Effect of high fiber intake in fish oil–treated patients with non-insulin-dependent diabetes mellitus

John P Sheehan, Irene W Wei, Magaret Ulchaker, and Kou-Yi Tserng

ABSTRACT The short-term effect of high fiber intake on fish-oil treatment in 15 free-living, non-insulin-dependent diabetic patients was evaluated by using a controlled, sequential study design. During an 8-wk fish-oil–treatment period when patients received 20 g fish oil/d, the usual daily fiber intake was increased with a 15-g pectin supplement at midpoint. Fish oil alone lowered triacylglycerol and very-low-density-lipoprotein-cholesterol concentrations by 41% and 36%, respectively (both P < 0.01 by the end of the treatment period) with unchanged mean total, low-density-, and high-density-lipoprotein-cholesterol concentrations. When the fiber intake was increased, however, total and low-density-lipoprotein-cholesterol concentrations decreased significantly (P < 0.001 and < 0.05, respectively) with fish-oil treatment. The cholesterol ester fraction of plasma lipids was reduced by 34% when compared with fish oil alone (P < 0.05). The plasma triacylglycerol fraction decreased further by 44% (P < 0.001). Other beneficial effects observed included a 30% decline in the fatty acid fraction (P < 0.002) by the end of the treatment period. Diabetic control was maintained during the 12-wk study. In conclusion, a high fiber intake may be beneficial in fish oil–treated diabetic patients. Am J Clin Nutr 1997;66:1183–7.

KEY WORDS n–3 Fatty acids, fish oil, fiber, diabetes, non-insulin-dependent diabetes mellitus, NIDDM, hyperlipidemia, lipids, lipoproteins, humans

INTRODUCTION

Abnormal lipid and lipoprotein metabolism is not only well documented in patients with non-insulin-dependent diabetes mellitus (NIDDM) (1, 2) but its significance to the development of coronary artery disease is also appreciated in the management of NIDDM (3, 4). The use of fish oils as a potential prophylactic or therapeutic intervention for coronary artery disease has been investigated in normal and hyperlipidemic nondiabetic populations. The active ingredient is believed to be polyunsaturated n–3 fatty acids and their effects are summarized in recent reviews (5, 6). In the past decade, studies using low, moderate, and high doses of fish oils have also been conducted with similar objectives in the diabetic patient population (7, 8).

Results from these studies on lipid and lipoprotein metabolism have not been completely satisfying. The most consistent and beneficial effects of fish oils are the lowering of serum triacylglycerol and very-low-density-lipoprotein (VLDL) concentrations (9–12). The triacylglycerol content of VLDL and low-density-lipoprotein (LDL) particles is also reduced (9). Fish oils appear to lower triacylglycerol concentrations by decreasing hepatic VLDL synthesis (13, 14). The reduction in VLDL synthesis may be due to an inhibitory effect of n–3 fatty acids on the esterification of glycerol (15). In contrast, the effects of fish oils on LDL and high-density lipoproteins (HDLs) are less consistent (7). Additionally, early reports of the worsening of glycemic control during fish-oil treatment supported an argument against any recommendation for this adjunctive therapy in the management of NIDDM (7, 10, 16).

In the present study we addressed some of these deleterious effects of fish oils and particularly the effects on total cholesterol and LDL cholesterol, with a concomitant high fiber intake. Current evidence suggests that high-fiber diets, especially of the soluble variety, and soluble fiber supplements offer some improvement in carbohydrate metabolism and lower total cholesterol and LDL-cholesterol concentrations among their many beneficial effects (17, 18). The American Diabetes Association (ADA) recommends an intake of up to 40 g fiber/d (or 25 g per 4184-kJ food intake) (4). The objective of the study was to evaluate the clinical effects of ADA-recommended fiber intakes during fish-oil therapy in patients with NIDDM. In this study the usual fiber intake of diabetic patients was increased by administration of apple pectin during an 8-wk fish-oil–treatment period.

SUBJECTS AND METHODS

Subjects

Fifteen nonobese NIDDM patients (12 men and 3 women) with a mean body mass index (in kg/m²) of 25.6 ± 3.5 were recruited. Their mean (± SD) baseline values were as follows: fasting glucose, 7.8 ± 2.7 mmol/L; total glycosylated hemoglobin, 7.0 ± 2.7%; and glycosylated albumin, 2.5 ± 1.7%. The age range of the study group was 32–74 y. Diabetic control was achieved

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by dietary modifications alone or in conjunction with oral agents \((n = 5)\) or insulin \((n = 5)\); these regimens remained unchanged during the study. Patients with any evidence of renal insufficiency, liver disease, uncompensated hypothyroidism, or a familial lipid disorder were excluded. The clinical protocol was approved by the Institutional Review Board, University Hospitals of Cleveland, and informed consent was obtained from all patients on admission to the study.

**Study design**

A controlled, sequential study design was used and included an 8-wk, fish-oil–treatment period followed by a 4-wk, follow-up control period. During the fish-oil–treatment period, subjects received 20 g fish oil/d, which is equivalent to 6 g \(n-3\) fatty acids (1 g fish oil/capsule, MaxEPA; RP Scherer Co, Troy, MI). The fish-oil–treatment period was divided into two phases: after the first phase of 4 wk of fish-oil treatment, the dietary fiber intake of the subjects was increased with a supplement of 15 g apple pectin/d (Hermann Herbstreith KG, Neuenburg/Wurtt, Germany) for the second phase of 4 wk of fish-oil treatment. During the 4-wk, follow-up control period, subjects were not treated with fish oil or pectin and followed their usual diabetic diet. Specific dietary instructions were given to maintain similar total fat and energy intakes during the treatment and control periods. The clinical routine for the free-living subjects involved 3-d inpatient admissions to the Clinical Research Center, University Hospitals of Cleveland, for the collection of all metabolic data, and regular outpatient visits to the Diabetes Management Center of the same hospital for the monitoring of protocol compliance.

Fasting and 2-h postprandial plasma glucose concentrations were determined by the glucose oxidase method with a Beckman Glucose Analyzer II (Beckman Instruments, Fullerton, CA). Diabetic control was also monitored by measuring glycated hemoglobin and albumin with column chromatography (Pierce Co, Rockford, IL). Plasma concentrations of insulin \((19)\), triacylglycerol \((20)\), total cholesterol \((21)\), HDL \((22)\) and LDL and VLDL \((23)\) cholesterol were measured in the fasting state. Plasma and 24-h urinary zinc, magnesium, and copper concentrations were quantified by flame-atomic-absorption spectroscopy \((24)\) with a Perkin-Elmer 460 atomic-absorption spectrophotometer (Norwalk, CT). Compliance with the dietary recommendations was evaluated by 4-d food records, which were estimated by using a Case Western Reserve University computerized nutrient database.

The fatty acid composition of the plasma lipid fractions was analyzed by gas chromatography (model 5890A; Hewlett-Packard, Avondale, PA) with an SP2330 capillary column (Supelco Co, Bellefonte, PA) after lipid class separation by silica-gel column chromatography \((25)\). In brief, a mixture of plasma sample and internal standards was extracted with chloroform, heptane, and phosphate buffer. The organic layer was dried and extracted with isooctane:ethyl acetate \((40:1\), by vol\). This extract was applied to a silica-gel column and the plasma lipid fractions were eluted by using various mixtures of solvents \((24)\). The collected fractions were evaporated to dryness and hydrolyzed in 1 mol KOH:95% ethanol/L at 90 °C. After acidification and extraction, the fatty acids were derived as methyl esters with dimethoxypropanol and analyzed by gas chromatography. The quantitation was determined from standard curves of fatty acids analyzed on the same day \((25)\).

**Statistical analysis**

Data are expressed as means ± SDs. Comparisons of treatment values with pretreatment values, which were obtained at the beginning of the fish-oil–treatment period, were evaluated by analysis of variance (ANOVA) for repeated measures. In addition, changes between the fish-oil and fish oil–pectin phases were evaluated for selective indexes by multiple-comparison \(F\) test in conjunction with Bonferroni inequality. As a control for the study, values at the end of the follow-up control period were compared with pretreatment values by two-tailed Student’s paired \(t\) test. A \(P\) value < 0.05 was considered significant in all data analyses and a Bonferroni correction was used if applicable. SYSTAT (Systat Inc, Evanston, IL) software was used for the analyses.

**RESULTS**

After a 4-wk, run-in treatment phase with fish oil alone, plasma triacylglycerol and VLDL-cholesterol concentrations were lowered by 41% and 36%, respectively, with no apparent changes in total cholesterol, LDL-cholesterol, or HDL-cholesterol concentrations \((Table 1)\). When the plasma lipid fractions were evaluated by gas chromatography, the data showed reductions in triacylglycerols \((46%)\) and phospholipids \((27%)\) with some trend toward a decrease in the fatty acid fraction but essentially no change in the cholesterol ester fraction \((from 8.57 ± 3.62 to 8.70 ± 4.17 \text{ mmol/L})\) \((Table 2)\).

**TABLE 1**

<table>
<thead>
<tr>
<th></th>
<th>Pretreatment</th>
<th>Fish oil</th>
<th>Fish oil and pectin</th>
<th>Follow-up control</th>
<th>(p^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triacylglycerols</td>
<td>3.87 ± 1.83(^1)</td>
<td>2.28 ± 1.13</td>
<td>2.38 ± 1.21</td>
<td>3.43 ± 1.48</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Total cholesterol</td>
<td>6.57 ± 1.81</td>
<td>6.15 ± 0.91</td>
<td>5.69 ± 0.67(^2)</td>
<td>6.23 ± 1.03</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>LDL cholesterol</td>
<td>4.32 ± 1.58</td>
<td>4.40 ± 0.93</td>
<td>4.01 ± 0.70(^2)</td>
<td>4.11 ± 0.98</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>VLDL cholesterol</td>
<td>1.42 ± 0.65(^3)</td>
<td>0.91 ± 0.44</td>
<td>0.88 ± 0.47</td>
<td>1.24 ± 0.49</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>HDL cholesterol</td>
<td>0.88 ± 0.28</td>
<td>0.88 ± 0.23</td>
<td>0.85 ± 0.23</td>
<td>0.93 ± 0.28</td>
<td>NS</td>
</tr>
</tbody>
</table>

\(^1\) ± SD; \(n = 15\). During the treatment period, 20 g fish oil \((6 g \text{n-3 fatty acids})\) and 15 g apple pectin were administered daily at selected times, as indicated in the text. There were no significant differences between follow-up control and pretreatment values, by paired \(t\) test.

\(^2\) Significance of comparison among pretreatment, fish oil, and fish oil and pectin \((repeated-measures ANOVA)\).

\(^3\) Significantly different from fish oil, \(P < 0.05\) \((multiple-comparison \text{ } F\) test).
When there was a high fiber intake during fish-oil therapy, there were no further apparent reductions in plasma triacylglycerol and VLDL-cholesterol concentrations. Plasma HDL-cholesterol concentrations also remained unchanged. In contrast, we noted apparent reductions in total cholesterol and LDL cholesterol (Table 1). When treatment values were compared with pretreatment values by ANOVA, the observed declines in mean total cholesterol and LDL-cholesterol concentrations were significant ($P < 0.001$ and $< 0.05$, respectively). The reductions in triacylglycerols and VLDL cholesterol were also significant ($P < 0.01$, Table 1).

During the high-fiber-intake phase, gas chromatographic analyses of the plasma lipid fractions showed an apparent decrease in cholesterol esters from $8.70 \pm 4.17$ to $5.73 \pm 0.68$ mmol/L (34% decrease), as well as further reductions in triacylglycerols (44%) and phospholipids (42%). When treatment values were compared with pretreatment values by ANOVA, the observed declines in the cholesterol ester and fatty acid concentrations were significant ($P < 0.05$ and $< 0.002$, respectively, Table 2). By multiple-comparison testing, the difference in the cholesterol ester fraction between the fish oil and the fish oil–pectin phases was confirmed to be significant ($P < 0.05$). Overall reductions in the triacylglycerol and phospholipid fractions were also significant by ANOVA ($P < 0.01$ and $< 0.005$, respectively; Table 2).

The fatty acid profile of the plasma lipid fractions confirmed protocol compliance with marked increases in eicosapentaenoic acid (EPA, 20:5n−3) and docosahexaenoic acid (DHA, 22:6n−3) concentrations during the fish-oil–treatment period. In the plasma triacylglycerol fraction (data not shown), EPA rose from $0.13 \pm 0.09\%$ to $2.18 \pm 1.16\%$ and DHA rose from $0.50 \pm 0.32\%$ to $3.45 \pm 1.16\%$ after the first 4-wk, run-in, fish-oil phase. During the fish oil–pectin phase, the percentages of EPA and DHA were $1.74 \pm 1.24\%$ ($P < 0.001$, by ANOVA) and $3.10 \pm 2.12\%$ ($P < 0.001$, by ANOVA), respectively.

In the plasma cholesterol ester fraction (Table 3), EPA rose from $2.32 \pm 3.41\%$ to $7.77 \pm 4.20\%$ and DHA rose from $0.57 \pm 0.29\%$ to $1.17 \pm 0.44\%$ after the first 4-wk, run-in, fish-oil phase. During the fish oil–pectin phase, the percentages of EPA and DHA were $4.58 \pm 3.45\%$ ($P < 0.01$, by ANOVA) and $1.05 \pm 0.78\%$ ($P < 0.005$, by ANOVA), respectively. The percentage of linoleic acid ($18:2n−6$) fell after the first 4 wk of fish-oil treatment but returned to the baseline value by the end of the study. There were no changes in the percentage of arachidonic acid ($20:4n−6$) during the study. The percentages of saturated fatty acids showed only a slight tendency to decline at the end of the 8-wk treatment period.

Selected plasma and urinary mineral concentrations were monitored during the study because of the fiber supplementation (Table 4). After 4 wk of fiber supplementation, there were no significant changes in the plasma concentrations of zinc, magnesium, or copper. Mean urinary concentrations of these minerals showed trends toward a decrease during the treatment period. Urinary zinc decreased from $16.7 \pm 9.9$ to $10.4 \pm 7.0$ mmol/d ($P < 0.05$) by the end of the treatment period. Similarly, urinary magnesium tended to decrease (from $5.25 \pm 2.45$ to $3.90 \pm 1.40$ mmol/d) as did urinary copper (from $1.21 \pm 0.61$ to $1.10 \pm 0.85$ mmol/d). In this study these mean changes were not significant.

To assess the metabolic control in this study, values of the metabolic indexes at the end of the two phases of the fish-oil–treatment period were compared with pretreatment values. As shown in Table 5, the small fluctuations observed in the mean plasma fasting glucose and 2-h postprandial glucose and fasting insulin concentrations were not significant. Furthermore, glycated hemoglobin, glycated albumin, and body weight indexes remained unchanged. When the fiber supplement was added to the fish-oil therapy, we noted amelioration of any potential deterioration of diabetic control in the individual values. The mean values of the metabolic indexes were essentially similar to those at baseline (Table 5).

With subjects serving as their own controls, data collected at the end of the control period were compared with pretreatment values. As shown in Table 1, lipid indexes returned to values similar to or slightly lower than those at baseline by the end of the control period, although any observed differences in this study were not significant. As shown in Table 5, fasting plasma glucose concentrations and 2-h postprandial glucose and fasting insulin concentrations at the end of the control period were not significantly different from baseline values. Diabetic control, as evidenced by glycated hemoglobin and albumin values as well as body weight changes, was maintained during the control period.

**TABLE 2**

<table>
<thead>
<tr>
<th>Plasma lipid fractions of fish-oil–treated diabetic patients with or without a high fiber intake</th>
<th>Pretreatment</th>
<th>Fish oil</th>
<th>Fish oil and pectin</th>
</tr>
</thead>
<tbody>
<tr>
<td>mmol/L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triacylglycerols</td>
<td>$10.79 \pm 6.86^1$</td>
<td>$5.81 \pm 3.97$</td>
<td>$3.26 \pm 2.13^2$</td>
</tr>
<tr>
<td>Phospholipids</td>
<td>$6.99 \pm 3.29^1$</td>
<td>$5.09 \pm 1.99$</td>
<td>$2.93 \pm 0.53^2$</td>
</tr>
<tr>
<td>Cholesterol esters</td>
<td>$8.57 \pm 3.62$</td>
<td>$8.70 \pm 4.17$</td>
<td>$5.73 \pm 0.68^2$</td>
</tr>
<tr>
<td>Fatty acids</td>
<td>$0.44 \pm 0.12$</td>
<td>$0.32 \pm 0.17$</td>
<td>$0.31 \pm 0.12^2$</td>
</tr>
</tbody>
</table>

$^1$SE; $n = 13$. During the treatment period, 20 g fish oil (6 g n−3 fatty acids) and 15 g apple pectin were administered daily at selected times, as indicated in the text.

$^2$Significance of comparison among pretreatment, fish oil, and fish oil and pectin (repeated measures ANOVA).

$^3$Significantly different from fish oil, $P < 0.05$ (multiple-comparison F test).

$^4$Significantly different from pretreatment, $P < 0.05$ (multiple-comparison F test).
TABLE 4
Plasma and urinary mineral concentrations of fish-oil–treated diabetic patients with or without a high fiber intake

<table>
<thead>
<tr>
<th></th>
<th>Pretreatment</th>
<th>Fish oil</th>
<th>Fish oil and pectin</th>
<th>P²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasma (μmol/L)</td>
<td>16.1 ± 2.1</td>
<td>16.7 ± 3.0</td>
<td>17.4 ± 5.1</td>
<td>NS</td>
</tr>
<tr>
<td>Urine (μmol/d)</td>
<td>16.7 ± 9.9</td>
<td>14.0 ± 9.1</td>
<td>10.4 ± 7.0*</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasma (mmol/L)</td>
<td>0.88 ± 0.08</td>
<td>0.90 ± 0.10</td>
<td>0.89 ± 0.10</td>
<td>NS</td>
</tr>
<tr>
<td>Urine (mmol/d)</td>
<td>5.25 ± 2.45</td>
<td>4.80 ± 2.60</td>
<td>3.90 ± 1.40</td>
<td>NS</td>
</tr>
<tr>
<td>Copper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasma (μmol/L)</td>
<td>18.7 ± 2.8</td>
<td>18.6 ± 4.1</td>
<td>18.5 ± 3.9</td>
<td>NS</td>
</tr>
<tr>
<td>Urine (μmol/d)</td>
<td>1.21 ± 0.61</td>
<td>1.23 ± 0.68</td>
<td>1.10 ± 0.85</td>
<td>NS</td>
</tr>
</tbody>
</table>

1. x ± SD; n = 15. During the treatment period, 20 g fish oil (6 g n-3 fatty acids) and 15 g apple pectin were administered daily at selected times, as indicated in the text.
2. Significance of main effect of treatment (repeated-measures ANOVA).
3. Significantly different from pretreatment, P < 0.05 (multiple-comparison F test).

DISCUSSION

The results of the present study in patients with NIDDM showed that when a high fiber intake is maintained during fish-oil treatment, plasma triacylglycerol and total cholesterol concentrations and fractions of plasma cholesterol, specifically VLDLs and LDLs, decrease. Furthermore, amelioration of the lipid and lipoprotein profiles appeared to result in beneficial changes in the plasma cholesterol ester and fatty acid fractions of the diabetic patients studied. Other observations on plasma lipids and lipoproteins noted in this study, specifically those observed with fish oil alone, have been documented in previous studies (5, 7). To ensure that the combined effects of fish oil and high fiber intake evaluated in the present study were not incidental, the subjects were followed for an additional 4 wk when they received no treatment.

Fiber intake has never been monitored in previous studies investigating the therapeutic potential of n-3 fatty acids in modulating the effects of lipids and lipoproteins in the treatment of diabetes-associated hyperlipidemias (5, 7). The lipid-lowering properties of soluble dietary fiber, such as pectin, have been documented in > 50 studies, both short- and long-term (17, 26, 27). The mechanism of action for its hypocholesterolemic effect is believed to include its binding action on bile acids (26, 28–30). Increased fecal excretion and interruption of the entero-hepatic circulation of the bile salts, which would result in decreased intestinal cholesterol as well as fat absorption, can all lead to lowering of plasma lipids and lipoproteins (26, 28–30). Although the mechanism is not known, fiber has been shown to lower plasma triacylglycerols in diabetic patients (31). The differences in plasma fatty acid results between our study and that of Ray et al (32) may be attributed to the use of fish oil in our study as well as to differences in characteristics of the patient population studied. They selected poorly controlled NIDDM patients who were unresponsive to all conventional therapeutic regimens, including diet and sulfonylureas. Using fish oil but different subject inclusion criteria than in the present study, Glauber et al (16) showed elevated plasma fatty acid concentrations, although the mean changes were not significant.

Fiber has also been implicated in the maintenance of glycemic control via its effect on fasting and pre- and postprandial plasma glucose (18, 29). The mechanism of action of these effects includes a slowing of glucose absorption (29). As shown in previous studies with fish oils (9–12), mean plasma triacylglycerol and VLDL-cholesterol concentrations in the present study were significantly lowered by fish-oil treatment, specifically by 38% for both, by the end of the 8-wk treatment period. In contrast with previous studies (7, 10, 16), however, our results showed comparable effects of fish-oil treatment in the absence of deleterious changes in fasting and 2-h postprandial glucose, glycated hemoglobin, and albumin, or body weight when compared with pretreatment values.

In the present study, the usual dietary fiber intake of the diabetic patients was ≤ 10–12 g/d. Their daily fiber intake was increased by supplementing their diet with 15 g soluble pectin powder; but, as estimated from the 4-d food records, the total daily fiber intake of the study patients did not exceed ADA recommendations (4). Nevertheless, the ability of fiber to chelate mineral ions is well-

TABLE 5
Metabolic indexes of fish-oil–treated diabetic patients with or without a high fiber intake

<table>
<thead>
<tr>
<th></th>
<th>Pretreatment</th>
<th>Fish oil</th>
<th>Fish oil and pectin</th>
<th>Follow-up control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fasting glucose (mmol/L)</td>
<td>7.72 ± 2.7</td>
<td>7.88 ± 2.6</td>
<td>7.72 ± 2.6</td>
<td>7.88 ± 3.0</td>
</tr>
<tr>
<td>2-h Postprandial glucose (mmol/L)</td>
<td>10.38 ± 5.3</td>
<td>10.77 ± 4.9</td>
<td>10.44 ± 5.1</td>
<td>10.21 ± 4.2</td>
</tr>
<tr>
<td>Fasting insulin (pmol/ml)</td>
<td>140 ± 81</td>
<td>159 ± 102</td>
<td>131 ± 71</td>
<td>138 ± 69</td>
</tr>
<tr>
<td>Glycated hemoglobin (% of total)</td>
<td>7.0 ± 2.7</td>
<td>6.5 ± 2.0</td>
<td>6.7 ± 2.6</td>
<td>7.0 ± 2.6</td>
</tr>
<tr>
<td>Glycated albumin (%)</td>
<td>2.5 ± 1.7</td>
<td>2.2 ± 1.0</td>
<td>2.7 ± 1.8</td>
<td>2.8 ± 1.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>76.5 ± 12.4</td>
<td>76.8 ± 12.2</td>
<td>76.3 ± 11.8</td>
<td>76.8 ± 11.7</td>
</tr>
</tbody>
</table>

1. x ± SD; n = 15. During the treatment period, 20 g fish oil (6 g n-3 fatty acids) and 15 g apple pectin were administered daily at selected times, as indicated in the text. There was no significant main effect of treatment (repeated-measures ANOVA) and no significant difference between follow-up control and pretreatment values (paired t test).
known and may be a concern (17). The potential for developing negative mineral balances when the fiber content of the diet is increased has been evaluated in past studies (33, 34).

Abnormal zinc, magnesium, and copper metabolism have been observed in patients with NIDDM (35–37). Because these minerals are important in normalizing body functions, such as glucose homeostasis (35, 36), we monitored their concentrations during the study. Although we did not completely assess mineral status, our results are similar to those from past investigations (17) and showed maintenance of plasma concentrations with some trend toward decreased urinary excretion of these minerals, perhaps suggesting improved metabolism with fiber intake (17).

In conclusion, the plasma lipid and lipoprotein profiles of the diabetic patients at the end of the 8-wk, fish-oil–treatment period were significantly improved compared with those at baseline. Although our study group was small and the duration of the study was limited, our observations warrant further investigation of this combined treatment regimen: optimal fish-oil treatment and high fiber intakes (meeting ADA recommendations) as adjunctive therapy in the management of diabetes-associated hyperlipemias.

We acknowledge the invaluable assistance of the staff of the General Clinical Research Center, University Hospitals of Cleveland.

REFERENCES