# Postprandial Serum Glucose, Insulin, and Lipoprotein Responses to High- and Low-Fiber Diets

James W. Anderson, Donna Spencer O'Neal, Susan Riddell-Mason, Tammy L. Floore, Debra W. Dillon, and Peter R. Oeltgen

**The effects of high-fiber (HF) and low-fiber (LF) meals on postprandial serum glucose, insulin, lipid, lipoprotein, and apolipoprotein concentrations of 10 hypercholesterolemic men were examined using a random-order, cross over design. HF and LF meals provided 15% of energy as protein, 40% as carbohydrate, and 45% as fat, 200 mg cholesterol/1,000 kcal, and 25 g fiber/1,000 kcal for HF or 3 g fiber/1,000 kcal for LF. Responses over a 15-hour period after multiple meals (MM) and over a 10-hour period after a single meal (SM) were compared. HF meals were associated with a significant reduction in postprandial serum glucose ($P < .0005$ after SM) and insulin ($P < .0005$ afer SM). Serum free fatty acid (FFA) levels decreased significantly after MM and SM, but differences between HF and LF meals were insignificant. Although serum triglyceride responses did not differ significantly (ANOVA) between HF and LF meals, values were higher at 2 and 3 hours after a HF SM than after a LF SM and at 16 hours after HF MM than after LF MM. Although serum cholesterol values did not differ significantly (ANOVA) between HF and LF meals, values were higher after a HF SM than after a LF SM. Other subtle differences in responses of high-density lipoprotein (HDL) cholesterol, HDL2, and HDL3 concentrations were noted. These studies indicate that large increases in dietary fiber intake are accompanied by small changes in postprandial serum lipoprotein concentrations.**


DIETARY FIBER content of meals has a major effect on postprandial serum glucose and insulin responses.[1] While certain dietary fibers have documented effects on fasting serum lipids,[2-4] the effects on postprandial serum lipid responses are less well characterized.[5,6] Soluble fibers such as gums, pectins, and psyllium are of particular interest because they decrease postprandial blood glucose responses and fasting serum cholesterol concentrations.[7] Whereas many others have examined the effects of fat intake on postprandial serum lipids, lipoproteins, and apoproteins,[8-15] this study focused on the effects of fiber intake on postprandial changes.

The effects of low-fiber (LF) and high-fiber (HF) meals on postprandial serum glucose, insulin, lipid, lipoprotein, and apolipoprotein levels in hypercholesterolemic men were examined using a random-order, crossover design. As anticipated, serum glucose and insulin responses were lower after HF meals rich in soluble fiber than after LF meals. However, serum triglyceride and cholesterol concentrations were significantly higher between 1 and 3 hours after HF than after LF meals. This study indicates that dietary fiber intake produced subtle but statistically significant alterations of postprandial serum lipid responses.

## SUBJECTS AND METHODS

### *Subjects*

Ten non-obese, middle-aged men were entered onto the study (Table 1). They had a body mass index of 21.4 to 28.3 kg/m$^2$, a fasting serum cholesterol value of 4.45 to 6.4 mmol/L, and a triglyceride value of 0.8 to 3.66 mmol/L. The enrollment criteria included multiple serum cholesterol values greater than 5.2 mmol/L before entry onto the study; although subject no. 1 met this criterion, his serum cholesterol level at admission to the hospital was less than this value. Subjects did not have diabetes, renal disease, liver disease, thyroid disease, or other secondary causes of hyperlipidemia. Subjects had not received lipid-lowering medications for $\geq 3$ months before enrollment. Table 1 lists medication use and major medical diagnoses. Ten men volunteered and completed the study. Five men completed the HF meals first, and five completed the LF meals first.

### *Study Protocol*

This was a random-allocation study with a crossover and washout period. Subjects entered the metabolic ward on the afternoon of day 1 and had a low-fat, LF evening meal at 5:30 PM. They had no additional food for 14 hours. On day 2, the multiple meal (MM) day, two blood samples were drawn before 7:30 AM. Subjects ate meals at 7:30 AM, 12:30 PM, and 5:30 PM. Blood was drawn at hourly intervals from 8:30 AM to 10:30 PM. After a 14-hour fasting period, two blood samples were drawn before 7:30 AM on day 3. Subjects ate a large single meal (SM) at 7:30 AM. Blood was drawn hourly from 8:30 AM to 4:30 PM. After eating a self-selected meal, subjects left the ward. After a 4-day washout period, subjects returned for the second series of meals.

### *Diets*

Subjects ate weight-maintaining diets of commonly available foods. The low-fat, LF evening meal provided 35% of estimated energy needs, 65% of energy as carbohydrate, 15% as protein, and 20% as fat, 200 mg cholesterol/1,000 kcal, and 3 g fiber/1,000 kcal. Representative menus for the SM and MM days are listed in Table 2. The MM and SM provided 15% of energy as protein, 40% as carbohydrate, and 45% as fat (Table 3). The SM provided half the nutrient intake of the MM and included 50 to 62 g fat. Intake of energy, protein, total carbohydrate, fat, saturated, monounsaturated, and polyunsaturated fatty acids, and cholesterol were similar for LF and HF meals. By design, total and soluble fiber intakes were approximately eightfold greater on HF than on LF diets. HF meals included psyllium (Regular Orange Flavored Metamucil; Procter & Gamble, Cincinnati, OH) as follows: on the MM day each meal included 3.4 g psyllium (11 g Metamucil), and

*From the Metabolic Research Group, Veterans Affairs Medical Center and University of Kentucky, Lexington, KY.*

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*Address reprint requests to James W. Anderson, MD, VA Medical Center, Medical Service 111C, 2250 Leestown Rd, Lexington, KY 40511.*


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**Table 1. Subject Characteristics**

| Subject No. | Age (yr) | BMI (kg/m²) | Serum Total Cholesterol (mmol/L) | Serum Triglycerides (mmol/L) | Medications |
|---|---|---|---|---|---|
| 1 | 70 | 26.4 | 4.45 | 0.80 | None |
| 2 | 67 | 25.7 | 5.45 | 1.28 | None |
| 3 | 67 | 27.1 | 5.55 | 1.86 | Enalapril, verapamil, triamterene |
| 4 | 66 | 26.7 | 5.60 | 1.50 | Furosemide |
| 5 | 67 | 27.5 | 5.70 | 1.80 | HCTZ, KCl |
| 6 | 43 | 27.6 | 5.70 | 2.86 | None |
| 7 | 58 | 27.5 | 5.90 | 1.88 | None |
| 8 | 59 | 24.7 | 5.95 | 3.66 | None |
| 9 | 63 | 21.4 | 6.40 | 2.32 | None |
| 10 | 67 | 28.3 | 6.40 | 2.58 | Pentoxifylline |
| Mean | 62.7 | 26.3 | 5.70 | 2.06 | |
| SEM | 2.5 | 2.0 | 0.55 | 0.82 | |

Abbreviations: BMI, body mass index; HCTZ, hydrochlorothiazide.

on the SM day the meal included 5.1 g psyllium (16.5 g Metamucil). This psyllium supplement provided less than 20% of the fiber in the HF meals. To achieve these high levels of fiber from commonly available foods, HF meals had significantly more complex carbohydrate and significantly less simple carbohydrate than LF meals.

### *Analyses*

Food intake on both diets was measured by weighing serving dishes before and after meals. Nutrient and fiber contents were calculated using a computerized nutrient data base[16] with revised fiber values.[17]

Serum glucose level was measured using glucose oxidase.[18] Serum insulin level was measured by radioimmunoassay using the Micromedic insulin radioimmunoassay kit (ICN Micromedic Systems, Horsham, PA). Serum free fatty acid (FFA) levels were measured using an enzymatic colorimetric method (WAKO; Wako Pure Chemical Industries, Osaka, Japan). Serum cholesterol, triglyceride, and high-density lipoprotein HDL cholesterol concentrations were determined by enzymatic methods using the Abbott VP Analyzer (Abbott Laboratories, North Chicago, IL). Serum cholesterol level was measured using a cholesterol esterase–cholesterol oxidase assay.[19] Serum triglycerides were determined by hydrolyzing the triglycerides and measuring the released glycerol.[20] Serum HDL cholesterol level was measured by the same method used for serum cholesterol after removal of low-density lipoprotein (LDL) and very-low-density lipoprotein (VLDL) cholesterol by magnesium–dextran sulfate precipitation.[21] Apolipoprotein (apo) A-I and B-100 levels were measured by a radioimmunodiffusion method using Tago Diffu-Gen Kits (Tago, Burlingame, CA). Selected samples were sent to the University of Alabama Lipoprotein Laboratory (Birmingham, AL) for vertical autoprofile (VAP) measurements.[22] Serum LDL cholesterol, intermediate-density lipoprotein (IDL) cholesterol, VLDL cholesterol, $HDL_2$, and $HDL_3$ measurements were available from VAP analysis.

### *Statistical Analysis*

Two-factor (time and diet) repeated-measures ANOVA was used to analyze data. The two values obtained before 7:30 AM were averaged and used for baseline (time 0) values. Paired *t* tests were used to compare postprandial values with baseline values and to compare values on HF versus LF diets at specific times.[23] A *P* value less than .05 was used to determine statistically significant differences.

## RESULTS

Table 4 lists fasting serum concentrations for all measurements. There were no significant differences between values for SM or MM days.

### *Glucose, Insulin, and FFA Responses*

Figure 1 summarizes serum glucose responses to HF and LF meals. With the SM, as expected, glucose values differed significantly over time ($P < .0005$, ANOVA), and differences at specific times are indicated. Serum glucose values were significantly lower ($P = .019$, ANOVA) with HF than with LF meals. At 1 hour, glucose values were significantly lower with HF than with LF meals. Peak glucose values (mean of peak values achieved for each subject) were 7.6 ± 1.4 (mean ± SD) mmol/L with HF meals and 9.6 ± 1.5 ($P < .001$) with LF meals. Incremental peaks (mean of individual increases above fasting) were 2.0 ± 1.2 mmol/L with HF meals and 4.2 ± 1.3 ($P < .001$) with LF meals. On MM days, as expected, glucose values differed significantly over time ($P < .0005$, ANOVA), and differences at specific times are indicated. Glucose values were significantly lower ($P = .043$, ANOVA) with HF than with LF meals. Glucose values at 1 hour after lunch and dinner were significantly lower with HF than with LF meals. Mean peak glucose values were 7.8 ± 1.4 mmol/L with HF meals and 9.6 ± 1.5 ($P < .002$) with LF meals. Mean incremental peaks were 2.3 ± 1.2 mmol/L with HF meals and 4.3 ± 1.4 ($P < .001$) with LF meals.

Serum insulin responses paralleled serum glucose responses. With the SM, as expected, insulin values varied significantly over time ($P < .0005$, ANOVA), and differences at specific times are indicated. Insulin values were significantly lower ($P < .001$, ANOVA) with HF than with LF meals. At 1 hour, insulin values were significantly lower after HF than after LF meals. On MM days, as expected, serum insulin values varied significantly over time ($P < .0005$, ANOVA), and differences at specific times are indicated. Insulin values were significantly lower ($P < .0005$, ANOVA) with HF than with LF meals. At 1 hour after the noon meal, insulin values were significantly lower with HF than with LF meals.

Serum FFA responses had a reciprocal relationship to serum insulin responses. Serum FFA values decreased significantly after HF and LF meals, decreasing with the SM and MM. After a SM, FFA values decreased more after LF than after HF, but these differences were not significant. After MM, absolute decreases (not shown) were similar for HF and LF meals, but FFA values remained lower after HF than after LF at later hours.

### *Triglyceride, Cholesterol, and HDL Cholesterol Responses*

Figure 2 summarizes serum triglyceride responses to HF and LF meals. With the SM, as expected, triglycerides differed significantly over time ($P < .0005$, ANOVA), and differences at specific times are indicated. Serum triglyceride values did not differ significantly ($P = .741$, ANOVA) after HF versus LF meals. However, at 2 and 3 hours, triglyceride values were significantly higher after HF than

**Table 2. Representative Menus for SM and MM Study Days**

| LF | | HF | |
|---|---|---|---|
| Food | Amount (g) | Food | Amount (g) |
| SM | | | |
| Breakfast | | | |
| Sausage (pork), cooked | 86.7 | Sausage (pork), cooked | 27.9 |
| Egg | 19.9 | Bacon (pork), fried | 10.0 |
| Egg substitute | 29.8 | Egg | 24.9 |
| Cheese, American | 25.0 | Pinto beans, cooked | 114.9 |
| Corn flakes | 29.1 | Oatbran cereal, dry | 23.9 |
| Biscuit, Hungry Jack* | 49.9 | Oatbran muffin | 119.9 |
| Banana | 24.8 | Pears, canned | 99.4 |
| Apricots, canned | 77.2 | Prunes, dried | 4.6 |
| Jelly, regular | 29.6 | Butter (regular), stick | 18.8 |
| Butter (regular), stick | 3.0 | Margarine (corn, regular), hard | 15.0 |
| Margarine (corn, regular), hard | 6.4 | Metamucil | 16.5 |
| Grape juice, canned | 134.2 | | |
| Milk, 2% | 238.6 | | |
| MM | | | |
| Breakfast | | | |
| Egg | 14.7 | Egg | 14.8 |
| Egg substitute | 52.1 | Egg substitute | 32.6 |
| Bacon (pork), fried | 14.7 | Sausage (pork), cooked | 23.9 |
| Corn flakes | 19.2 | Oatbran cereal, dry | 29.6 |
| Apricots, canned | 42.0 | Wheat bran, Kretschmer† | 2.0 |
| Bread, white | 49.9 | Apricots, canned | 89.2 |
| Jelly, regular | 13.8 | Prunes, dried | 19.7 |
| Butter (regular), stick | 5.6 | Oatbran muffin | 100 |
| Margarine (corn, regular), hard | 5.9 | Jelly, regular | 4.7 |
| Milk, whole | 177.9 | Butter (regular), stick | 18.4 |
| | | Metamucil | 11.0 |
| Lunch | | | |
| Chicken breast, roast | 53.8 | Chicken breast, roast | 25.4 |
| Egg | 12.2 | Egg | 17.6 |
| Macaroni, cooked | 53.3 | Pinto beans, cooked | 84.4 |
| Cheese, American | 14.5 | Corn kernels, cooked | 104.7 |
| Apricots, canned | 98.7 | Broccoli, cooked | 99.4 |
| Roll, white | 49.8 | Peaches, canned | 88.9 |
| Jelly, regular | 3.7 | Oatbran muffin | 84.9 |
| Butter (regular), stick | 8.6 | Butter (regular), stick | 19.6 |
| Margarine (corn, regular), hard | 19.1 | Margarine (corn, regular), hard | 22.3 |
| Grape juice, canned | 174 | Metamucil | 11.0 |
| Dinner | | | |
| Beef (lean), roast | 54.7 | Pork shoulder (lean), roast | 39.7 |
| Egg | 11.1 | Bacon (pork), fried | 8.0 |
| Carrots, cooked | 66.2 | Egg | 16.5 |
| Roll, white | 60.9 | Carrots, cooked | 123.8 |
| Butter (regular), stick | 5.3 | Navy beans, cooked | 99.8 |
| Margarine (corn, regular), hard | 21.0 | Zucchini, cooked | 111.1 |
| Grape juice, canned | 203.6 | Oatbran muffin | 63.0 |
| Milk, whole | 118.4 | Apricots, canned | 109.8 |
| | | Butter (regular), stick | 13.9 |
| | | Margarine (corn, regular), hard | 17.4 |
| | | Grape juice, canned | 114.8 |
| | | Metamucil | 11.0 |

*Hungry Jack.

†Kretschmer (Quaker Oats, Chicago, IL).

**Table 3. Nutrient, Energy, and Fiber Intake on SM and MM (mean ± SEM)**

| | SM | | MM | |
|---|---|---|---|---|
| Component | LF | HF | LF | HF |
| Energy (kcal) | 1,103 ± 39 | 1,049 ± 46 | 2,245 ± 71 | 2,191 ± 81 |
| Protein (g) | 41.3 ± 1.4 | 39.2 ± 1.9 | 84.3 ± 2.7 | 83.6 ± 3.0 |
| Carbohydrate (g) | 109 ± 5 | 106 ± 6 | 226 ± 7 | 224 ± 8 |
| Simple | 52 ± 5 | 24 ± 5* | 119 ± 7 | 69 ± 10* |
| Complex | 61 ± 5 | 82 ± 5* | 111 ± 10 | 157 ± 6* |
| Fat (g) | 56.0 ± 1.7 | 52.2 ± 2.2 | 112 ± 4 | 109 ± 5 |
| PUFA | 10.0 ± 0.4 | 9.0 ± 0.5 | 18.8 ± 0.6 | 20.3 ± 0.6 |
| MUFA | 21.9 ± 0.6 | 20.7 ± 1.0 | 47.1 ± 1.4 | 42.5 ± 2.2 |
| Saturated | 20.2 ± 0.9 | 18.8 ± 0.7 | 37.8 ± 1.4 | 39.8 ± 1.8 |
| Fiber (g) | | | | |
| Total | 3.41 ± 0.14 | 26.1 ± 1.2* | 6.71 ± 0.23 | 55.6 ± 1.9* |
| Soluble | 1.68 ± 0.07 | 13.2 ± 0.6* | 3.33 ± 0.12 | 27.9 ± 0.9* |
| Cholesterol (mg) | 223 ± 7 | 215 ± 6 | 444 ± 14 | 437 ± 16 |

Abbreviations: PUFA, polyunsaturated fatty acids; MUFA, monounsaturated fatty acids.

*Significantly different from LF, $P < .001$.

after LF meals. The mean peak values and incremental peak values did not differ significantly between HF and LF meals. On MM days, as expected, triglyceride values differed over time ($P < .0005$, ANOVA), and differences at specific times are indicated. Serum triglycerides did not differ significantly ($P = .256$, ANOVA) between HF and LF meals, and the only difference noted was at 16 hours, when HF values were significantly higher than LF values.

Serum cholesterol response patterns differed between HF and LF meals after the SM: after the HF meal values increased significantly at 1 hour, whereas after the LF meal values decreased significantly between 2 and 4 hours. These differences were not seen during the MM day.

HDL cholesterol values decreased significantly after the SM for both the LF and HF diets. On the MM day, HDL cholesterol values were lower at most time points after LF than after HF.

*Serum Lipoprotein Responses (VAP Analysis)*

VAP analyses are only available for seven subjects after the SM and for six subjects after MM, because inadequate samples were obtained for measurements at all time points for some subjects. Serum LDL cholesterol values decreased significantly on all days (Fig 3). Decreases tended to be greater on the LF diet, but these differences were not significant.

After the SM, serum VLDL cholesterol values showed nonsignificant decreases and then increased with HF diets. After MM, VLDL cholesterol values were stable except for the significant increase with HF at the last collection.

Changes in serum IDL cholesterol were not significant. After the SM, values tended to increase with LF and HF meals. As noted for LDL and VLDL cholesterol, increases tended to be larger after HF meals.

Serum cholesterol values for $HDL_2$ and $HDL_3$ tended to show reciprocal changes (Fig 4). Changes in $HDL_3$ tended to follow changes in HDL cholesterol (Fig 2). Thus, $HDL_3$ decreased significantly after the SM, and decreases tended

**Table 4. Fasting Serum Concentrations on SM and MM Days With LF and HF Diets (mean ± SEM)**

| Component | SM | | MM | |
|---|---|---|---|---|
| | LF | HF | LF | HF |
| Glucose (mmol/L) | 5.53 ± 0.13 | 5.58 ± 0.16 | 5.30 ± 0.08 | 5.52 ± 0.17 |
| Insulin (pmol/L) | 72.9 ± 11.1 | 46.5 ± 1.4 | 60.4 ± 6.9 | 56.9 ± 6.3 |
| FFA (mEq/L) | 0.81 ± 0.21 | 0.66 ± 0.1 | 0.63 ± 0.11 | 0.91 ± 0.29 |
| Triglycerides (mmol/L) | 1.90 ± 0.23 | 2.08 ± 0.28 | 1.92 ± 0.28 | 2.13 ± 0.26 |
| Cholesterol (mmol/L) | 5.81 ± 0.19 | 5.67 ± 0.19 | 5.65 ± 0.18 | 5.74 ± 0.23 |
| HDL | 1.05 ± 0.08 | 1.03 ± 0.07 | 1.05 ± 0.09 | 1.01 ± 0.07 |
| LDL | 3.05 ± 0.11 | 2.86 ± 0.16 | 2.92 ± 0.09 | 2.78 ± .22 |
| VLDL | 0.88 ± 0.09 | 0.84 ± 0.07 | 0.78 ± 0.05 | 0.72 ± 0.07 |
| IDL | 1.06 ± 0.05 | 0.94 ± 0.04 | 1.02 ± 0.13 | 0.86 ± 0.10 |
| $HDL_2$ (mmol/L) | 0.147 ± 0.021 | 0.147 ± 0.021 | 0.189 ± 0.054 | 0.168 ± 0.047 |
| $HDL_3$ (mmol/L) | 0.705 ± 0.065 | 0.700 ± 0.072 | 0.796 ± 0.101 | 0.767 ± 0.085 |
| Apo B-100 (g/L) | 1.09 ± 0.07 | 1.06 ± 0.05 | 1.03 ± 0.06 | 0.99 ± 0.05 |
| Apo A-I (g/L) | 1.65 ± 0.11 | 1.66 ± 0.1 | 1.63 ± 0.1 | 1.68 ± 0.09 |

to be larger with LF meals. After MM, the only significant change in $HDL_3$ was a decrease at 13 hours after the LF meal. $HDL_2$ tended to increase on all 4 test days. This increase was significant at 9 hours after the SM for HF and at 13 hours after MM for LF.

*Apolipoprotein Changes*

Serum apo B-100 values decreased after the SM with LF and HF (Fig 5). These changes parallel changes for LDL cholesterol (Fig 3). With MM, apo B levels were consistently lower for LF than for HF.

Serum apo A-I changes were not statistically significant. Apo A-I values decreased to a greater extent with LF than with HF meals (Fig 5). These changes were consistent with changes in HDL cholesterol after the SM and MM.

## DISCUSSION

In this study, dietary fiber had a major effect on postprandial serum glucose and insulin responses, as previously documented.[1,24] Although HF meals (25 g fiber/1,000 kcal) provided over eightfold more dietary fiber than LF meals (3 g fiber/1,000 kcal), differences in postprandial lipoproteins were small. These observations, in agreement with prior studies,[5,6] suggest that incorporation of large amounts of fiber into a SM over the short term does not have a major impact on postprandial serum lipoproteins.

HF meals had significantly different effects on serum glucose, insulin, and triglyceride values as compared with LF meals. The significant reduction of the increase in postprandial serum glucose and insulin values after meals that include soluble fiber is well documented.[1,7,24] However, except for studies reported by Irie et al,[25] Redard et al,[5] and Cara et al,[6] serum lipoprotein responses to HF and LF meals have not been well characterized.

Under the experimental conditions of this study, two differences in postprandial serum triglyceride responses to HF and LF meals were observed. First, triglyceride values increased more rapidly, and second, values were elevated for a longer period after HF than after LF diets. With HF meals, the early increase in triglyceride values was accompanied by a significant increase in serum cholesterol values and an insignificant increase in HDL cholesterol values. With HF meals, VLDL cholesterol values, like triglyceride values, were significantly higher at 16 hours.

Comparisons of prior studies[5,6,25] and this study are difficult because of the following differences: gender of subjects, baseline levels of serum lipoproteins, design of the studies, levels of fat intake (0.5 to 1.0 g/kg body weight), amounts of dietary cholesterol (200 to 560 mg/1,000 kcal), amounts of dietary fiber (8 to 26 g/meal), and types of dietary fiber. Irie et al[25] examined effects of meals with or without guar gum. Increases in plasma triglyceride values were smaller after guar meals than after control meals, but triglyceride values were slightly higher at 6 hours after guar meals.

Redard et al[5] examined plasma lipoprotein responses to meals with or without guar gum plus oat bran in healthy men and women. Plasma triglyceride responses were greater after fiber-supplemented meals than after control meals, and differences were significant for women but not for men. In women, plasma cholesterol values decreased significantly below baseline values after LF meals but not after HF meals.

Cara et al[6] compared serum triglyceride and cholesterol responses to meals with or without fiber supplementation (oat bran, rice bran, wheat fiber, and wheat germ) in healthy young men. Triglyceride responses to fiber test meals tended to be lower than responses to LF meals: incremental areas were significantly lower for oat bran, wheat fiber, and wheat germ than for LF meals. Serum cholesterol values decreased after all test meals, and the largest decrease was seen after oat bran meals.

Meals for this study were designed to be palatable and to achieve a LF intake from commonly available foods for LF meals and a HF intake from foods and psyllium supplementation for HF meals. We were not able to match simple- and complex-carbohydrate intake for HF and LF meals. Thus, differences in simple-sugar intake[26,27] and in glycemic indices[26,28] between HF and LF meals may have contributed to differences, especially in serum glucose and insulin responses to meals.

Different dietary fibers have different effects on gastrointestinal physiology,[7] and preliminary evidence indicates that they have different effects on rates of fat absorption.[29]

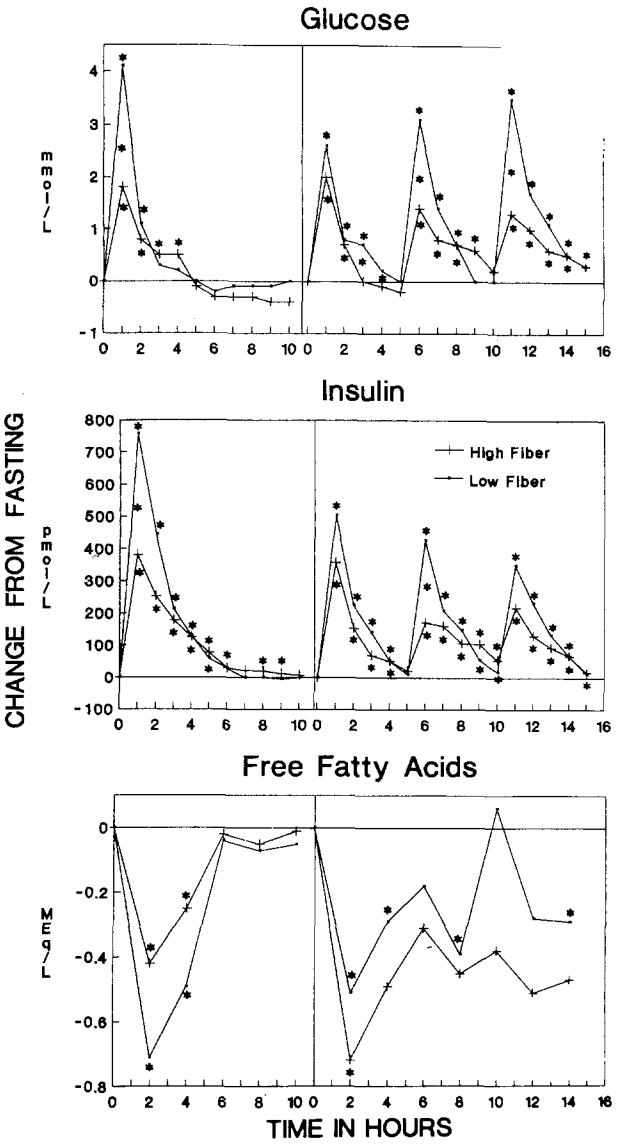


**Fig 1. Serum glucose, insulin, and FFA responses to SM (left) and MM (right) levels. Incremental changes from fasting levels. Values that differ significantly from baseline (time 0) are indicated by an asterisk above or below the line; values at the same time that differ significantly from each other (diet effect) are indicated by an asterisk between lines.**

Dietary fibers may affect postprandial lipid metabolism by these and other mechanisms[29]: (1) altering gastric emptying—soluble fibers slow gastric emptying, which would delay lipid absorption[7,30-33]; (2) influencing intestinal transit time—insoluble fibers hasten intestinal transit and soluble fibers may slow the process in a manner that might affect the timing and quantity of lipid hydrolysis, absorption, and secretion as chylomicrons[7,32,33]; (3) modifying pancreatic secretion or pancreatic enzyme activity—fiber may bind, inactivate, or physically separate enzymes from lipids and thus affect their hydrolysis[33,34]; (4) acting on micelle formation—binding of bile acids or decreased mixing may decrease micelle formation and slow or decrease lipid hydrolysis and absorption[31-33]; (5) varying intestinal motility—soluble fiber may decrease and insoluble fiber may increase mixing of intestinal contents in such a way as to affect micelle formation and exposure of lipids to hydrolytic enzymes and absorptive surfaces[30]; (6) changing transport barriers—soluble fibers may decrease lipid absorption by affecting transport barriers such as the unstirred layer[31-33]; (7) altering lymphatic flow rates—affecting the rate of entry of lipids into the peripheral circulation[29,32]; and (8) influencing secretion of insulin or other hormones—which could affect hepatic lipid and lipoprotein synthesis and secretion rates.[7,32,35]

In addition to dietary fiber, many other factors affect the serum lipid response to meals: amount of fat in the meal—the postprandial serum triglyceride response to oral administration of a fat load is proportional to the amount of

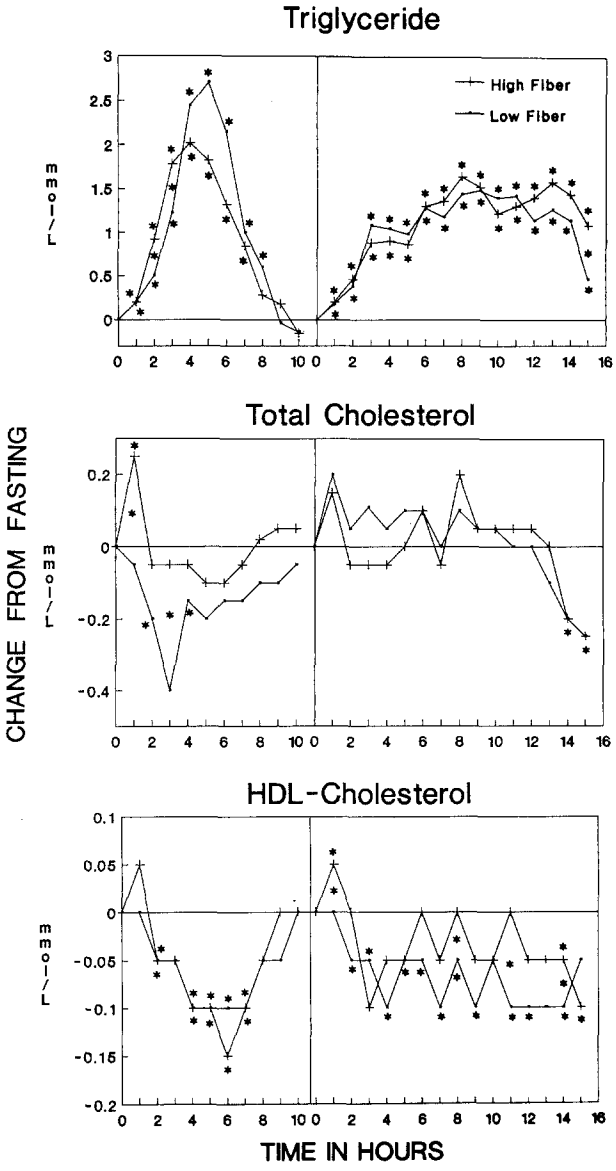


**Fig 2. Serum triglyceride, total cholesterol, and HDL cholesterol responses to SM (left) and MM (right). Incremental changes from fasting levels. Values that differ significantly from baseline (time 0) are indicated by an asterisk above or below the line; values at the same time that differ significantly from each other (diet effect) are indicated by an asterisk between lines.**

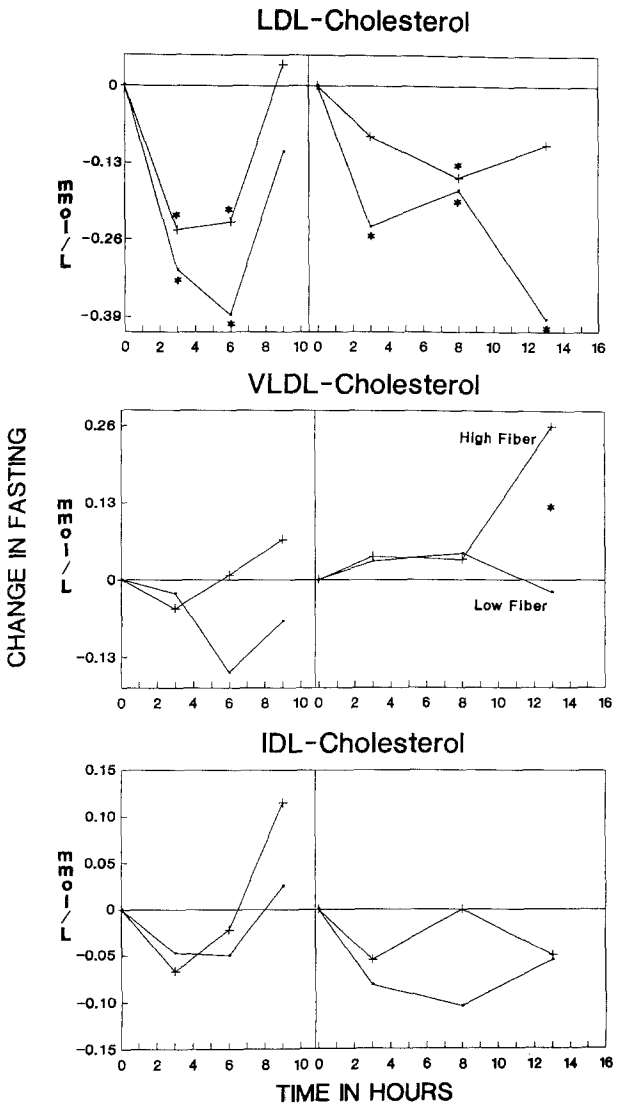


**Fig 3. Serum LDL, VLDL, and IDL cholesterol responses to SM (left) and MM (right). Incremental changes from fasting levels. Values that differ significantly from baseline (time 0) are indicated by an asterisk above or below the line; values at the same time that differ significantly from each other (diet effect) are indicated by an asterisk between lines.**

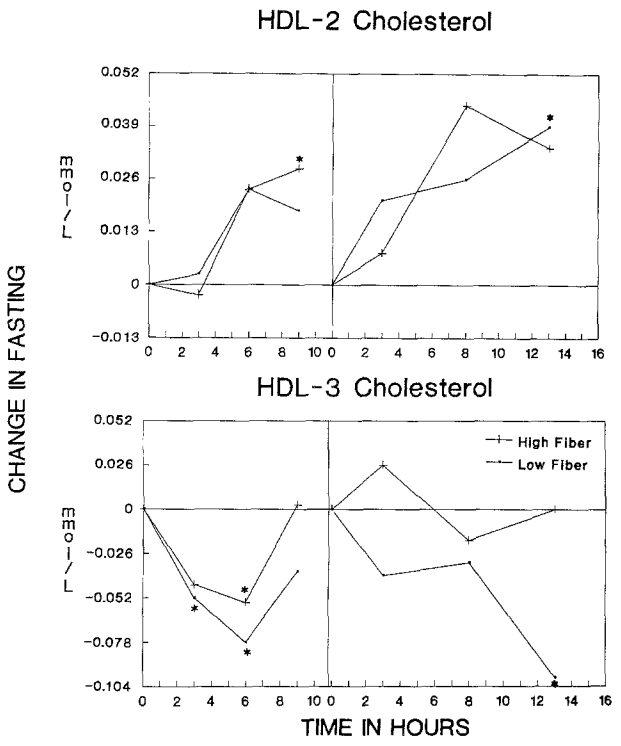


**Fig 4. Serum $HDL_2$ and $HDL_3$ cholesterol responses to SM (left) and MM (right). Incremental changes from fasting levels. *Values that differ significantly from baseline (time 0).**

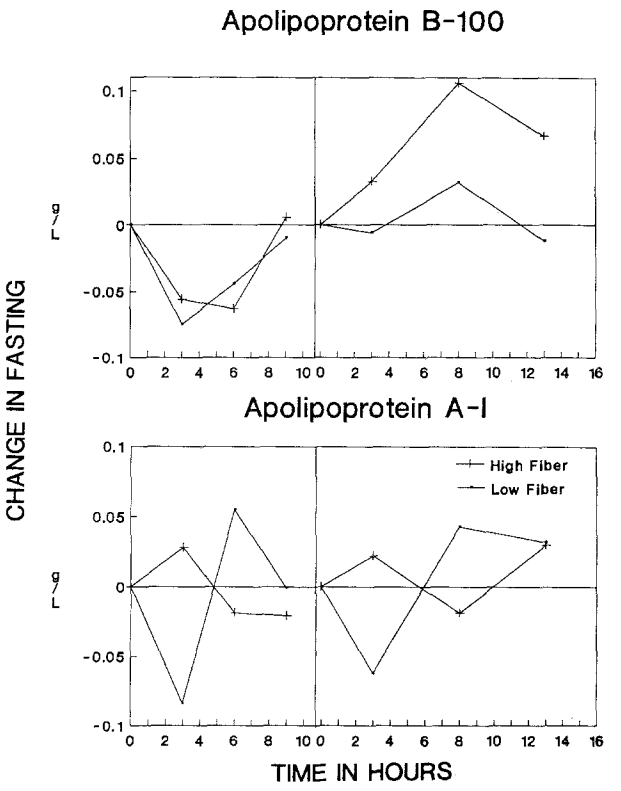


**Fig 5. Serum apo B-100 and A-I responses to SM (left) and MM (right). Incremental changes from fasting levels.**

fat in the meal[36]; fasting serum triglyceride concentration—the postprandial serum triglyceride level is also proportional to the fasting level[8,12,37]; influence of types of dietary fat on postprandial triglyceride responses[11,29,38]; fasting HDL cholesterol concentration—postprandial triglyceride responses are inversely related to HDL cholesterol values[5,13,39]; gender[5,39]; body mass index[12]; and drug treatment.[37] In the current study, most of these factors were controlled for by the crossover design, by matching total fat and type of fat for HF and LF diets, and by having subjects avoid drug treatment for 3 months before study.

These studies confirm the important effect of dietary fiber on postprandial blood glucose and insulin responses. However, a large increase in dietary fiber intake produced only subtle and largely insignificant effects on postprandial serum lipids, lipoproteins, and apolipoproteins. Several

suggestive patterns of response were noted: serum triglyceride values tended to increase more quickly and remain elevated longer after HF versus LF meals, suggesting that both insoluble and soluble components were exerting independent effects; and serum cholesterol values tended to increase after HF meals and decrease after LF meals. The effects of dietary fiber on postprandial serum lipoprotein changes require further study.

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