

Effects of a Dietary Portfolio of Cholesterol-Lowering Foods vs Lovastatin on Serum Lipids and C-Reactive Protein

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MOST DIETARY MANIPULATIONS result in modest cholesterol reductions of 4% to 13%,¹⁻¹⁰ and diet has been considered by some as a relatively ineffective therapy.¹¹ In contrast, 3-hydroxy-3-methylglutaryl coenzyme A reductase inhibitors (statins) repeatedly have been shown to reduce mean serum low-density lipoprotein cholesterol (LDL-C) concentrations by 28% to 35% in long-term trials,¹²⁻¹⁴ with corresponding reductions in cardiovascular death of 23% to 32% in both primary and secondary prevention trials.^{13,14} Recently, to boost effectiveness of diet for primary prevention of cardiovascular disease, the Adult Treatment Panel (ATP III)

For editorial comment see p 531.

Context To enhance the effectiveness of diet in lowering cholesterol, recommendations of the Adult Treatment Panel III of the National Cholesterol Education Program emphasize diets low in saturated fat together with plant sterols and viscous fibers, and the American Heart Association supports the use of soy protein and nuts.

Objective To determine whether a diet containing all of these recommended food components leads to cholesterol reduction comparable with that of 3-hydroxy-3-methylglutaryl coenzyme A reductase inhibitors (statins).

Design Randomized controlled trial conducted between October and December 2002.

Setting and Participants Forty-six healthy, hyperlipidemic adults (25 men and 21 postmenopausal women) with a mean (SE) age of 59 (1) years and body mass index of 27.6 (0.5), recruited from a Canadian hospital-affiliated nutrition research center and the community.

Interventions Participants were randomly assigned to undergo 1 of 3 interventions on an outpatient basis for 1 month: a diet very low in saturated fat, based on milled whole-wheat cereals and low-fat dairy foods (n=16; control); the same diet plus lovastatin, 20 mg/d (n=14); or a diet high in plant sterols (1.0 g/1000 kcal), soy protein (21.4 g/1000 kcal), viscous fibers (9.8 g/1000 kcal), and almonds (14 g/1000 kcal) (n=16; dietary portfolio).

Main Outcome Measures Lipid and C-reactive protein levels, obtained from fasting blood samples; blood pressure; and body weight; measured at weeks 0, 2, and 4 and compared among the 3 treatment groups.

Results The control, statin, and dietary portfolio groups had mean (SE) decreases in low-density lipoprotein cholesterol of 8.0% (2.1%) ($P=.002$), 30.9% (3.6%) ($P<.001$), and 28.6% (3.2%) ($P<.001$), respectively. Respective reductions in C-reactive protein were 10.0% (8.6%) ($P=.27$), 33.3% (8.3%) ($P=.002$), and 28.2% (10.8%) ($P=.02$). The significant reductions in the statin and dietary portfolio groups were all significantly different from changes in the control group. There were no significant differences in efficacy between the statin and dietary portfolio treatments.

Conclusion In this study, diversifying cholesterol-lowering components in the same dietary portfolio increased the effectiveness of diet as a treatment of hypercholesterolemia.

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of the National Cholesterol Education Program has recommended addition of plant sterols (2 g/d) and viscous fibers (10-25 g/d) to the diet.¹⁵ The American Heart Association has also drawn atten-

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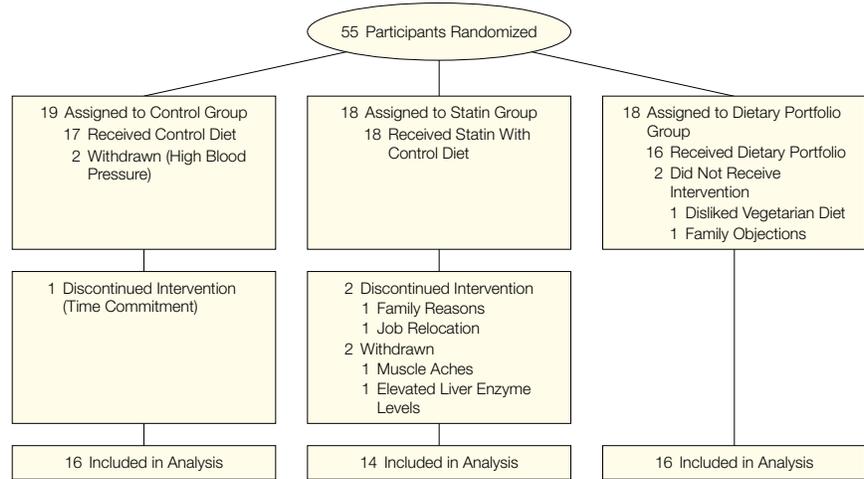
tion to the possible benefits of soy proteins and the potential value of nuts.¹⁶ In turn, the US Food and Drug Administration now permits health claims for coronary heart disease (CHD) risk reduction, based on cholesterol lowering, for foods delivering adequate amounts of plant sterols,¹⁷ viscous fibers (oat β -glucan and psyllium),^{18,19} and soy protein,²⁰ and a health claim for nuts is being considered. Despite the large potential for cholesterol reduction, this dietary combination has never been compared directly with a statin. To assess the effectiveness of this dietary portfolio approach, we therefore studied a group of hyperlipidemic adults who were randomized to 1 of 3 treatments: the combination dietary portfolio, a diet lacking the additional active dietary ingredients but with a similar very low-saturated-fat content (control), or the same low-saturated-fat diet with addition of a statin.

METHODS

Participants

Fifty-five participants were recruited from hyperlipidemic patients attending the Clinical Nutrition and Risk Factor Modification Center at St Michael's Hospital, Toronto, Ontario, and from newspaper advertisements. Postmenopausal women were recruited because of the increase in LDL-C and CHD risk in women in this age group and to avoid possible fluctuations in blood lipids related to the menstrual cycle. All participants were reluctant to take statins and wished to determine the relative effectiveness of diet. Four participants who were randomized did not start the study. Additionally, 3 withdrew during the first study week because of family ill health, job relocation, or time commitment required by the metabolic diet, and 2 were withdrawn because of either a transient elevation of liver enzymes or symptoms of muscle discomfort (FIGURE 1). Forty-six healthy, hyperlipidemic participants completed the study (25 men and 21 postmenopausal women); the mean (SE) age was 59 (1) years (range, 36-85 years) and mean (SE) body mass index (calculated as weight in kilo-

Figure 1. Flow of Patients Through the Trial



grams divided by the square of height in meters) was 27.6 (0.5) (range, 20.5-35.5) (TABLE 1). All participants had previously high LDL-C levels (>158 mg/dL [>4.1 mmol/L]).¹⁵ No participants had a history of cardiovascular disease, untreated hypertension (blood pressure $>140/90$ mm Hg), diabetes, or renal or liver disease, and none were taking medications known to influence serum lipids apart from 3 women who were taking stable doses of thyroxine, 1 of whom was also taking estrogen therapy. Twenty-one participants had started statins and had discontinued them at least 2 weeks prior to the study (9 control participants, 7 dietary portfolio participants, and 5 statin participants). Five participants were taking antihypertensive medications at a constant dose prior to and during the study. The majority ($n=26$) were taking vitamin preparations. Other, more commonly used non-prescription drugs and supplements taken throughout the study period included aspirin and anti-inflammatory drugs ($n=5$), calcium ($n=8$), glucosamine ($n=3$), grapeseed oil ($n=2$), saw palmetto ($n=2$), garlic ($n=2$), and magnesium ($n=2$).

Study Protocol

The study followed a randomized parallel design and was carried out between October and December 2002.

Participants followed their own low-saturated-fat therapeutic diets for 1 month prior to the start of the study. They were then stratified based on sex and pretreatment LDL-C level and were randomized to a very low-saturated-fat dairy and whole-grain cereal diet either with or without a statin or a diet containing viscous fibers, plant sterols, soy foods, and almonds. Each treatment lasted for 1 month. All foods were provided except for fresh fruits and vegetables. Body weight was measured weekly and blood samples were obtained after 12-hour overnight fasts at 2-week intervals. On each clinic visit, blood pressure was measured twice in the nondominant arm using a mercury sphygmomanometer by the same observer. Seven-day diet histories were obtained for the week prior to the 1-month treatment period. Completed menu checklists were returned at weekly intervals during the 4-week diet period and checked by the dietitians, who also recorded the participants' previous week's exercise and ensured that it was constant over the course of the study period.

At weekly intervals, participants recorded their overall feeling of satiety using a 9-point bipolar semantic scale in which -4 was excessively hungry, 0 was neutral, and $+4$ was discomfort due to excess food intake.

Table 1. Baseline Characteristics of Participants*

| | Control | | Statin | | Dietary Portfolio | |
|-----------------------|--------------|---------------|--------------|---------------|-------------------|---------------|
| | Men (n = 11) | Women (n = 5) | Men (n = 7) | Women (n = 7) | Men (n = 7) | Women (n = 9) |
| Race/ethnicity, No. | | | | | | |
| European | 8 | 5 | 7 | 6 | 6 | 9 |
| East Indian | 2 | 0 | 0 | 0 | 0 | 0 |
| Chinese | 1 | 0 | 0 | 0 | 0 | 0 |
| Black | 0 | 0 | 0 | 1 | 0 | 0 |
| Hispanic | 0 | 0 | 0 | 0 | 1 | 0 |
| Age, y | 60.4 (2.0) | 60.4 (2.1) | 54.4 (4.2) | 59.6 (2.6) | 51.6 (3.4) | 65.1 (3.7) |
| Body weight, kg | 82.9 (9.2) | 65.1 (7.9) | 84.9 (16.0) | 74.4 (11.0) | 84.2 (7.1) | 66.6 (9.1) |
| Body mass index† | 27.7 (0.8) | 26.2 (0.9) | 26.9 (1.7) | 29.2 (1.4) | 27.5 (0.6) | 27.7 (1.2) |
| Blood pressure, mm Hg | | | | | | |
| Systolic | 119.0 (8.0) | 123.0 (8.0) | 126.0 (18.0) | 122.0 (9.0) | 121.0 (12.0) | 125.0 (18.0) |
| Diastolic | 76.0 (7.0) | 75.0 (4.0) | 82.0 (8.0) | 80.0 (8.0) | 80.0 (2.0) | 74.0 (10.0) |
| Cholesterol, mmol/L‡ | | | | | | |
| Total | 6.27 (0.79) | 6.59 (1.14) | 6.48 (0.68) | 6.80 (0.75) | 7.10 (1.27) | 6.81 (0.69) |
| LDL-C | 4.22 (0.69) | 4.45 (1.08) | 4.31 (0.76) | 4.61 (0.72) | 4.61 (1.04) | 4.62 (0.86) |
| HDL-C | 1.12 (0.21) | 1.34 (0.34) | 1.20 (0.17) | 1.16 (0.18) | 1.13 (0.16) | 1.24 (0.45) |
| Triglycerides | 2.05 (0.81) | 1.76 (0.55) | 2.15 (0.98) | 2.28 (0.95) | 2.99 (1.34) | 2.06 (1.02) |

*Data are expressed as mean (SD) unless otherwise noted. No significant baseline differences were observed when data for men and women were analyzed either separately or combined.

†Body mass index was calculated as weight in kilograms divided by the square of height in meters.

‡To convert total cholesterol, low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) to mg/dL, divide by 0.0259; to convert triglycerides to mg/dL, divide by 0.0113.

Table 2. Nutritional Profiles of Self-selected Prestudy Diets Recorded by Participants Prior to Randomization*

| | Control (n = 16) | Statin (n = 14) | Dietary Portfolio (n = 16) |
|--|------------------|-----------------|----------------------------|
| Energy, kcal/d | 1903 | 1766 | 1829 |
| Total protein | 84 (18.0) | 79 (18.0) | 80 (17.8) |
| Vegetable protein | 38 (7.8) | 38 (8.5) | 35 (8.1) |
| Available carbohydrates | 256 (53.9) | 223 (50.3) | 223 (49.4) |
| Total dietary fiber (g/1000 kcal) | 30 (15.9) | 28 (16.6) | 28 (16.7) |
| Total fat | 56 (26.1) | 59 (30.3) | 62 (30.3) |
| Saturated fatty acids | 15 (7.0) | 15 (7.6) | 17 (8.1) |
| Monounsaturated fatty acids | 24 (10.9) | 27 (13.6) | 27 (13.1) |
| Polyunsaturated fatty acids | 12 (5.7) | 13 (6.4) | 13 (6.6) |
| Dietary cholesterol, mg/d (mg/1000 kcal) | 190 (96.1) | 142 (82.8) | 161 (86.9) |
| Alcohol | 6 (2.0) | 3 (1.3) | 8 (2.4) |

*Data are expressed as mean grams per day (percentage of calories) unless otherwise noted.

Participants were randomized by the statistician using a random number generator and SAS version 6.12 software (SAS Institute Inc, Cary, NC) in a separate location from the clinic. The statistician held the code for the placebo and statin tablets provided with the control and statin diets, respectively. This aspect of the study was therefore double-blind. The dietitians were not blinded to the diet because they were responsible for patients' diets and for checking diet records. The laboratory staff re-

sponsible for analyses were blinded to treatment and received samples labeled with name codes and dates.

The study was approved by the ethics committees of the University of Toronto and St Michael's Hospital. Written informed consent was obtained from all participants.

Diets

The diets eaten before the 4-week study were the participants' routine therapeutic low-fat diets, which were similar to

current National Cholesterol Education Program guidelines (<7% energy from saturated fat and <200 mg/d of dietary cholesterol)¹⁵ and previously referred to as a Step II diet²¹ (TABLE 2).

During the 4-week study period, weight-maintaining diets were provided based on estimated caloric requirements using foods available in supermarkets and health food stores. All diets were vegetarian. The aim of the dietary portfolio was to provide 1.0 g of plant sterols per 1000 kcal of diet in a plant sterol ester-enriched margarine; 9.8 g of viscous fibers per 1000 kcal of diet from oats, barley, and psyllium; 21.4 g of soy protein per 1000 kcal as soy milk and soy meat analogs; and 14 g of whole almonds per 1000 kcal of diet. Emphasis was placed on eggplant and okra as additional sources of viscous fiber (0.2 g/1000 kcal and 0.4 g/1000 kcal, respectively). Thus, 200 g of eggplant and 100 g of okra were prescribed to be eaten as part of a 2000-kcal diet on alternate days. Eggs (1/wk) and butter (9 g/d) were also provided in the dietary portfolio to balance the saturated fat and dietary cholesterol in the control diet. This di-

etary portfolio has been described in detail previously.²²

The control diet used skim milk, fat-free cheese and yogurt, and egg substitute and liquid egg white to achieve low intake of saturated fat. High fiber intake was obtained by use of whole-grain breakfast cereals (fiber, 2.5 g/1000 kcal of diet) and bread (fiber, 2.0 g/1000 kcal of diet) made from 100% whole-wheat flour and wheat bran added to a high-dairy-protein muffin (fiber, 7.3 g/1000 kcal of diet). This diet therefore lacked sources of viscous fibers, plant sterols, and almonds. Skim-milk products replaced the soy and vegetable protein foods consumed as part of the dietary portfolio, and high monounsaturated sunflower oil (9 g/1000 kcal) and safflower oil (5 g/1000 kcal) were incorporated into the control diet (eg, muffins) to balance the fatty acid profile of the dietary portfolio. The macronutrient profile of the diets recorded as consumed in week 4 is shown in TABLE 3. Typical 1-day menus for the control diet and dietary portfolio are shown in TABLE 4.

Participants were provided with self-taring electronic scales (Salter Housewares, Kent, England) and asked to weigh all food items consumed prior to and during the study period. During the study period, all foods to be consumed by participants were provided initially by courier and then at weekly clinic visits, with the exception of fruit and low-calorie, non-starch-containing vegetables. Okra was the exception and was provided in the dietary portfolio. Participants were instructed to obtain specific fruits and vegetables from their local stores and were reimbursed on presentation of receipts. Participants were provided with a 7-day rotating menu plan on which they checked off each item as eaten and confirmed the weight of the foods. The same menu plan was used for all participants but was modified to suit individual preferences, provided that the goals for viscous fiber, soy protein, plant sterol, and almond consumption were met. Non-caloric beverages were not restricted.

Food use was made as straightforward as possible so that commercial

Table 3. Nutritional Profiles of Diets Provided and Recorded as Eaten at Week 4

| | Control (n = 16) | Statin (n = 14) | Dietary Portfolio (n = 16) |
|--|---------------------|--------------------|-------------------------------|
| Energy, kcal/d | 2421 | 2519 | 2383 |
| Total protein | 134 (22.2) | 131 (21.0) | 128 (21.7) |
| Vegetable protein | 26 (4.4) | 28 (4.4) | 127 (21.3) |
| Available carbohydrate | 319 (52.8) | 340 (53.8) | 286 (48.0) |
| Total dietary fiber (g/1000 kcal) | 57 (23.4) | 57 (22.9) | 78 (33.1) |
| Total fat | 67 (24.6) | 70 (24.9) | 80 (30.0) |
| Saturated fatty acids | 12 (4.5) | 13 (4.6) | 17 (6.3) |
| Monounsaturated fatty acids | 28 (10.3) | 28 (10.0) | 34 (12.7) |
| Polyunsaturated fatty acids | 23 (8.4) | 26 (9.2) | 27 (10.1) |
| Dietary cholesterol, mg/d (mg/1000 kcal) | 28 (11.8) | 31 (12.4) | 54 (22.6) |
| Alcohol | 0.3 (0.1) | 0 | 0.4 (0.1) |

*Data are expressed as mean grams per day (percentage of calories) unless otherwise noted.

dishes were ready for microwave or oven cooking, packs of instant soups were provided to be reconstituted with boiling water, and, when possible, meal portions were prescribed in multiples of whole units (eg, 1 cup of instant soup, 1 frozen dinner, 2 soy hot dogs, or 4 soy deli slices). Diet foods were packed in a designated central location and shipped by courier in separate boxes for dry, refrigerated, and frozen goods. Egg substitutes and soy and dairy foods were shipped in their commercial packages to be refrigerated on receipt by the participants.

Compliance was assessed from the completed weekly checklists and from the return of uneaten food items.

Statin Therapy

Twenty-milligram lovastatin tablets (Genpharm Inc, Etobicoke, Ontario) were crushed and delivered in Vegicap capsules (Capsugel, Morris Plains, NJ). Identical placebo capsules containing lactose and blue food coloring were also prepared (Pharmacy.ca, Toronto, Ontario). Both lovastatin and placebo capsules were dispensed by the hospital pharmacy in identical containers marked with the participant's name according to the randomization determined by the statistician. Participants were asked to take 1 capsule (20 mg of lovastatin or placebo) per day in the evening for the 28 days of the study and to return the containers for capsule counts at the end of the month.

Analyses

All samples from a given individual were labeled by code and analyzed in the same batch. Serum was analyzed according to the Lipid Research Clinics protocol²³ for total cholesterol, triglycerides, and high-density lipoprotein cholesterol (HDL-C) after dextran sulphate-magnesium chloride precipitation.²⁴ Low-density lipoprotein cholesterol was calculated.²⁵ Serum apolipoprotein A1 and B were measured by nephelometry (intra-assay coefficient of variation, 2.2% and 1.9%, respectively).²⁶ Serum samples, stored at -70°C , were analyzed for C-reactive protein by end-point nephelometry (coefficient of variation, 3.5%) (Behring BN-100, N high-sensitivity C-reactive protein reagent, Dade-Behring, Mississauga, Ontario).

Diets were analyzed using a program based on US Department of Agriculture data and developed in our laboratory to allow addition of data on foods relevant to ongoing studies after analysis in the laboratory for protein, total fat, and dietary fiber using American Organization of Analytical Chemists methods and fatty acids by gas chromatography.²² More than half of the foods used in the diets had been analyzed in the laboratory.

Statistical Analysis

Results were calculated as mean (SE). The mean differences in blood lipid values between week 2 and week 4 were not greater than 9.3 mg/dL (≤ 0.24 mmol/L)

(range, -7.7 to 9.3 mg/dL [-0.20 to 0.24 mmol/L]) and the week 4 level was therefore used throughout for all analyses as the end-point value. The significance of the differences between treatments was assessed by the Student-Neuman-Keuls multiple range test (SAS PROC GLM).²⁷ The analysis of covariance model used the change from week 0 to week 4 as the response variable and treatment and sex by treatment interaction as main effects, with baseline as covariate. Response variables were normally distributed, with the exception of C-reactive protein and the ratio of apolipoprotein B to apolipoprotein A1 in the dietary portfolio group, triglycerides in the statin

group, and body mass index in the control group. An intention-to-treat analysis was also carried out by including the 5 participants for whom baseline samples were available but who dropped out or were withdrawn prior to the week 2 blood sample. Three assumptions were assessed: that these participants would show no change, 50% of the mean change, or 100% of the mean change observed for that treatment. A 2-tailed paired *t* test was used to assess the significance of the percentage change from baseline. With 15 participants per treatment group, and assuming a 10% SD of effect with $\alpha = .05$ and $\beta = .80$, we had sufficient power to detect an 8% change in

LDL-C across treatments as significant. The CHD risk equations were used as described by Anderson et al.²⁸ Ten-year CHD risk was calculated, including in the model age, sex, systolic blood pressure, total cholesterol and HDL-C, smoking, diabetes, and definite electrocardiographic evidence of left ventricular hypertrophy.²⁸ Only 1 participant smoked and did so consistently throughout the study, and none had diabetes or evidence of left ventricular hypertrophy.

RESULTS

For the majority of participants, compliance was good as assessed from completed metabolic diet checklists and return of uneaten food items. When expressed as the percentage of prescribed calories recorded as eaten during week 4, compliance was 93% (3%) for control, 95% (3%) for statin, and 94% (3%) for the dietary portfolio. Similarly, 98% of capsules provided were taken. All participants believed they were eating as much food as they were capable of without experiencing discomfort (satiety rating, <3.0) at week 4 (control, 2.3 [0.4]; statin, 2.4 [0.3]; and dietary portfolio, 2.8 [0.2]). Participants lost a similar amount of weight in all 3 treatments (control, 0.3 [0.2] kg; $P = .22$; statin, 0.2 [0.1] kg; $P = .15$; dietary portfolio, 0.4 [0.2] kg; $P = .06$).

Blood Lipids and C-Reactive Protein

No differences were observed among the 3 treatment groups in baseline blood measurements. In the control group, percentage changes from baseline to week 4 were as follows: LDL-C, -8.0% (2.1%) ($P = .002$); LDL-C-HDL-C ratio, $+3.0\%$ (2.8%) ($P = .31$); and C-reactive protein, -10.0% (8.6%) ($P = .27$). In the statin and dietary portfolio groups, the respective data were as follows: LDL-C, -30.9% (3.6%) ($P < .001$) and -28.6% (3.2%) ($P < .001$); LDL-C-HDL-C ratio, -28.4% (4.2%) ($P < .001$) and -23.5% (3.2%) ($P < .001$); and C-reactive protein, -33.3% (8.3%) ($P = .002$) and -28.2% (10.8%) ($P = .02$), with no differences between week 2 and week 4 values (FIGURE 2). The reduc-

Table 4. Representative Diets Followed in Control/Statin and Dietary Portfolio Treatment Groups

| Control/Statin | Dietary Portfolio |
|---|--|
| Breakfast | |
| Raisin bran cereal | Hot oat bran cereal |
| Skim milk | Soy beverage |
| Strawberries | Strawberries |
| Fat-free vanilla yogurt | Sugar and psyllium |
| Double-fruit jam | Oat bran bread |
| | Enriched margarine† |
| | Double-fruit jam |
| Snack* | |
| Bran muffin | Almonds |
| Light margarine | Soy beverage |
| Fresh fruit | Fresh fruit |
| Lunch | |
| Italian noodle soup with vegetables | Spicy black bean soup |
| Sandwich (grilled fat-free cheese, whole-wheat bread, light margarine) | Sandwich (soy deli slices, oat bran bread, enriched margarine†, lettuce, tomato, cucumber) |
| Salad (mixed greens and lettuce, tomato, cucumber, oil and vinegar dressing) | |
| Snack* | |
| Bran muffin | Almonds |
| Light margarine | Psyllium |
| Fresh fruit | Fresh fruit |
| Dinner | |
| Egg omelette (egg white, egg substitute, fat-free cheese, green peppers, onions, safflower oil) | Tofu bake with ratatouille (firm tofu, eggplant, onions, sweet peppers) |
| Pasta primavera | Pearled barley |
| Vegetables (eg, broccoli, cauliflower) | Vegetables (eg, broccoli, cauliflower) |
| Snack* | |
| Fresh fruit | Fresh fruit |
| Skim milk | Psyllium |
| | Soy beverage |

*Snacks could be eaten with meals if desired.
†Margarine was enriched with plant sterols.

tions in blood lipids in both the dietary portfolio and statin groups were significantly greater ($P < .005$) than the respective changes in the control group for total cholesterol, LDL-C, apolipoprotein B, and the ratios of total cholesterol to HDL-C, LDL-C to HDL-C, and apolipoprotein B to apolipoprotein A1, with no significant differences between the dietary portfolio and statin groups (TABLE 5). No differences in response were observed between sexes. In both the dietary portfolio and statin groups, C-reactive protein was reduced significantly more than in the control group ($P < .005$), but again, no difference was observed between the dietary portfolio and statin groups.

Blood Pressure

No significant treatment differences were observed in blood pressure (Table 5).

Calculated CHD Risk

In the dietary portfolio and statin groups, the calculated CHD risk was reduced similarly (24.9% [5.5%]; $P < .001$ and 25.8% [4.4%]; $P < .001$, respec-

tively). These reductions were also significantly different from the reduction (3.0% [5.2%]; $P = .57$) in the control group ($P < .005$) (Table 5). The risk reductions were largely due to the reductions in blood lipids. When blood pressure was held constant at 120 mm Hg in the risk equations, the blood lipid changes accounted for 70% and 82% of the risk reduction in the dietary portfolio and statin groups, respectively.

Intention-to-Treat Analysis

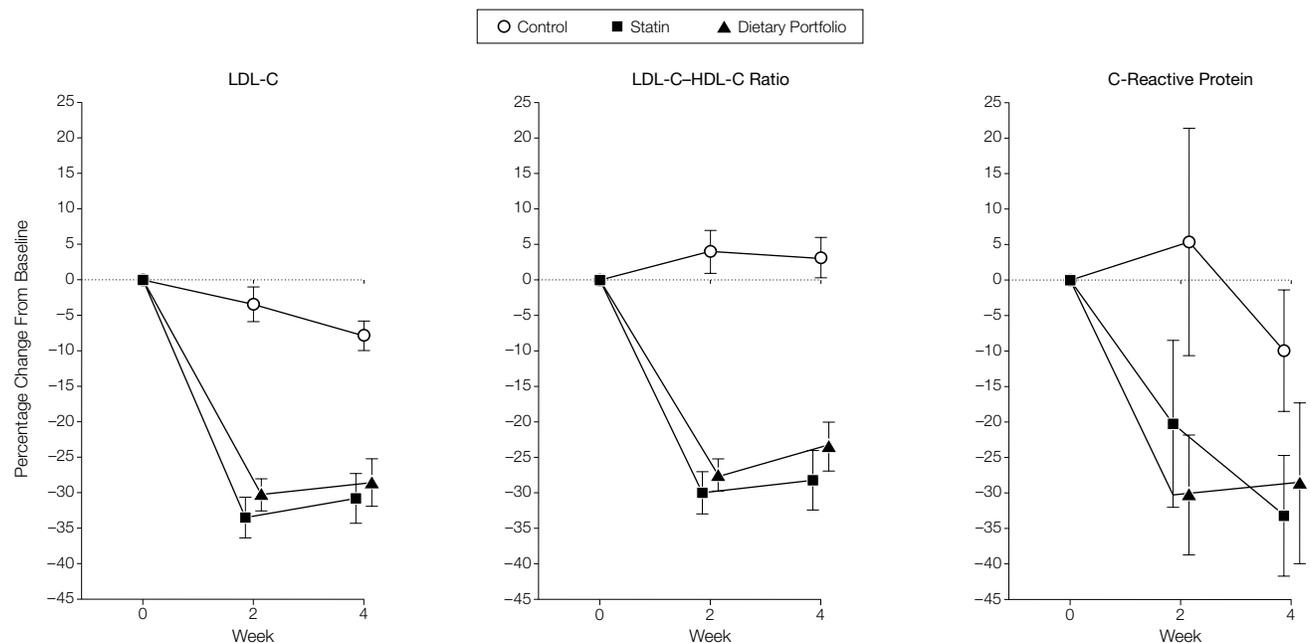
This study was also analyzed on the basis of intention to treat, including the 5 individuals with baseline values who dropped out or were withdrawn during the first and second weeks (before the week 2 and week 4 samples were taken for determination of blood lipids). (The 4 randomized participants for whom no baseline samples were obtained could not be included in this analysis.) Irrespective of whether it was assumed that the additional participants would have shown no response or 50% or 100% of the observed mean response, the same differences in blood

lipid levels were preserved as significantly different among the treatment groups, as observed when these participants were not included in the analysis. Furthermore, the mean reductions across treatments in LDL-C were still significant at -7.5% (2.0%) ($P = .002$) for control; -28.6% (3.2%) ($P < .001$) for dietary portfolio; and -24.0% (4.2%) ($P < .001$) for statin when it was assumed that the 5 additional participants showed no change in response to the treatments. Only for C-reactive protein and CHD risk was the significance level reduced (from $P < .005$ to $P < .05$) for the differences between control and both dietary portfolio and statin treatments.

COMMENT

These data confirm that use of a particular formulation of more recent general recommendations (ATP III, American Heart Association)^{15,16} can greatly enhance the cholesterol-lowering effect of diet. The reductions in blood lipids were not significantly smaller than those achieved with the initial dose of lovas-

Figure 2. Change From Baseline in LDL-C, LDL-C–HDL-C Ratio, and C-Reactive Protein



LDL-C indicates low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol. Values are expressed as mean (SE) because, with the number of participants involved, approximately twice the SE represents a significant difference.

tatin, the first-generation statin marketed for cholesterol reduction.

The dietary components used in our portfolio are all well recognized for their cholesterol-lowering properties.^{1,16-20} Meta-analyses have indicated reductions in serum LDL-C of 6% to 7% for 9 to 10 g/d of psyllium,³ with smaller reductions for other viscous fibers²⁹; 13% for 1 to 2 g/d of plant sterols⁴; 12.5% for 45 g/d of soy protein²; and 1% for 10 g/d of almonds.¹ Lower intakes of saturated fat may lead to smaller reductions in cholesterol for soy protein,⁵ and the same may be true for other interventions, including plant sterols.³⁰ A reduction in LDL-C of 4% to 7% may therefore be more appropriate for each component when taken with very low-saturated-fat diets and account for the decrease in LDL-C of 28% observed in this dietary portfolio. In this study, the fatty acid and cholesterol intakes were both low and similar in the dietary portfolio and control groups. The benefits on blood lipids of higher monounsaturated fat intake associated with nut consumption, though not expected in the

present study because of the balanced fatty acid profiles of the diets,^{31,32} would be expected under conditions of mono-unsaturated fatty acid substitution.³¹⁻³⁴

The lower saturated fatty acid intakes made possible by the nature of the foods selected for the dietary portfolio may be a further advantage. Despite the relatively low saturated fatty acid and cholesterol content of the prestudy diets, application of the Hegsted equation³⁵ suggested that the differences in fatty acid and cholesterol intakes between the prestudy and study diets could account for 88%, 25%, and 27%, respectively, of the reductions observed in serum cholesterol in the control, statin, and dietary portfolio groups.

The different modes of action of the components on the dietary portfolio may have contributed to the additive effect. Viscous fibers increase bile acid losses,²⁹ plant sterols reduce cholesterol absorption,⁷ and soy proteins reduce hepatic cholesterol synthesis and increase LDL receptor messenger RNA and so potentially increase uptake of cholesterol.^{8,9} Almonds contain a mono-

unsaturated fatty acid- and plant sterol-rich oil that has been shown to lower LDL-C³⁴ together with vegetable proteins, fiber, and other phytochemicals, which are likely to operate through a range of mechanisms.¹⁰

Another feature of interest relating to the dietary portfolio was its ability to reduce C-reactive protein concentrations. This function, also observed with statins, has been related to their direct anti-inflammatory effect³⁶ and has been considered possibly responsible for some of the reduction in CHD observed with statin use, best demonstrated in women with normal LDL-C levels.³⁷ C-reactive protein reductions have not previously been reported with conventional cholesterol-lowering diets. It is therefore possible that lower C-reactive protein concentrations are a general consequence of effective cholesterol reduction, but in the present study, in common with other studies, C-reactive protein change was not significantly related to the change in LDL-C ($r=0.20$; $n=46$; $P=.17$).^{37,38} Also, in the present study, caution must be

Table 5. Effect of Control, Statin, and Dietary Portfolio Treatments on Blood Lipids, C-Reactive Protein, and Blood Pressure

| | Control (n = 16) | | | Statin (n = 14) | | | Dietary Portfolio (n = 16) | | |
|--|------------------|--------|-----------------|-----------------|--------|-----------------|----------------------------|--------|-----------------|
| | Week 0 | Week 4 | Difference (SE) | Week 0 | Week 4 | Difference (SE) | Week 0 | Week 4 | Difference (SE) |
| Body weight, kg | 77.4 | 77.1 | -0.3 (0.2) | 79.6 | 79.4 | -0.2 (0.1) | 74.3 | 74.0 | -0.4 (0.2) |
| Cholesterol, mmol/L† | | | | | | | | | |
| Total | 6.37 | 5.97 | -0.40 (0.11) | 6.64 | 5.09 | -1.55 (0.23)* | 6.94 | 5.41 | -1.52 (0.22)* |
| LDL-C | 4.29 | 3.93 | -0.37 (0.09) | 4.46 | 3.03 | -1.43 (0.18)* | 4.62 | 3.26 | -1.36 (0.18)* |
| HDL-C | 1.19 | 1.07 | -0.12 (0.03) | 1.18 | 1.14 | -0.04 (0.04) | 1.19 | 1.11 | -0.08 (0.03) |
| Triglycerides | 1.96 | 2.15 | 0.19 (0.15) | 2.21 | 2.03 | -0.19 (0.18) | 2.47 | 2.28 | -0.19 (0.18) |
| Apolipoproteins, g/L‡ | | | | | | | | | |
| A1 | 1.54 | 1.44 | -0.10 (0.03) | 1.56 | 1.48 | -0.08 (0.03) | 1.57 | 1.45 | -0.12 (0.03) |
| B | 1.38 | 1.30 | -0.08 (0.03) | 1.43 | 1.05 | -0.38 (0.05)* | 1.49 | 1.15 | -0.34 (0.06)* |
| Ratios | | | | | | | | | |
| Total cholesterol to HDL-C | 5.53 | 5.78 | 0.25 (0.15) | 5.75 | 4.51 | -1.24 (0.22)* | 6.14 | 5.09 | -1.05 (0.24)* |
| LDL-C to HDL-C | 3.73 | 3.78 | 0.05 (0.09) | 3.85 | 2.68 | -1.17 (0.17)* | 4.10 | 3.07 | -1.03 (0.19)* |
| Apolipoprotein B to A1 | 0.91 | 0.92 | 0.01 (0.02) | 0.92 | 0.71 | -0.21 (0.03)* | 0.97 | 0.81 | -0.17 (0.04)* |
| C-reactive protein, mg/L | 1.36 | 1.08 | -0.28 (0.16) | 3.40 | 2.05 | -1.50 (0.42)* | 2.39 | 1.13 | -1.25 (0.62)* |
| Blood pressure, mm Hg | | | | | | | | | |
| Systolic | 120 | 113 | -7.6 (2.7) | 124 | 122 | -2.4 (2.8) | 123 | 117 | -5.9 (2.9) |
| Diastolic | 75 | 71 | -4.1 (1.9) | 81 | 76 | -5.0 (1.8) | 76 | 71 | -5.4 (1.1) |
| 10-Year coronary heart disease risk,%§ | 12.6 | 12.3 | -0.3 (0.7) | 11.3 | 7.9 | -3.3 (0.9)* | 11.0 | 8.1 | -2.9 (0.5)* |

*Comparisons of statin and dietary portfolio differences with control differences are statistically significant ($P<.005$) as assessed by Student-Neuman-Keuls procedure, but statin and dietary portfolio differences are not significantly different from each other.

†To convert total cholesterol, low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) to mg/dL, divide by 0.0259; to convert triglycerides to mg/dL, divide by 0.0113.

‡To convert apolipoprotein A1 and B to mg/dL, multiply by 100.

§Coronary heart disease risk was estimated using the Framingham cardiovascular risk equation.²⁸

taken specifically in interpreting the C-reactive protein findings because of the substantial but nonsignificant differences between treatment baseline values and, more generally, because no intervention studies exist specifically to test the effect of C-reactive protein reduction on CHD risk.

The data currently available from clinical trials demonstrating reductions in cardiovascular disease risk support an important role for dietary change, which includes increased intakes of fiber, vegetable oils, and proteins from soy and other legumes, nuts, fruits, and vegetables.³⁹⁻⁴¹ Furthermore, in large cohort studies, high fiber intakes have consistently been associated with reduction in CHD risk³⁹ and CHD risk factors⁴²; more recently, so has increased nut consumption.⁴³⁻⁴⁵ In this respect, the recent dietary recommendations (ATP III, American Heart Association, US Food and Drug Administration) may further increase the effectiveness of diet in reducing the risk of cardiovascular disease. In the future, other plant food components with specific mechanisms of action may be added to this portfolio.⁴⁶⁻⁴⁸

Despite the effectiveness and safety of statins, there are still some individuals for whom physicians are reluctant to prescribe statins because of elevations of muscle or liver enzymes.⁴⁹ There are also those who would prefer to control their blood lipid levels by nonpharmacological means, particularly in view of recent, less satisfactory outcomes with statin use in older people.^{50,51} For such individuals, the dietary portfolio approach might provide a therapeutic option.

From our participants' perspective, of the 36 (78%) who completed the study and provided formal comments, 40% found the dietary portfolio acceptable with little further modification; however, an equal number thought that a greater variety of foods was required, 27% thought that the food volume was too great, and 13% required meat as part of their meals. The 5 most popular foods were almonds, ground soy (simulated ground beef), oat bran

cereal, oat bran bread, and plant sterol margarine.

In conclusion, current dietary recommendations¹⁵ focusing on diets low in saturated fat have been expanded to include foods high in viscous fibers (eg, oats and barley) and plant sterols. These guidelines, together with additional suggestions to include vegetable protein foods (soy)¹⁶ and nuts (almonds), appear to reduce LDL-C levels similarly to the initial therapeutic dose of a first-generation statin. However, before the true effectiveness of this dietary change can be assessed, studies must be undertaken in patients who assemble the diets for themselves on a routine basis. Using the experience gained, further development of this approach may provide a potentially valuable dietary option for cardiovascular disease risk reduction in primary prevention.

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