One-Year Comparison of a High–Monounsaturated Fat Diet With a High-Carbohydrate Diet in Type 2 Diabetes

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OBJECTIVE — The purpose of this study was to compare the effects of high–monounsaturated fatty acid (MUFA) and high-carbohydrate (CHO) diets on body weight and glycemic control in men and women with type 2 diabetes.

RESEARCH DESIGN AND METHODS — Overweight/obese participants with type 2 diabetes ($n = 124$, age = 56.5 ± 0.8 years, BMI = 35.9 ± 0.3 kg/m^2, and A1C = 7.3 ± 0.1%) were randomly assigned to 1 year of a high-MUFA or high-CHO diet. Anthropometric and metabolic parameters were assessed at baseline and after 4, 8, and 12 months of dieting.

RESULTS — Baseline characteristics were similar between the treatment groups. The overall retention rate for 1 year was 77% (69% for the high-MUFA group and 84% for the high-CHO group; $P = 0.06$). Based on food records, both groups had similar energy intake but a significant difference in MUFA intake. Both groups had similar weight loss over 1 year (−4.0 ± 0.8 vs. −3.8 ± 0.6 kg) and comparable improvement in body fat, waist circumference, diastolic blood pressure, HDL cholesterol, A1C, and fasting glucose and insulin. There were no differences in these parameters between the groups. A follow-up assessment of a subset of participants ($n = 36$) was conducted 18 months after completion of the 52-week diet. These participants maintained their weight loss and A1C during the follow-up period.

CONCLUSIONS — In individuals with type 2 diabetes, high-MUFA diets are an alternative to conventional lower-fat, high-CHO diets with comparable beneficial effects on body weight, body composition, cardiovascular risk factors, and glycemic control.

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The prevalence of type 2 diabetes in the U.S. continues to increase, in large part due to rising rates of obesity (1). In fact, the prevalence of diabetes in obese individuals is 13.6%, >70% higher than that of the general population. Medical nutrition therapy is an integral component of diabetes management, but there have been few controlled clinical trials on which to base nutritional recommendations for individuals with diabetes. Decreasing the intake of saturated fat and cholesterol with the goal of decreasing plasma lipid levels has been an almost universal prescription for those with or at risk for diabetes. There has been controversy about whether to replace saturated fat with carbohydrate (CHO) or monounsaturated fat because evidence suggests that diets high in monounsaturated fatty acids (MUFAs) may be healthier than low-fat, high-CHO diets (2). High-MUFA diets typical of the Mediterranean region emphasize vegetables, fruits, whole grains, legumes, nuts, and olive oil and limit saturated fats from meat, poultry, and dairy products (3).

Short-term studies (4) have demonstrated that Mediterranean-type diets improve plasma lipid levels and glycemic control at least as well as isocaloric high-CHO diets, without detrimental changes in triglyceride and HDL cholesterol concentrations. Preclinical data support the notion that increased intake of MUFA, such as oleate, would have physiological benefits. Whereas chronic exposure of pancreatic islets to increased concentrations of fatty acids reduces insulin secretion (5), saturated fatty acids such as palmitate seem to cause greater rates of β-cell death, whereas oleate has a neutral or protective effect (6). In addition, although chronically elevated circulating fatty acids cause insulin resistance, this effect seems to be more pronounced with saturated fat than with MUFA (7). Thus, current evidence from in vitro and animal studies supports the substitution of MUFA for saturated fat in diabetic individuals based on distinct effects on key parameters of glucose metabolism (8).

A systematic review of Mediterranean-type diet studies (9) identified only one published randomized controlled trial (RCT) with the primary objective of testing the long-term effects of dieting on anthropometric parameters in overweight and obese adults (10). Recently, a 2-year RCT examined the effectiveness and safety of three diets (i.e., Mediterranean, low-CHO, and low-fat diets) in >300 obese men and women, but this study included relatively few diabetic participants (11). No long-term studies of high-monounsaturated fatty acids (MUFAs) diets have specifically addressed individuals with type 2 diabetes in a non-Mediterranean area. Therefore, the objective of the study described here was to compare the effects of a high-MUFA diet with a high-CHO, low-fat diet on anthropometric and metabolic parameters in participants with type 2 diabetes over 1 year.

RESEARCH DESIGN AND METHODS

— Overweight/obese individuals with moderately well-controlled type 2 diabetes were recruited by advertisement. Inclusion criteria were BMI of 27–40 kg/m^2, age 30–75 years, stable body weight for the preceding 6 months, diagnosis of type 2 diabetes for at

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least 6 months, A1C of 6.5–9.0%, and treatment by diet or oral agents only (no insulin). Exclusion criteria were pregnancy or lactation; active cardiac, pulmonary, renal, liver, or gastrointestinal disease; untreated thyroid disease or hypertension; triglyceride concentrations >500 mg/dl; and use of medications that may alter lipid metabolism (other than HMG-CoA reductase inhibitors), corticosteroids, and weight loss drugs.

All individuals in the first two cohorts who completed the 52-week intervention were invited via telephone calls to participate in an extension study (i.e., a post-intervention assessment). All participants gave informed consent for the study, which was approved by the University of Cincinnati and Cincinnati Children's Hospital Medical Center institutional review boards.

Assessments

All participant screenings and assessments were conducted at the General Clinical Research Center of Cincinnati Children's Hospital Medical Center by trained research nurses. At the screening visit, participants' height, weight, and fasting A1C were measured. Height was measured with a wall-mounted stadiometer to the nearest 0.1 cm. Two height measurements were obtained and averaged, with a third measurement taken if the first two differed by >0.1 cm. Body weight was determined to the nearest 0.1 kg on the same properly calibrated electronic digital scale, without shoes, with minimal clothing, and after voiding. Two measurements were taken in immediate succession and averaged, with a third measurement taken if the first two differed by >0.1 kg. A1C was analyzed using a DCA 2000 analyzer.

At the baseline assessment, participants' height and weight were measured again. Waist circumference was determined by placing a measuring tape in a horizontal plane around the abdomen just above the right iliac crest. Three measurements were made to the nearest 0.1 cm and averaged. Blood pressure was measured using the appropriate size cuff and a standard mercury sphygmomanometer. Blood samples were obtained by venipuncture after a 10-h fast. Total cholesterol, HDL cholesterol, triglycerides, A1C, glucose, and insulin were measured using conventional methods. LDL cholesterol was determined by calculation (total cholesterol − [HDL cholesterol + triglycerides ÷ 5]). Insulin resistance (homeostasis model assessment of insulin resistance [HOMA-IR]) was calculated as follows: insulin (units per milliliter) × glucose (millimoles per liter) ÷ 22.5. Body composition (i.e., body fat and lean mass) was measured via dual-energy X-ray absorptiometry using a Hologic 4500A total body scanner by trained technicians. Reassessment of the baseline measures was made after 4, 8, and 12 months of dieting.

Extension study

Individuals in the extension study participated in an additional assessment that was conducted 18 months after completion of the 1-year intervention to determine whether beneficial changes that occurred during the intervention were maintained over time, with no contact between the participants and research team. Body weight, height, waist circumference, body composition, blood pressure, A1C, and lifestyle habits were assessed at this final visit.

Diets/activity

After the baseline assessment, participants were randomly assigned to either a high-MUFA or a high-CHO diet. Energy was distributed as 45% CHO, 15% protein, and 40% fat (with 20% MUFA) in the high-MUFA diet and as 60% CHO, 15% protein, and 25% fat in the high-CHO diet. Both diets included similar amounts of saturated fat and protein. Diet plans were individualized to include 200–300 calories/day less than calculated daily caloric requirements (using the Harris-Benedict equation), thus allowing for a moderate weight loss of ~½ pound/week. Caloric prescriptions were adjusted by the dietitians throughout the study on the basis of participants' weight loss and reported intake.

Each participant was given a meal plan based on their calorie allotment; meal plans included *1*) food groups with healthful foods, serving sizes, and number of servings allowed in each group, *2*) a list of "free" minimal calorie foods, and *3*) a sample menu. Meal plans included the following food groups: starches, fruits, vegetables, low-fat dairy products, meat/meat substitutes, and fat. Compared with the high-CHO diet, the high-MUFA diet included fewer servings of starches, fruit, and meat/meat substitutes and more servings of fat (emphasizing olive and canola oils); it also included an additional food group of beans, legumes, and nuts.

At the onset of the study, participants were instructed to maintain their level of physical activity and not to initiate more vigorous regimens during the 52-week intervention. If participants were not engaging in physical activity on a regular basis, they were encouraged to adopt a walking program of 30 min/day several days per week.

Diet support

Participants met with a dietitian weekly during months 1 and 2, biweekly during months 3 and 4, and monthly during months 5 through 12 for either individual counseling or a group session (alternating every other visit). To control for possible bias, each of the three study dietitians was assigned participants from each diet group for counseling and alternated as the meeting facilitator for both diet groups. To monitor food intake, participants kept detailed 3-day food records during the weeks of scheduled sessions. Trained research assistants entered the food records into the nutrition software Food Processor (ESHA Research; Salem, OR), which generated reports of the participants' mean 3-day intake of energy, macronutrients, vitamins, minerals, alcohol, and six food groups. To monitor physical activity, participants wore pedometers and recorded pedometer readings and physical activity concurrent with their food records.

Participants were weighed at each counseling visit. Group sessions brought together all participants consuming the same diet to discuss topics, such as portion control, record keeping, cooking tips, healthy recipes, and behavior modification. During individual sessions, the dietitians completed a counseling checklist to enhance consistency of counseling across sessions and participants. They reviewed the participants' diet and activity records to ascertain compliance with the assigned diet. The dietitians rated the participants' adherence to their regimen on a scale of 1 to 10 (1 = did not follow diet; 10 = followed diet all the time); the participants estimated their own adherence on a scale of 1 to 10. Average adherence ratings were calculated for each participant. Bivariate and multivariable logistic regression was used to calculate the odds ratios (ORs) for completing the study compared with dropping out of the study.

Statistical analyses

For this study, SAS (version 9.1; SAS Institute, Cary, NC) was used. Before analysis, the data were examined by

calculating frequency distributions, means, SDs, and other measures. Intention-to-treat analyses were performed using estimated values for missing data. Baseline characteristics were compared between the two groups using *t* tests. To assess the effects of the diets, the anthropometric measures, blood pressure, lipid measurements, A1C, and plasma glucose and insulin were the dependent variables, whereas the independent variable was diet. For the main analyses, three mixed models were constructed for each dependent variable, with the covariates of age, race, sex, and adherence rating. Each used a repeated-measure model with no random intercepts or random slopes fitted. The first analysis included all the data collected, the second model included only data for those participants who completed the study, and the third model included data for all participants but with estimates for missing data inserted. Multiple regression was used for imputation of missing data with predictive values based on age, sex, race, and adherence. The level of significance was set at 0.05 for testing the effects of diet, time, and their interaction; the interaction was the primary basis of distinguishing between the diets. If the interaction was significant, an α level of 0.05 was divided by 3 as the comparisons of interest were at 4, 8, and 12 months. The results presented in this article are based on the participants who completed the intervention ($n = 95$). However, intention-to-treat analyses using estimated data for missing values of all participants yielded similar results. Data are presented as means ± SEM.

RESULTS

Participant characteristics and retention

A total of 124 overweight or obese individuals (46 men and 78 women; 92 Caucasians and 32 African Americans) with type 2 diabetes were enrolled in three successive groups of 32, 48, and 44 participants. At baseline, participants ranged in age from 37.9 to 74.9 years, with a mean ± SEM age of 56.5 ± 0.8 years, BMI of 35.9 ± 0.3, waist circumference of 111.9 ± 1.1 cm, body fat of 38.0 ± 0.6%, and A1C of 7.3 ± 0.1%, indicative of moderate glycemic control. Baseline characteristics did not differ between the diet groups.

The overall retention rate was 77%, with 69% for the high-MUFA diet group and 84% for the high-CHO diet group ($\chi^2 = 3.65$; $P = 0.06$). The majority of participants who dropped out of the study (24 of 29) cited relocation, work schedules, and family responsibilities as reasons for not attending the counseling sessions and discontinuing the study. Only three participants left the study because of diet-related reasons (i.e., two high-CHO dieters wanted a lower-CHO diet and one high-MUFA dieter decided to follow a higher-protein diet). There were no differences in sex, race, or age between participants who completed the study and those who dropped out of the study.

Extension study

Of the 57 participants in the first two enrollment cycles who completed the intervention, 36 (18 from each diet group) consented to the additional assessment. These participants were representative of the intervention study population in terms of age, race, and adherence ratings. However, there was a greater ratio of female to male participants in the extension study than in the intervention study (i.e., 81 vs. 63% were female).

Adherence

There were no significant differences in adherence ratings between diet groups or between dietitian and participant ratings (6.45 ± 0.21 vs. 6.67 ± 0.20 for the high-MUFA group; 6.31 ± 0.16 vs. 6.41 ± 0.16 for the high-CHO group). When diet group, sex, race, and age were controlled, those participants with higher adherence ratings were 50% more likely to complete the study than those with lower adherence ratings (OR = 1.5; $P = 0.012$).

Nutrients, foods, and physical activity

Analyses of 3-day food records indicated that the participants followed their assigned diets. Based on self-report, baseline caloric intake was similar in both groups (1,900 vs. 1,984 calories) and both groups restricted their intake to ~1,550 calories/day throughout the study. In regard to macronutrients, the high-MUFA group consumed 46% of total energy as CHO and 38% as fat; the high-CHO group consumed 54% of total energy as CHO and 28% as fat. Both diet groups consumed comparable amounts of protein, saturated fat, and cholesterol. The high-MUFA diet group consumed significantly more total fat, polyunsaturated fat, and MUFA than the high-CHO diet group (14 vs. 7%, 15 vs. 8%, and 14 vs. 9% of energy as MUFA at 4, 8, and12 months; $P < 0.001$).

At baseline, the participants were consuming 1.1 ± 0.1 servings from the dairy group (milk, yogurt, and cheese), 3.9 ± 0.3 servings from the protein group (meat, poultry, fish, eggs, and dry beans), 7.1 ± 0.3 servings from the starch group (bread, cereal, rice, and pasta), 2.7 ± 0.2 servings of vegetables, and 1.6 ± 0.1 servings of fruit. Compared with baseline, participants in both groups reported sustained intake of dairy products (1.2 ± 0.1 servings) during the intervention, decreased intake of servings from the protein group (3.2 ± 0.3 servings) and starch group (5.5 ± 0.2 servings), and increased intake of vegetables (3.2 ± 0.2 servings) and fruits, with the high-CHO group consuming even more fruit than the high-MUFA group at 12 months (2.3 ± 0.2 vs. 2.0 ± 0.3 servings; $P = 0.012$).

In regard to specific foods, participants following the high-MUFA diet reported increased intake of olive or canola oils as sautés and salad dressings and as additions to stir-fries, pastas, yogurt, soup, and oatmeal; avocados in salads and guacamole; and olives, nuts, seeds, and legumes (e.g., walnuts, peanuts, sunflower seeds, mixed nuts, chick peas, and beans). In the low-fat diet group, the use of low-fat versions of salad dressings, spreads, ice cream, and other products increased. Participants in both groups reported increased intake of whole grains, fruits, and vegetables, particularly salads. Daily fiber intake increased significantly in both diet groups from 17.4 ± 0.7 g at baseline to 20.9 ± 0.9 g at 12 months ($P < 0.0001$).

Analysis of pedometer readings showed no differences between diet groups or over time, indicating that participants maintained their baseline activity during the study.

Anthropometric/metabolic outcomes

Body weight, BMI, waist circumference, and body fat in the two groups were similar at baseline. Both groups had significant reductions in weight over 52 weeks (i.e., −4.0 ± 0.8 and −3.8 ± 0.6 kg in the high-MUFA and high-CHO diet groups, respectively; $P = 0.867$) (Table 1), but there was no difference in weight loss between the diet groups. Likewise, the reduction in BMI was similar in both groups after 12 months (−1.3 vs. −1.4 kg/m^2; $P = 0.720$). Changes in weight and BMI were not affected by differences in age, race, sex, or insulin sensitivity as

Table 1—*Anthropometric and metabolic measures of participants before dieting and after 4, 8, and 12 months of dieting*

	High-CHO diet group				High-MUFA diet group			
	Baseline	4 months	8 months	12 months	Baseline	4 months	8 months	12 months
n (men/women)	52 (17/35)				43 (17/26)			
Body weight (kg)	102.1 ± 2.0*	98.2 ± 2.0	98.3 ± 2.1	98.3 ± 2.0	103.7 ± 2.8*	99.2 ± 2.8	99.3 ± 2.9	99.7 ± 3.0
Lean body mass (kg)	62.1 ± 1.5*	61.6 ± 1.6	61.9 ± 1.6	61.3 ± 2.2	63.2 ± 2.2*	62.5 ± 2.2	63.0 ± 2.2	62.5 ± 2.2
Body fat (kg)	38.9 ± 1.0*	36.5 ± 1.1	36.3 ± 1.1	37.1 ± 1.1	38.8 ± 1.3*	35.6 ± 1.6	36.3 ± 1.4	36.9 ± 1.4
Blood pressure (mmHg)	130/77 ± 2.0/1.6*	128/73 ± 2.2/1.4	130/74 ± 2.3/1.1	129/73 ± 2.3/1.4	132/78 ± 2.3/1.4*	128/73 ± 2.7/1.2	127/75 ± 2.4/1.3	130/73 ± 2.4/1.5
Total cholesterol (mg/dl)	178 ± 4.9	183 ± 5.1	188 ± 5.5	180 ± 5.2	179 ± 7.2	177 ± 6.3	182 ± 6.4	184 ± 6.5
Triglycerides (mg/dl)	182 ± 17.9	179 ± 14.9	174 ± 12.7	177 ± 17.4	202 ± 17.3	188 ± 14.6	197 ± 27.2	201 ± 20.0
LDL (mg/dl)	100 ± 4.6	103 ± 4.9	107 ± 5.1	97 ± 4.9	104 ± 7.0	99 ± 6.5	104 ± 5.9	101 ± 6.1
HDL (mg/dl)	43 ± 1.4*	44 ± 1.4	46 ± 1.4	48 ± 1.4	42 ± 1.2*	44 ± 1.2	46 ± 1.3	47 ± 1.3
A1C (%)	7.2 ± 0.1*	6.8 ± 0.1	7.1 ± 0.2	7.2 ± 0.2	7.4 ± 0.1*	6.8 ± 0.2	7.0 ± 0.2	7.5 ± 0.3
Glucose (mg/dl)	135 ± 4.7*	122 ± 4.4	137 ± 7.3	127 ± 5.5	150 ± 7.0*	130 ± 6.4	141 ± 7.7	142 ± 8.1
Insulin (pmol/l)	314 ± 37.1*	283 ± 23.4	260 ± 23.9	287 ± 26.7	309 ± 25.4*	244 ± 17.2	217 ± 14.7	251 ± 23.6
HOMA-IR†	7.6 ± 0.6*	7.0 ± 0.6	7.4 ± 0.9	7.6 ± 0.8	9.2 ± 0.8*	6.7 ± 0.6	6.7 ± 0.8	7.8 ± 1.0

Data are means ± SEM. *Variables with significant time effects, $P < 0.01$. †HOMA-IR = insulin (units per milliliter) × glucose (millimoles per liter) ÷ 22.5.

reflected by HOMA-IR; however, adherence rating was a significant predictor of changes in weight and BMI ($P < 0.01$). Changes in body composition were similar in both diet groups over time, with decreased body fat and lean body mass ($P < 0.0001$) (Table 1) and waist circumference ($P = 0.01$). There were significant increases in HDL cholesterol and reductions in diastolic blood pressure, A1C, fasting glucose and insulin concentrations, and insulin resistance for both diet groups over time ($P < 0.01$) but no differences in any of these parameters between the groups (Table 1).

Extension study

There were no significant changes in the participants' weight, BMI, waist circumference, body fat, blood pressure, or A1C from the completion of the 52-week diet to the final assessment, 18 months later. In other words, the participants maintained the positive changes that occurred during the study. Food records revealed that the participants continued to consume appropriate portions of nutrient-dense foods and maintained their energy intake and relative distribution of total energy as CHO, protein, and fat during the postintervention period. However, intake of MUFA by the high-MUFA diet group decreased from 14 to 9% of total energy.

CONCLUSIONS — This RCT demonstrated comparable beneficial effects of energy-restricted high-MUFA and high-CHO, low-fat diets in individuals with type 2 diabetes. Rates of completion of the 1-year study were relatively high, and, on the basis of food records, both diet groups made important modifications in their customary intake toward the recommended proportions of MUFA and CHO. Both diets successfully caused a loss of ~4% of initial body weight with improvement in anthropometric and metabolic measures. Adherence to either the high-MUFA or the high-CHO diet predicted weight loss and body fat reduction. The results of the extension study suggest that the weight loss was maintained 18 months after participants completed the intervention study. These results, the first to test the effectiveness of a high-MUFA diet over a lengthy period in free-living diabetic individuals in the U.S., indicate that either dietary approach can provide clinical benefits in individuals with type 2 diabetes.

Our diabetic participants had generally good metabolic control, with blood pressure and plasma lipid levels only mildly elevated or near the recommended goal. In response to the 1-year intervention, there was a significant decrease in diastolic blood pressure of 4–5 mmHg and an increase in HDL cholesterol levels of ~5 mg/dl or 11% in both groups. Fasting insulin and HOMA-IR decreased significantly in both groups, consistent with an improvement in insulin sensitivity that was most likely due to weight loss and/or reduced caloric intake. Reductions of A1C were similar in both groups, and although much of this effect was lost over the 12-month period, fasting glucose remained 5–6% lower than at the initiation of the study. Overall, 75 of the 95 participants had improved or stable A1C levels over the course of the study, whereas 20 individuals had an increase in A1C levels of at least 0.5%. Thus, despite differences in macronutrient provision, there were parallel improvements in glycemia and insulin sensitivity, indicating that in the context of tolerable diets and weight loss, mild variations in nutrient fuels have limited impact on glucose metabolism. However, the positive effects of both diets on outcomes in this diabetic cohort were clinically meaningful in that they would be expected to improve cardiovascular risk.

Previous short-term comparisons (i.e., 6 weeks–3 months) of high-MUFA and high-CHO diets in overweight or obese individuals with type 2 diabetes demonstrated similar weight loss with both diets (12,13). In an 18-month RCT of nondiabetic adults comparing energy-controlled Mediterranean-type and low-fat diets, participants in both diet groups lost ~5% of body weight at 12 months (10). In contrast to our study, only the Mediterranean diet group was able to maintain their lost weight at 18 months. A recent RCT also reported greater weight loss (~5% of body weight) in the Mediterranean diet group compared with the low-fat diet group after 24 months (11).

Several prior studies indicated that high-MUFA diets might have metabolic benefits in individuals with diabetes and abnormal glucose metabolism. In a meta-analysis of randomized, crossover trials involving adults with diabetes, high-MUFA intake improved fasting glucose, triglyceride, total cholesterol, and HDL cholesterol concentrations, but not A1C or LDL cholesterol levels (4). This report included highly controlled studies with metabolic diets, whereas our design focused on prescribed diets in free-living individuals. A 2-year RCT of individuals with metabolic syndrome, conducted in the Mediterranean region, showed greater improvement in body weight and cardiovascular risk factors (e.g., blood pressure, total cholesterol, HDL cholesterol, triglycerides, insulin resistance, and inflammatory markers) in a Mediterranean diet group compared with a low-fat diet group (14). The results of this trial differed from ours, possibly because of relative differences in the health status of the study populations and distinctions in familiarity, preference, and access to Mediterranean-type foods. In our participants, the high-MUFA diet presented a greater change in typical patterns of macronutrient intake than the high-CHO diet, and the extension study suggests a shift back to more usual food choices after the intervention was completed.

A significant effect on A1C levels may have been realized with a greater energy and/or CHO restriction and, subsequently, a greater loss of body weight. Short-term studies have shown that moderate weight loss (i.e., 5% of body weight) improves glycemia in participants with type 2 diabetes (15). In addition, both the amount and type of CHO influence glycemic control. A 2-year RCT in individuals with type 2 diabetes showed improved BMI and A1C with a CHO-restricted diet compared with a conventional diet (45 vs. 57% of energy as CHO) (16). In a meta-analysis of 14 studies with an average duration of 10 weeks, Brand-Miller et al. (17) demonstrated that low–glycemic index diets reduced A1C by 0.4% more than high–glycemic index diets in diabetic individuals.

The intense, year-long behavioral intervention delivered by registered dietitians undoubtedly influenced the dietary compliance and positive outcomes achieved by both diet groups. It is interesting to note that the largest amount of weight loss and improvement in A1C occurred when participants were counseled on a weekly basis and leveled off as contact with the dietitians became less frequent. In a recent study using dietitian-led group and individual counseling sessions, the authors concluded that the behavioral intervention promoted dietary adherence to the Mediterranean diet compared with adherence in a control group who received minimal education (i.e., one session) about a low-fat diet (18). However, the results of our extension study imply that at least over time, the participants were able to adopt lifestyle habits that sustained the beneficial effects of the intervention without ongoing counseling. Although this positive outcome is not typical of diet studies, there is evidence that long-lasting change is possible in motivated cohorts. In a 3-year follow-up to the Finnish Diabetes Prevention Study, the effects of the intervention on weight loss and lifestyle habits persisted even after cessation of the counseling intervention (19).

There are several important limitations to our study. Compliance with prescribed diets is a challenge both in clinical trials and clinical practice. Although there were significant differences between the groups in total fat and MUFA intake, neither the high-MUFA nor high-CHO group reached their target goals for MUFA and CHO intake, respectively. However, the participants' self-reported food records indicate that they were relatively compliant with the diet recommendations. Although there is considerable documentation of the shortcomings of self-reporting as a measure of energy intake (20), the limited information available on self-reporting of macronutrients suggests that macronutrient distribution is reported more accurately than total intake (21). Although we have no biomarker to support the systematic differences in MUFA intake reported in our groups, we have no reason to suspect that there was selective inaccuracy in reporting this parameter.

The study results are also limited by the lack of information about the participants' drug usage throughout the study period. In the limited number of participants ($n = 32$) in which drug usage was tracked, there were only modest changes, with no systematic differences between the diet groups. However, we cannot exclude the possibility that some of the observed changes in weight, A1C, and other metabolic parameters were influenced by concomitant changes in antidiabetes medication. Finally, we did not perform sophisticated measures of glucose metabolism but relied on parameters commonly available in the clinic as markers of diet effects.

To our knowledge, our study is the first long-term RCT to compare the relative effectiveness of energy-restricted high-MUFA and high-CHO diets on anthropometric and metabolic parameters specifically in diabetic individuals in the U.S. Our study results suggest that high-

MUFA diets can be healthy alternatives to conventional lower-fat diets without a negative impact on body weight, body composition, cardiovascular risk factors, or glycemic control. Therefore, practitioners can offer ongoing counseling for a variety of diets higher in either CHO or MUFA while controlled in energy. By forgoing the "one size fits all" philosophy and providing diet options, practitioners may enhance patients' dietary compliance and ultimately reduce disease risk.

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