistically higher at 12 mo and numerically higher at 18 mo in the HiVeg group. Had the HiVeg group continued to consume 6.6 vegetable and 2.0 fruit servings, which was the mean intake at 3 mo, they may have continued to lose or maintain the weight loss. In a mechanistic review (33), obese patients often did not continue to lose weight when treated long-term with low-calorie diets. This finding was attributed to difficulties with patient adherence and not metabolic or gastrointestinal adaptations (33).

The 8 servings of vegetables daily goal was not achieved by most subjects in the HiVeg group over the long-term. Between baseline and 3 mo, achievement of this goal is assumed to be high, because the HiVeg group received 7–8 servings vegetables daily, and no food was returned or reported uneaten. However, at 3 mo, when subjects began the transition to following the dietary advice independently, only 39% of those returning diet records were consuming 7 servings of vegetables or more. By 12 mo, only 1 subject maintained this high level of intake. HiVeg subjects were encouraged to successfully adopt the high vegetable strategy by giving them recipes and offering strategies for including high amounts of vegetables daily. Yet, as was evidenced by follow-up questions, some subjects found it difficult to purchase, prepare, and/or cook the suggested amount of vegetables. For some HiVeg subjects, people not enrolled in the study, such as children and spouses, contributed to subjects' difficulty in adopting the diet long-term.

Although the vegetable goal was not achieved in the HiVeg group, it is still important to recognize the successful weight and fat loss after 3 mo in this group, when mean vegetable intake was the greatest (~7 servings/d). This result indicates that with regular support, daily vegetable consumption of at least 7 servings (~3.5 cups, 0.83 L) with 2–3 servings (~1–1.5 cups, 0.24–0.35 L) of fruit can result in moderate weight loss. Furthermore, in addition to the improved cholesterol:HDL reported herein, this increased vegetable intake resulted in improved carotenoid concentrations (34), which may reflect increased tissue concentrations. Indeed, increased carotenoid intake from carrots resulted in enhanced antioxidant activity in animal liver after sustained feeding (35). Long-term, this could result in decreased incidence of disease (36). Increased vegetable consumption may also enhance an energy and fat reduction diet. There is some evidence supporting this possibility in the Ello-Martin et al. trial (11), where subjects in the reduced fat and increased water-rich foods (especially vegetables and fruits) group lost more weight over 1 y compared to the reduced-fat only group.

The HiVeg group in our study did not gain weight above baseline at 12 and 18 mo ($P \geq 0.88$, *t* tests). This is in contrast to the trend of age-related weight gain of 0.45–0.90 kg/y in adult Americans (37) and supports the possibility that small improvements in diet, such as including 6 or more servings of vegetables and fruits, could prevent long-term weight gain and contribute to weight maintenance. This hypothesis needs to be tested and strategies to improve the long-term sustainability of high vegetable intake need to be developed.

Although this study started before the release of *MyPyramid*, the diet patterns of both groups during the first 3 mo of the study were similar to the *MyPyramid* recommendations (27). Therefore, it may be hypothesized that the current guidelines (i.e., 3.5–4.5 cups vegetables and fruits as part of a healthy 1600–2000 kcal diet) may induce weight loss or maintain weight in obese individuals if followed consistently. A trial that specifically tests the guidelines of *MyPyramid* as a dietary strategy for weight-loss in obese individuals is merited.

The results of our study contribute to the growing body of evidence that suggests recommendations to individuals seeking to lose weight and maintain weight loss should focus on controlling total energy and fat intake, as well as increasing vegetable and fruit intake as part of a healthy, reduced energy and fat diet.

The authors thank Maria Lanasa, Katy Mijal, Jessica Nehring, and Lisa Stanek for their assistance with food preparation and data gathering; Rachel Staffeldt and Sara Kroes for organizing the phlebotomy; and Dr. Earl Shrago for serving as back-up physician. We thank Karla Horsfall, Emily Nuss, and Amy Petersen for assistance with data entry.

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