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High–Monounsaturated Fat, Olive Oil–Rich Diet Has Effects Similar to a High-Carbohydrate Diet on Fasting and Postprandial State and Metabolic Profiles of Patients With Type 2 Diabetes

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Whether metabolic control in type 2 diabetes mellitus (DM) is best achieved with the traditional high-carbohydrate (CHO), low-fat diet or a low-CHO, high-fat diet is still controversial. In a randomized crossover study, we compared the effects of a low-fat (30% of daily energy) diet and a high-fat (40% of daily energy), high–monounsaturated-fat diet for 6 weeks each on fasting and postprandial glucose, insulin, and lipoprotein concentrations in 12 patients with well-controlled type 2 DM (fasting blood glucose, 176 ± 54 mg/dL; hemoglobin A_{1c}, 6.4% ± 0.7%) and no overt dyslipidemia (serum total cholesterol, 235 ± 43 mg/dL; triglycerides, 180 ± 63 mg/dL). Home-prepared foods were used and olive oil was the main edible fat, accounting for 8% and 25% of daily energy requirements in the low-fat and high-fat diets, respectively. For postprandial studies, the same mixed meal containing 36% fat was used in both dietary periods. Body weight and fasting and 6-hour postprandial blood glucose, insulin, and lipoprotein levels were similar after the two diets. The mean incremental area under the curve of serum triglycerides 0 to 6 hours after the challenge meal, adjusted for baseline levels, did not change significantly after the high-fat diet compared with the low-fat diet (1,484 ± 546 *v* 1,714 ± 709 mg · 6 h/dL, respectively, $P = .099$). Mean postprandial triglyceride levels at 6 hours were increased about 2 times over fasting levels and were still greater than 300 mg/dL after either diet. A diet high in total and monounsaturated fat at the expense of olive oil is a good alternative diet to the traditional low-fat diet for patients with type 2 DM. However, ongoing postprandial hypertriglyceridemia with either diet points to the need for other therapies to decrease triglyceride-rich lipoproteins (TRL) and the inherent atherogenic risk in type 2 diabetics.

CORONARY HEART DISEASE is the main cause of death in patients with type 2 diabetes mellitus (DM).[1] This is due to the high prevalence of atherosclerosis in these patients, in relation to the frequent association of several cardiovascular risk factors, principally hyperglycemia, hyperinsulinemia, diabetic dyslipidemia, arterial hypertension, and truncal obesity. However, this cluster of risk factors does not completely explain why atherosclerotic complications are 2 to 4 times higher in type 2 DM than in the general population.[2]

The most frequent lipoprotein abnormality in subjects with type 2 DM is fasting hypertriglyceridemia associated with reduced plasma levels of high-density lipoprotein (HDL) cholesterol,[3] and the fasting triglyceride level is a powerful predictor of coronary heart disease in this patient population.[4-6] Both very–low-density lipoproteins (VLDL) and their remnants, together with those derived from the partial lipolysis of intestinally derived chylomicrons, contribute to the increase in plasma triglyceride; these particles, which tend to accumulate in conditions of enhanced triglyceride synthesis and/or disturbed lipolysis, are collectively called triglyceride-rich lipoproteins (TRL). The insulin resistance syndrome characteristic of type 2 DM promotes TRL accumulation by way of increased hepatic VLDL production due to excess substrate (free fatty acids) and reduced peripheral catabolism of both VLDL and chylomicrons secondary to decreased activity of lipoprotein lipase, the enzyme that hydrolyzes triglycerides in TRL.[7]

Because VLDL and chylomicrons compete for the common removal pathway dependent on lipoprotein lipase activity,[8] the

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variable increase in TRL in the postabsorptive state (usually after 9 to 12 hours of fasting overnight) is accentuated after the ingestion of fat-containing foods, giving rise to the so-called postprandial hyperlipidemia.[9] The response of plasma lipoproteins, particularly total triglyceride and TRL, during the postprandial state has received much attention in the past decade because of the accumulating evidence that postprandial triglyceride concentrations may be more closely related to atherogenic risk than the values observed in the fasting state.[10-14] Therefore, interest has been kindled recently for studies of postprandial lipemia in subjects with type 2 DM.[15] Similar to the situation in coronary heart disease patients, where normal or mildly elevated triglyceride levels during fasting are greatly increased after an oral fat load,[10-14] the underlying lipid disorder is uncovered only in the postprandial state in many type 2 DM subjects.[15-18]

There is a large body of data indicating that TRL, whether of intestinal or hepatic origin, are directly atherogenic because they can enter the vessel wall and convert macrophages to foam cells.[19,20] In addition, delayed triglyceride clearance alters both HDL and low-density lipoprotein (LDL) metabolism, accelerating core-lipid exchange between these lipoprotein particles and TRL, with the consequence of a reduced cholesterol concentration in HDL[21] and the induction of atherogenic small, dense LDL.[22] These detrimental lipoprotein alterations are potentially reversible by the decrease of postprandial hyperlipidemia and TRL that can be induced in hypertriglyceridemic subjects with dietary changes[23,24] or hypolipidemic medication therapy.[25-27]

The modification of dietary habits is the first approach to treatment of type 2 DM. As recommended by the American Diabetic Association (ADA),[28] there is still a widely held view that the low-fat, high-carbohydrate (CHO) diet, with a classic nutrient distribution as a percentage of daily calories of 15% protein, 55% CHO, and 30% fat (ratio of saturated/monounsaturated/polyunsaturated fatty acids $<$1:1:1), is the most appropriate for body weight and glycemic control in diabetic patients. However, the convenience of high-CHO diets for diabetic patients has been challenged recently on the grounds that they may worsen postprandial glycemia and insulin levels and fasting triglyceridemia in comparison to diets rich in total fat.[29] This argument is ambiguously stated in the most recent dietary recommendations of the ADA.[30] Because an increased intake of saturated fatty acids is not recommendable and no Western population naturally consumes more than an average of 10% of daily calories as polyunsaturated fatty acids, the ideal fatty acids to enrich the diet when the proportion of carbohydrate is reduced are monounsaturated fats. There are few dietary intervention studies comparing a monounsaturated fatty acid–rich diet with the traditional low-fat diabetic diet in subjects with type 2 DM, with contradictory results (decrease or no change) regarding the effects on postprandial lipemia.[31-33] Two of these studies[31,32] were performed with meals provided by the investigators, not with meals prepared at home by the experimental subjects, thus providing little information about the acceptability and practicality of the monounsaturated fatty acid–rich diet. Furthermore, olive oil, the natural monounsaturated fat consumed by Mediterranean populations, was not used in these studies.

Therefore, we designed a dietary intervention study in type 2 DM subjects to assess the effects of a diet rich in monounsaturated fatty acids from olive oil on fasting and postprandial glucose, insulin, and lipoprotein levels in comparison to the usual high-CHO, low-fat diabetic diet.

SUBJECTS AND METHODS

Patients

Sixteen patients with type 2 DM attending the outpatient Lipid Clinic or the Diabetes Clinic were studied. Inclusion criteria were as follows: fasting total serum cholesterol 300 mg/dL (7.7 mmol/L) or less and triglyceride 300 mg/dL (3.4 mmol/L) or less, apolipoprotein E (apo E) genotype 3/3, body mass index less than 30 kg/m^2, serum hemoglobin A_{1c} 8% or less, treatment with diet or oral hypoglycemic agents, and no hypolipidemic medication therapy within the 6 weeks prior to study. Patients on insulin treatment, with alcohol intake above 20 g/d, smoking more than 10 cigarettes daily, or with a diagnosis of diabetic gastroparesis or enteropathy, diabetic nephropathy, thyroid disease, or arterial hypertension requiring pharmacologic therapy were excluded from the study.

Trial Design

The studies were performed on an outpatient basis. During the pre-inclusion period, the patients consumed their usual low-fat, high-CHO diet. This was followed by a 12-week intervention period in which two diets were prescribed in random crossover design for 6 weeks each, a low-fat, high-CHO diet (CHO diet) and a high-fat, high–monounsaturated fatty acid diet (MONO diet).

Initially and weekly during each diet, the patients were individually evaluated by an expert dietitian and completed 3-day food records (including 1 weekend day). They were also trained to follow the recommended diets, which were isoenergetic with the usual diet and differed only in fat and complex CHO content. The diets were composed of natural foodstuffs, with a limitation on red meat, eggs, and whole-fat dairy products, and an emphasis on vegetable products and fish. The number of servings of cereal products, legumes, and fruits was increased while the use of olive oil was restricted in the CHO diet in comparison to the MONO diet. The olive oil used in the MONO diet (cold-pressed virgin olive oil; Borges-Pont, Tárrega, Spain) was provided to the patients together with a measuring spoon and was incorporated crude (uncooked) into the food constituents of the diet as a dressing or a spread or soaked in bread, with instructions to remove any remaining oil on the spoon or plate with a small piece of bread to be ingested with the meal. To keep the fiber content of the diet relatively constant during both dietary periods, we compensated for the fiber contained in the extra amount of complex CHO during the CHO diet with a recommendation to consume only whole-grain products throughout the MONO diet period. The caloric ranges for both dietary periods were 1,600 to 2,200 kcal/d. Table 1 shows the nutrient content of the two diets prescribed and actually consumed. Dietary protein, fiber, and cholesterol contents were similar in the study diets. The CHO diet contained (mean $\pm$ SD) 16.3 $\pm$ 7.6 g olive oil ($\approx$8% of daily energy requirements), while the MONO diet contained 55.6 $\pm$ 4.2 g olive oil per day, corresponding to about 25% of total energy. The patients' weight and waist to hip ratio were monitored weekly, and any trend for weight change was addressed by small caloric increments or decrements. Instructions to maintain a similar level of physical activity for the duration of the study were provided.

At the end of each dietary period, patients were admitted to the Clinical Research Center after an overnight fast for fasting and postprandial blood tests.

Test Meal and Biochemical Determinations

At 9 AM, an intravenous catheter was inserted in a brachial vein and a basal blood sample was obtained, followed by administration of the test

Table 1. Nutrient Content of the Prescribed and Actually Consumed Study Diets

Nutrient	CHO Diet		MONO Diet		*P*
	Prescribed	Actual	Prescribed	Actual	
Energy (kcal/d)	1,600-2,200	1,947 ± 242	1,600-2,200	1,992 ± 245	>.2
Carbohydrate (% kcal)	55	53.5 ± 2.1	45	43.3 ± 2.6	.002
Protein (% kcal)	15	17.3 ± 1.7	15	16.3 ± 1.2	.107
Fat (% kcal)	30	28.6 ± 0.7	40	40.1 ± 0.7	.002
Saturated	<10	6.4 ± 0.8	<10	7.9 ± 0.6	.005
Monounsaturated	12	11.6 ± 2.3	25	24.8 ± 0.7	.002
Polyunsaturated					
Total	<10	4.7 ± 0.6	<10	5.2 ± 0.8	.096
n-6		4.1 ± 0.5		4.7 ± 0.8	.012
n-3		0.45 ± 0.1		0.41 ± 0.1	>.2
Cholesterol (g/d)	<300	241 ± 38	<300	233 ± 39	>.2
Fiber (g/d)	25	26.9 ± 3.2	25	24.3 ± 2.4	.035

meal. To control for a dose-dependent effect of fat content on postabsorptive serum triglyceride concentrations, the challenge meals were similar in the two dietary periods. The meal contained 880 kcal, 50% carbohydrate, 36% fat (10% saturated, 19% monounsaturated, and 7% polyunsaturated fatty acids), and 14% protein. The fat load was 35 g, accounting for 52% to 66% and 39% to 49% of the daily fat intake in the CHO and MONO diets, respectively. The meal contained 17 g sucrose and 5 g fructose. The composition of the test meal was as follows: 200 mL skim milk, 80 g white bread, 10 g butter, 10 g olive oil, 15 g jam, 20 g salami, 15 g cheese, 1 egg, and 200 mL unsweetened orange juice. To label intestinally derived lipoproteins, vitamin A (60,000 U/m^2) was administered with the challenge meal.

Blood samples were drawn before the test meal and 2, 4, and 6 hours postprandially for determination of serum glucose, insulin, total cholesterol and triglycerides, lipoproteins, apo AI and apo B, and retinyl palmitate. Patients were free to walk around between blood sampling periods, but they were requested to be recumbent for at least 30 minutes before each venipuncture. Only calorie-free and caffeine-free beverages were allowed during the 6-hour period of blood sampling.

Analytical Methods

Blood for plasma was drawn into sterile tubes containing EDTA (1.0 mg/mL), and samples for serum were placed in empty sterile tubes. Plasma or serum was separated from cells by centrifugation at 2,500 rpm for 30 minutes at 4°C. Plasma to be used for determination of retinyl palmitate was protected from light and stored under nitrogen at −80°C until analysis. Cells obtained after separation of the plasma were used for DNA extraction and apo E genotyping. The blood glucose level was measured by the glucose-oxidase method. Serum insulin was determined by radioimmunoassay (IRI-CIS Biointernational, Gif-Sur-Yvette, France) and hemoglobin A_{1c} by high-performance liquid chromatography. Cholesterol and triglyceride levels were measured by automated enzymatic methods (Trinder; Bayer Diagnostics, Tarrytown, NY). For the separation of lipoproteins, 2-mL aliquots of serum were covered with 2 mL NaCl (d = 1.006) and centrifuged at 105,000 × *g* for 18 hours at 15°C. The cholesterol and triglyceride concentrations were determined in the supernatant fraction containing VLDL. HDL cholesterol was determined in the infranate by precipitation of apo B–containing lipoproteins with phosphotungstate/magnesium. LDL cholesterol was calculated by subtraction of VLDL and HDL cholesterol from total cholesterol. Apo E genotyping was performed with the polymerase chain reaction essentially as previously described.[34] Plasma retinyl palmitate levels were measured by reversed-phase high-performance liquid chromatography.[35]

Statistical Analysis

The data are expressed as the mean ± SD or mean ± SE as appropriate. Comparisons between values from the two dietary periods were made using nonparametric tests (Wilcoxon). ANOVA for repeated measures was used for comparisons of postprandial variables between diets. A 5% α risk level was required for statistical significance ($P < .05$). Plasma glucose, insulin, total triglyceride, VLDL triglyceride, and retinyl palmitate responses during the 6-hour profile were analyzed by calculating the incremental area under the curve (AUC) with a formula based on the trapezoid rule with adjustment for baseline levels. All statistical analyses were performed with SPSS software (SPSS, Chicago, IL).

RESULTS

Food records showed that dietary compliance was excellent throughout the study in 12 patients, with a deviation of less than 15% between actual and prescribed nutrient intake (Table 1). Four patients were withdrawn from the study due to poor compliance with dietary instructions. Thus, 12 patients with a duration of diabetes of 6 ± 2 years completed the study. Their baseline characteristics show that they had good glycemic control and no overt dyslipidemia. Half of the patients consumed the CHO diet first; the order of the diets did not affect the results. Anthropometric features, glycemic control, and fasting lipid levels did not change with either diet (Table 2). Fasting and postprandial glycemia and insulinemia were also similar with the two diets (Fig 1). Likewise, there were no significant

Table 2. Anthropometric Features, Glycemic Control, and Fasting Lipid Values in Patients With Type 2 DM at Baseline and After Ingestion of the Two Experimental Diets for 6 Weeks

Parameter	Baseline	CHO Diet	MONO Diet
Weight (kg)	74.3 ± 9.5	73.8 ± 10.6	73.3 ± 9.4
Body mass index (kg/m^2)	27.9 ± 2.1	28.0 ± 2.0	27.8 ± 2.0
Waist to hip ratio	0.98 ± 0.10	0.97 ± 0.12	0.99 ± 0.09
Fasting blood glucose (mg/dL)	176 ± 54.4	164 ± 58	177 ± 58
Hemoglobin A_{1c} (%)	6.4 ± 0.7	6.5 ± 1.0	6.7 ± 1.3
Total cholesterol (mg/dL)	235 ± 42.6	232 ± 50	233 ± 73
Triglyceride (mg/dL)	180 ± 63	175 ± 65	160 ± 65
LDL cholesterol (mg/dL)	159 ± 36	155 ± 45	160 ± 44
HDL cholesterol (mg/dL)	46 ± 13	47 ± 11	48 ± 10

NOTE. Values are the mean ± SD. None of the differences between the CHO diet and MONO diet were significant ($P > .2$ for all).

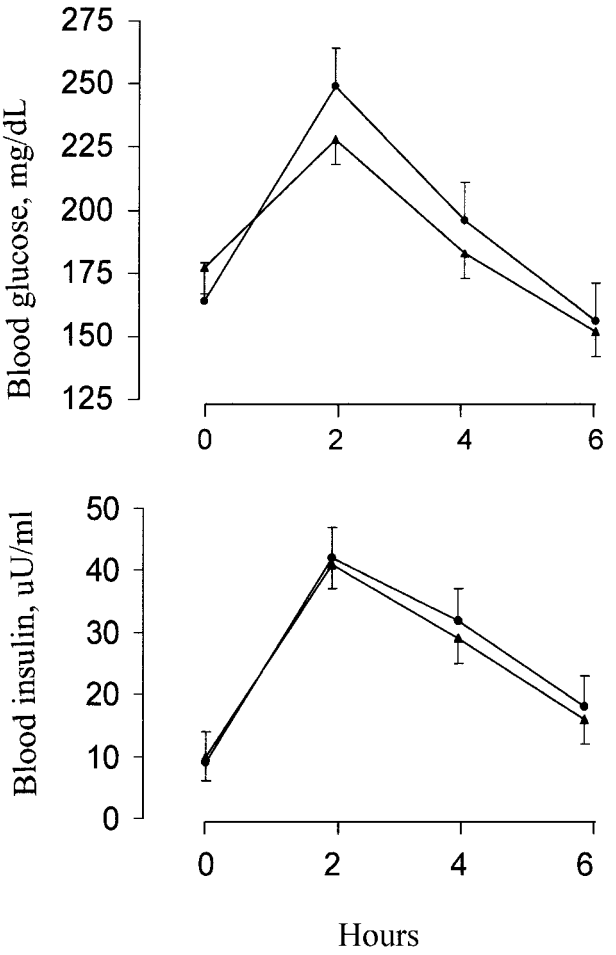

Fig 1. Plasma insulin and glucose responses (mean ± SD) after the test meal given with 2 different background diets. (●) CHO diet; (▲) MONO diet.

differences in the integrated AUC of glycemia (CHO *v* MONO diet, 1,211 ± 478 *v* 1,150 ± 437 mg · 6 h/dL) or the AUC of insulinemia (CHO *v* MONO diet, 165 ± 73 *v* 177 ± 74 μU · 6 h/mL).

Fasting lipoprotein cholesterol and retinyl palmitate levels and their response to the test meal at the end of the two dietary periods are shown in Table 3. Essentially no differences were found between the diets for fasting levels of lipoprotein cholesterol and their response to the test meal. HDL cholesterol and LDL cholesterol exhibited a slight postprandial decrease with the two diets. The postprandial responses of total triglyceride and VLDL triglyceride were also similar with the MONO diet and CHO diet. Although there were no significant differences in comparison to the CHO diet, triglyceride levels increased less after the MONO diet at all time points after the challenge meal (Fig 2). Postprandial plasma levels of retinyl palmitate were also nonsignificantly lower with the MONO diet versus the CHO diet (Table 3). Likewise, the integrated AUCs of total triglycerides and VLDL triglycerides were nonsignificantly lower after the MONO diet in comparison to the CHO diet (1,484 ± 546 *v* 1,714 ± 709 mg · 6 h/dL, $P = .099$, and 559 ± 259 *v* 608 ± 383 mg · 6 h/dL, $P > .2$, respectively).

Table 3. Serum Concentration (mean ± SD) of Lipoprotein Cholesterol and Retinyl Palmitate 0 to 6 Hours After a Challenge Meal Performed at the End of Two Dietary Periods in Patients With Type 2 DM

Variable	Hours After the Challenge Meal			
	0	2	4	6
Total cholesterol (mg/dL)				
CHO diet	232 ± 50	220 ± 50	230 ± 54	233 ± 56
MONO diet	233 ± 73	225 ± 74	221 ± 71	223 ± 68
VLDL cholesterol (mg/dL)				
CHO diet	28 ± 21	27 ± 17	29 ± 20	28 ± 16
MONO diet	19 ± 10	22 ± 8	22 ± 9	24 ± 12†
HDL cholesterol (mg/dL)				
CHO diet	47 ± 11	47 ± 21	45 ± 14	42 ± 14
MONO diet	48 ± 10	44 ± 11	44 ± 11	43 ± 10
LDL cholesterol (mg/dL)				
CHO diet	155 ± 45	138 ± 56	151 ± 58	151 ± 56
MONO diet	160 ± 44	151 ± 52*	140 ± 65	136 ± 57
Total triglyceride (mg/dL)				
CHO diet	175 ± 65	247 ± 87	333 ± 178	378 ± 199
MONO diet	160 ± 65	233 ± 89	277 ± 144‡	304 ± 152‡
VLDL triglyceride (mg/dL)				
CHO diet	83 ± 53	97 ± 55	114 ± 86	109 ± 71
MONO diet	59 ± 30‡	89 ± 35	113 ± 119	116 ± 66
Retinyl palmitate (μg/dL)				
CHO diet	0.4 ± 0.4	43 ± 97	123 ± 193	294 ± 288
MONO diet	2.0 ± 1.7*	25 ± 33	112 ± 119	198 ± 212

*$P < .05$, †$P = .06$; ‡$P > .1$ and $< .2$ *v* the same time point during the CHO diet; $P > .2$ for all other differences between the 2 diets by 2-tailed *t* test.

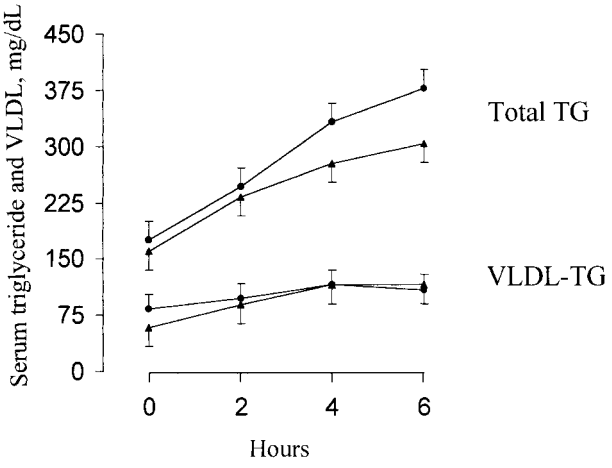

Fig 2. Incremental postprandial response (mean ± SD) of total triglyceride and VLDL triglyceride after a challenge meal with 2 different background diets. (●) CHO diet; (▲) MONO diet.

DISCUSSION

In this randomized crossover trial of two isoenergetic, weight-maintaining diets, the traditional low-fat, high-CHO diabetic diet and a diet enriched in monounsaturated fatty acids at the expense of olive oil, given for 6 weeks each, had a similar effect on body weight, glucose metabolism, and fasting and postprandial lipids in diabetic subjects who were in fair glycemic control and had no overt dyslipidemia at baseline. One limitation of this study is the short period of postprandial sampling, although one might argue that free-living individuals in general and diabetics in particular rarely spend more than 6 hours without a meal during the daytime. Its strengths are the relatively long duration of the experimental dietary periods, the real-life conditions, home-prepared natural foods, utilization of olive oil as the main edible fat in the MONO diet, and identity of apo E genotype 3/3 to obviate postabsorptive triglyceride changes related to apo E polymorphism.[36,37] Because the magnitude and duration of the postprandial response to a challenge meal depends on its fat content[38,39] and is higher with a high-fat meal versus a high-CHO meal,[40] to best reflect the postabsorptive profile dependent on the background diet, we maintained constant dietary CHO and fat loads and fatty acid composition of the test meal in the two phases of the study. Furthermore, the challenge meal had a fat content of 35 g, more closely reflecting normal food intake than the oral fat load of 80 to 120 g often chosen to maximize potential differences between control and experimental groups.[41]

The prescribed and actually consumed diets were closely matched (Table 1). The differences between the two diets in total fat (10% of daily energy) and monounsaturated fat (13% of daily energy) are relatively small, but these diets best reflect customary intakes in our patient population. Thus, it should be underlined that a decrease in CHO intake from 55% to 45% of total daily calories while increasing fat intake from 30% to 40%, with 25% of total energy intake as olive oil, is well within the acceptable range of usual food consumption in subjects living in a Mediterranean region like ours, and prescribed diets with a fat content outside of this range would be difficult to follow in the long term.

A frequent concern when a high-fat diet is used in exchange for a high-CHO diet is the possibility of inducing weight gain and promoting obesity, a very detrimental effect in diabetic patients. However, as shown in this study, a high-fat diet should not induce an accumulation of body fat provided that energy intake is controlled.[42,43] In the case of monounsaturated fatty acids, their addition to a hypocaloric diet promotes weight loss to an extent similar to that achieved with a hypocaloric low-fat diet while ameliorating glycemic control in subjects with type 2 DM.[44]

A recent meta-analysis of 9 short-term randomized crossover studies comparing these two approaches to diet therapy in patients with type 2 DM reveals that high–monounsaturated fat diets improve the fasting lipoprotein profile and glycemic control in comparison to low-fat, high-CHO diets.[45] Regarding lipid effects, high–monounsaturated fat diets reduce fasting triglyceride and VLDL cholesterol concentrations and cause modest increases in HDL cholesterol without adversely affecting LDL cholesterol.[45] The converse, namely that CHO in exchange for fat in the diet increases triglycerides and decreases HDL cholesterol, has been known for some time,[46,47] although it also has been reported that the gradual increase of CHO content in a low-fat diet, as opposed to sudden increases, does not induce hypertriglyceridemia.[48] In our study, no differences in glucose control or fasting triglyceride concentrations were observed between the high–monounsaturated fat diet and the high-CHO diet. A reason for this discrepancy with Garg's meta-analysis[45] might be that, in all the studies cited therein, there were wide, unphysiologic differences in total fat content between the two experimental diets ranging from 15% to 25% of daily energy, whereas the difference was only 10% in our trial (Table 1). However, improved glycemic control in type 2 diabetics also can be obtained with soluble fiber supplementation of a low-fat, high-CHO diet.[49,50]

Besides the evidence that low-fat, high-CHO diets increase fasting triglycerides, Chen et al[31,32] have recently shown that such diets given as pre-prepared food have deleterious effects on postprandial lipemia as well, whether used for 2 weeks[31] or 6 weeks,[32] in patients with type 2 DM. On the other hand, Campbell et al[33] used home-prepared food and found that compared with a low-CHO, high–monounsaturated fat diet, a low-fat, high-CHO diet given for 2 weeks to 10 men with type 2 DM resulted in higher fasting triglyceride levels but had no discernible effect on postprandial triglyceridemia. Our results on postprandial lipemia were similar to those of the Australian study,[33] which used experimental diets with macronutrient proportions similar to ours. On the other hand, the wider differences between the CHO and fat content of the background diets in the studies by Chen et al[31,32] might have magnified the dietary effects on postprandial triglycerides. As it has been shown recently that monounsaturated fat in the background diet may lead to faster rates of triglyceride entry (earlier postprandial peak) and clearance (more pronounced late decline) compared with saturated–fatty acid diets,[51] it is also possible that we missed a putative beneficial effect of the monounsaturated fat diet due to a too-short postprandial sampling period. The triglyceride concentrations at 6 hours were still increasing for both diets under study, and differences or similarities might have occurred at later time points had blood samples been taken. Nevertheless, in a recent study of patients with type 1 DM, a high–monounsaturated fat diet impaired postprandial fat clearance compared with a high-CHO diet.[52] Further studies may be needed before firm conclusions can be made for the relationship between diet and postprandial lipemia in diabetic subjects.

Recent studies[32,53] suggest that increased hepatic synthesis and secretion of VLDL is the mechanism underlying the triglyceride-elevating effect of high-CHO diets in patients with type 2 DM. The resultant competition between endogenous and exogenous (intestinal) TRL for removal from the blood would secondarily increase the magnitude of postprandial lipemia; in this situation, intestinally derived lipoproteins should also accumulate in the blood postprandially in response to the high-CHO diet, as shown by some[31,32] but not all[53] researchers who have compared high-CHO and high–monounsaturated fat diets in patients with type 2 DM. The incremental AUC of plasma retinyl palmitate was similar with the two diets in our study. Although the use of plasma retinyl esters as markers for intestinally derived lipoproteins has been questioned,[54,55] the

transfer of triglycerides from TRL to lower-density lipoproteins does not occur during the initial 6 hours after a fat load.[54] Furthermore, Karpe et al[55] reported that retinyl palmitate is a valid tracer of intestinal lipoproteins during the first postprandial hours.

Again using experimental diets with a 20% energy difference in fat and CHO content, Jeppesen et al[56] have shown recently that a high-CHO diet has untoward effects on fasting and postprandial measures of glucose and lipoprotein metabolism also in healthy women, and that these effects are reversed by a high-fat, high–monounsaturated fat diet. Because the LDL cholesterol concentration is not affected with either diet, it seems reasonable to suggest that a high–monounsaturated fat diet is a valid alternative to the traditionally recommended low-fat diets for patients with type 2 DM.[57] As shown in this study, incorporation of reasonable amounts of olive oil into the diet of free-living individuals provides glucose and lipid control at least as good as that obtained with the low-fat diet while enhancing palatability, at least for those living in the Mediterranean area, where olive oil has been the principal edible fat for centuries. Nevertheless, ongoing postprandial hypertriglyceridemia with either diet points to the need for other therapies to decrease TRL in type 2 diabetics. It is also evident that to better assess and manage cardiovascular risk in this patient population, the diagnostic procedure used to identify postprandial lipid intolerance needs to be simplified.

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