Serum Lipid Effects of a High–Monounsaturated Fat Diet Based on Macadamia Nuts

J. David Curb, MD; Gilbert Wergowske, MD; Joan C. Dobbs, PhD; Robert D. Abbott, PhD; Boji Huang, MD, PhD

Background: Recent studies have identified potential beneficial effects of eating nuts, most of which have substantial amounts of monounsaturated fats. Macadamia nuts are 75% fat by weight, 80% of which is monounsaturated.

Objective: To examine variations in serum lipid levels in response to a high–monounsaturated fat diet based on macadamia nuts.

Methods: A randomized crossover trial of three 30-day diets was conducted in 30 volunteers aged 18 to 53 years from a free-living population. Each was fed a "typical American" diet high in saturated fat (37% energy from fat); an American Heart Association Step 1 diet (30% energy from fat); and a macadamia nut–based monounsaturated fat diet (37% energy from fat) in random order. Serum total cholesterol, high-density lipoprotein cholesterol, and triglyceride levels were measured.

Results: Mean total cholesterol level after the typical American diet was 5.20 mmol/L (201 mg/dL). After the Step 1 diet and the macadamia nut diet, total cholesterol level was 4.99 mmol/L (193 mg/dL) and 4.95 mmol/L (191 mg/dL), respectively. Low-density lipoprotein cholesterol level was 3.37 mmol/L (130 mg/dL) (typical diet), 3.21 mmol/L (124 mg/dL) (Step 1 diet), and 3.22 mmol/L (125 mg/dL) (macadamia nut diet). High-density lipoprotein cholesterol level was 1.43 mmol/L (55 mg/dL) (typical), 1.34 mmol/L (52 mg/dL) (Step 1), and 1.37 mmol/L (53 mg/dL) (macadamia nut). Lipid values after the Step 1 and macadamia nut diets were significantly different from those after the typical diet ($P<.05$).

Conclusions: The macadamia nut–based diet high in monounsaturated fat and the moderately low-fat diet both had potentially beneficial effects on cholesterol and low-density lipoprotein cholesterol levels when compared with a typical American diet.

Arch Intern Med. 2000;160:1154-1158

From the Division of Clinical Epidemiology, Department of Medicine (Drs Curb, Wergowske, Abbott, and Huang), and Division of Geriatric Medicine (Drs Curb and Wergowske), John A. Burns School of Medicine, University of Hawaii at Manoa, Honolulu; Exploring New Concepts, Honolulu (Dr Dobbs); and Division of Biostatistics and Epidemiology, University of Virginia School of Medicine, Charlottesville (Dr Abbott).

TRADITIONALLY, the inhabitants of regions such as Greece and southern Italy, where rates of coronary heart disease are low, have consumed relatively high-fat diets containing substantial amounts of olive oil, a substance with high concentrations of the monounsaturated fatty acid oleic acid.[1,2] These "Mediterranean diets" frequently contain more energy from fat than the typical American diet but are higher in monounsaturated fats. Less than 10% of energy in such diets comes from saturated fats.

A number of studies have demonstrated apparently beneficial effects of diets based on high monounsaturated fatty acid content primarily derived from olive oil.[3-5] Few have looked at the effects of whole complex foods high in monounsaturated fatty acids. Nuts are a complex food that contains considerable amounts of monounsaturated fat, and they have also long been part of the traditional diet in many Mediterranean countries. Recent studies have shown potential beneficial effects of tree nuts in the diet.[6-8] The macadamia nut, a tree nut that originated in Australia, has become a primary export crop from Hawaii in recent years. The macadamia nut is approximately 75% fat by weight, with 88% of its energy from fat. Monounsaturated fatty acids are the predominant fat. Oleic acid is the predominant monounsaturate, but a considerable portion is palmitoleic acid, a component not present in substantial amounts in olive oil. Macadamia nuts are a complex food with large amounts of carbohydrates and fiber as well as a number of vitamins and minerals.[9]

Because of the high fat content of the macadamia nut, it has popularly been thought to be bad for health. However, since some nuts, including the macadamia nut, could be substituted for food

SUBJECTS AND METHODS

The study was a controlled, crossover design feeding study of three 30-day dietary options. Subjects eligible to participate were men and women with a fasting cholesterol level above 3.9 mmol/L (150 mg/dL) and a triglyceride level below 4.5 mmol/L (400 mg/dL); taking no current pharmacological treatment for hyperlipidemia; between 18 and 55 years of age; weighing between 80% and 130% of ideal weight; with no history of diabetes mellitus or pancreatic insufficiency, or an unstable medical condition of any kind; having no history of food allergies, especially to tree-grown nuts; and not pregnant, breastfeeding, or taking certain birth control pills. Approximately 450 individuals were screened by telephone or in person. Forty-two individuals participated in the run-in. Of these, 16 men and 18 women began the experimental diet period, of whom 15 men and 15 women completed the study.

To minimize study group imbalance resulting from dropouts or exclusions during the run-in or early in the first dietary period, dietary assignments were randomly made in 2 phases. Both randomizations were stratified by sex. For the first dietary period, subjects were randomized to 1 of the 3 study diets. Subsequently, during the later part of the first diet period, subjects were randomized to the remaining diets they would follow during the next 2 periods. Thus, randomization remained balanced throughout the study, and all subjects had equal probability of being in each of the 3 diet sequences, despite several early dropouts. Study personnel involved in performing measurements and analyses were blinded to the diet sequences. To avoid dropouts, telephone screening, individual and group meetings, and a 6-day run-in period were used to screen participants for compliance and willingness to accept the restrictions imposed by the dietary regimens.

Every day, the subjects ate breakfast and dinner at the study site and were given a bag lunch prepared by study personnel. The one exception was Saturday night, when participants were allowed a "free" meal with specific guidelines on the amount of fat consumed. Additional energy was made available in the form of "unit" foods consumed ad libitum in addition to the subjects' diet regimen, as long as they maintained their weight. These were in the form of 420-kJ (100-kcal) muffins or 420- and 840-kJ (100- and 200-kcal) packages of chili, developed to match the nutrient profile for each diet. Body weight was measured 2 times per week, and energy intake levels were altered when necessary to maintain each subject's weight. A daily diary was used to monitor illness, medication use, and deviations from usual physical activity patterns or the study diet.

The diets used were a "typical American" diet, a macadamia nut diet high in monounsaturated fat, and an AHA Step 1 "prudent" diet. A 10-day cycle menu was designed with the Genesis Ingredient Database (ESHA Research, Portland, Ore) with the use of whole foods to match the nutrient profile. All 3 diets were designed to contain 17% of total energy from protein, with the percentage of energy from carbohydrate and fat depending on the diet (46% for the AHA Step 1 and macadamia nut diets; 53% for the typical American diet). Polyunsaturated fatty acids (7%) and cholesterol content (300 mg) of all diets were kept constant. Up to 5 alcoholic beverages a week were allowed, as were 5 non–energy-containing beverages with caffeine per day. The foods were prepared by means of recipes and methods similar to those commonly used in which the experimental diets are adapted to contain modified amounts of the appropriate foods and nutrients. For the macadamia nut diet, finely ground macadamia nuts were used.

After a 12- to 14-hour fast, each subject had blood drawn on the last 3 consecutive days of each dietary period, with no alcoholic beverages allowed in the 5 days before a blood draw. Analyses for total cholesterol, high-density lipoprotein (HDL) cholesterol, and triglyceride levels were carried out at the Penn Medical Laboratory, Washington, DC, in 1 batch after the end of study with the use of serum specimens frozen at −70°C for 3 to 6 months. Cholesterol level was measured enzymatically using an autoanalyzer (Hitachi 717 Autoanalyzer; Hitachi Instruments Inc, San Jose, Calif),[11] and HDL cholesterol level was determined directly after manganese chloride–heparin precipitation. The laboratory was standardized according to the Lipid Standardization Program of the Centers for Disease Control and Prevention and the National Heart, Lung, and Blood Institute. Values for low-density lipoprotein cholesterol were calculated by subtraction by means of the Friedewald algorithm.[12] To reduce the impact of interindividual variability, the average of the 3 daily values at each time was used for statistical calculations. For each of the 3 dietary treatments, chemical analyses were conducted on homogenized samples of 4 complete days of the 10-day cycle menu (n = 12). Chemical analyses were conducted by Food Products Laboratory, Portland, Ore.

Body weight measurements were taken to the nearest 10th of a pound on a digital scale (Precision Health Scale UC-300; A & D Weighing, Milpitas, Calif) 2 times per week, before breakfast in street clothes, without shoes or heavy clothing.

This study was approved by the University of Hawaii institutional review board, Honolulu. All subjects gave written informed consent after thorough explanation of the study.

Statistical methods included linear models for the analysis of a 3-period crossover design.[13] Such models included variables for assessing the influence of diet, period, and carryover effects into subsequent dietary periods. Transforming the data by log transformations had no effect on the findings reported herein. All reported *P* values were based on 2-sided tests of significance.

items high in saturated fat as a potential element in a healthy diet, we thought it would be valuable to investigate the effects of consuming a diet with a large percentage of energy derived from macadamia nuts. We report herein the results of a carefully controlled feeding study with a crossover design comparing a diet rich in macadamia nuts with 37% energy from fat; a "typical American" diet with 37% energy from fat; and a Step 1 diet conforming to the recommendations of the American Heart Association (AHA)[10] with 30% energy from fat.

Table 1. Mean Serum Concentrations of Lipids and Lipoproteins at the End of Each Dietary Period for All Subjects Combined and by Sex*

	Baseline Values		Typical American Diet		AHA Diet		Macadamia Nut Diet	
Lipid	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total study group								
Cholesterol, mmol/L	5.31	0.86	5.20	0.79	4.99†	0.89	4.95†	0.84
(mg/dL)	(205.1)	(33.3)	(201.2)	(30.4)	(193.1)	(34.5)	(191.3)	(32.6)
LDL, mmol/L	3.47	0.77	3.37	0.66	3.21‡	0.79	3.22‡	0.76
(mg/dL)	(134.0)	(29.8)	(130.4)	(25.7)	(124.3)	(30.4)	(124.5)	(29.5)
Triglyceride, mmol/L	0.91	0.38	0.87	0.37	0.94‡	0.37	0.79‡	0.29
(mg/dL)	(80.2)	(33.1)	(77.5)	(32.7)	(83.6)	(32.6)	(70.4)	(26.0)
HDL, mmol/L	1.42	0.18	1.43	0.20	1.34§	0.19	1.37†	0.21
(mg/dL)	(55.0)	(6.8)	(55.3)	(7.6)	(52.0)	(7.2)	(52.8)	(8.2)
Men								
Cholesterol, mmol/L	5.30	0.88	5.26	0.71	5.01‡	0.86	5.04	0.73
(mg/dL)	(204.5)	(34.1)	(203.5)	(27.6)	(193.7)	(33.2)	(195.0)	(28.3)
LDL, mmol/L	3.50	0.74	3.47	0.58	3.28‡	0.71	3.40	0.64
(mg/dL)	(135.2)	(28.4)	(134.2)	(22.4)	(126.8)	(27.3)	(131.5)	(24.7)
Triglyceride, mmol/L	0.89	0.35	0.97	0.41	1.01	0.42	0.79‡	0.33
(mg/dL)	(78.3)	(30.8)	(82.0)	(36.3)	(89.8)	(36.8)	(70.0)	(28.9)
HDL, mmol/L	1.39	0.18	1.37	0.24	1.26§	0.21	1.28†	0.23
(mg/dL)	(53.6)	(6.8)	(52.8)	(9.1)	(48.9)	(8.0)	(49.5)	(9.0)
Women								
Cholesterol, mmol/L	5.33	0.87	5.15	0.71	4.98	0.95	4.85‡	0.96
(mg/dL)	(205.7)	(33.8)	(199.0)	(33.7)	(192.5)	(36.9)	(187.7)	(37.1)
LDL, mmol/L	3.44	0.83	3.27	0.75	3.15	0.88	3.04‡	0.85
(mg/dL)	(132.8)	(32.0)	(126.6)	(28.9)	(121.9)	(34.0)	(117.6)	(33.0)
Triglyceride, mmol/L	0.89	0.35	0.82	0.33	0.87	0.31	0.80	0.27
(mg/dL)	(78.3)	(30.8)	(73.0)	(29.1)	(77.5)	(27.6)	(70.8)	(23.9)
HDL, mmol/L	1.39	0.18	1.49	0.13	1.42‡	0.12	1.45	0.16
(mg/dL)	(53.6)	(6.8)	(57.8)	(4.9)	(55.0)	(4.8)	(56.0)	(6.0)

*AHA indicates American Heart Association; LDL, low-density lipoprotein; and HDL, high-density lipoprotein.
†*P*<.01 vs typical American diet.
‡*P*<.05 vs typical American diet.
§*P*<.001 vs typical American diet.

RESULTS

Sixteen (53%) of the 30 participants who completed the study were white, 11 (37%) were Asian-Pacific Islanders, and 3 (10%) were black. Ages ranged between 18 and 53 years, with a mean age of 36.7 years for men and 33.8 years for women. The mean body mass index (weight in kilograms divided by the square of the height in meters) of the men was 24 ± 2.4 (range, 19.5-27.9). The mean body mass index for the women was 22 ± 2.6 (range, 19.1-28.3). Only 1 subject had more than a 1.35-kg weight change during the study period (1.53-kg loss). No differences in skinfold thickness were seen throughout the study. The mean baseline cholesterol level ranged from normal to high. However, the majority of participants did not meet clinical criteria for hypercholesterolemia. In men, the mean baseline cholesterol level was 5.30 mmol/L (204.5 mg/dL) and ranged from 3.9 to 6.9 mmol/L (158 to 267 mg/dL). In women, the mean was 5.33 mmol/L (206 mg/dL) and ranged from 4.1 to 7.0 mmol/L (157 to 272 mg/dL) (**Table 1**). Triglyceride levels tended to be relatively low and HDL cholesterol levels relatively high compared with average American values. Energy requirements for subjects ranged from 6300 to 14 700 kJ (1500 to 3500 kcal) for women and 10 500 to 16 700 kJ (2500 to 4000 kcal) for men, somewhat higher than the range reported in many studies. A comparison between the actual macronutrient profiles expressed as percentage of energy consumed and those formulated with Genesis software is shown in **Table 2**. The differences between the values were minimal.

Shown in Table 1 are the mean and SD for lipid and lipoprotein factors at the baseline evaluation and at the end of each dietary period for the overall group and for the 2 sexes. Since the baseline free-living diets were not necessarily comparable, all statistical comparisons were made between values at the end of the dietary periods and not between changes from the baseline to the end of the diet period. Compared with the typical American diet, the mean total cholesterol level was significantly lower (*P*<.01) for the macadamia nut and AHA Step 1 diets. The mean low-density lipoprotein cholesterol level was also lower for these 2 experimental diets (*P*<.05). Mean triglyceride values were significantly higher than with the typical American diet (*P*<.05) for the Step 1 diet and significantly lower (*P*<.05) for the macadamia nut diet. The mean HDL cholesterol level was lower after the Step 1 (*P*<.001) and the macadamia nut (*P*<.01) diets. When men and women were compared, lipid profile trends were not statistically different.

When the mean cholesterol trends for each of the 6 randomization sequences were examined, there was a tendency for total cholesterol level to drop during the study period, in all randomization groupings, a phenomenon

Table 2. Energy Content and Nutritional Profile of Macronutrients as Planned and as Observed From Chemical Analyses of 12 Complete-Day Samples*

	% of Energy Intake					
	Typical American Diet		AHA Diet		Macadamia Nut Diet	
Nutrient	Planned	Observed	Planned	Observed	Planned	Observed
Protein	17	17	17	16	17	17
Carbohydrate	46	48	53	54	46	48
Total fat	37	35	30	30	37	35
Saturated	16	14	9	9	9	9
Polyunsaturated	7	9	7	7	7	6
Monounsaturated	14	12	14	15	21	20
Energy, kJ	13 422	13 797	13 778	14 322	13 724	14 288
Cholesterol, mg	300	305	300	297	300	300

**Diets were formulated and nutrients calculated by Genesis Software Version 4.2 from ESHA Research, Portland, Ore. AHA indicates American Heart Association.*

that is common in individuals who become involved in studies in which their diets are controlled to a greater extent than in a free-living environment.[14] These trends did not exceed expectations, and there were no significant carryover effects between dietary periods. Adjustment for period effects demonstrated only minimal effects.

COMMENT

The 3 diets used in this investigation were designed both to evaluate substitution of monounsaturated fat (primarily derived from macadamia nuts) for saturated fat and to compare the high–monounsaturated fat diet with the lower-fat AHA Step 1 diet. The findings indicate that the macadamia nut–based high-fat (37%) diet and the moderately low-fat (30%) AHA Step 1 diet had similar effects on lipid profiles. The results suggest that replacing saturated fats in the typical American diet with monounsaturated fats present in macadamia nuts has a favorable effect on serum cholesterol concentrations of healthy adults. This effect was seen despite the fact that the study included a wide range of ethnic groups, had a broad age range, and included only relatively lean, healthy individuals of both sexes, many of whom had relatively low cholesterol concentrations. It should be noted that simply adding foods high in monounsaturated fats to the diet instead of substituting for foods high in saturated fats could be deleterious because of the adverse effects associated with weight gain. It is of interest that the results of the study were similar in men and women. Although women appeared to have somewhat greater lowering of cholesterol and low-density lipoprotein cholesterol levels with the experimental diets, the small sex-specific sample sizes may have contributed to these findings, and caution must be used in interpretation of the sex-specific results. Most previous studies either have been done only in men or have not reported sex-specific findings. These data would be most appropriately viewed as generating hypotheses for use in future investigations. A 30-day diet period is the minimum that should be used to see dietary effects on lipids. It is possible that the differences seen herein would be increased with a longer period for each diet.

Making direct comparisons between studies is difficult because of widely variable differences in the length of studies, the characteristics of the participants, and the range of fat, cholesterol, and fiber contents of diets used in the various studies. However, the results of this study are generally consistent with those seen in other studies contrasting high–monounsaturated fat diets to high–saturated fat and low-fat diets.[15-23] The magnitude of the decrease of serum cholesterol level with both the moderately low-fat and the high–monounsaturated fat diets in this study is lower than in some studies. On the other hand, the decrease in triglyceride levels with the macadamia nut diet is larger than that reported in most other similar studies. The 4.5% lower HDL cholesterol level with the macadamia nut diet compared with the high-fat diet is greater than the changes seen in some other published studies, which generally report anywhere from a 2% increase to a 6% drop.[15-23] The differences in lipid levels, including those in HDL cholesterol level, are similar to those seen in the recently reported Dietary Effects on Lipoproteins and Thrombogenic Activity (DELTA) study, which also compared diets that replaced saturated fats with monounsaturated fats or carbohydrates and that had a nutrient profile similar to that used in this study.[23] Such changes in HDL cholesterol level are significant and potentially important. However, Hegsted et al[4] pointed out that the effects of diet on HDL cholesterol level are complex and may not be subject to meaningful interpretation. Thus, interpretation of the HDL results of the present study may also be difficult. In general, the changes in HDL cholesterol level induced by diet are relatively small, the day-to-day variation is large, and the clinical significance of such changes is not known.[24] Further investigation of HDL effects is longer-term studies with close attention to other dietary components is warranted.

Given the data available on the effects of monounsaturated fats in the diet and the nutrient composition of the macadamia nut, a beneficial effect could be hypothesized. However, nuts are complex foods that contain many nutrients, and macadamia nuts have a fatty acid profile that differs somewhat from that of most common sources of monounsaturated fatty acids in the diet. One of these monounsaturated fatty acids, palmitoleic acid, was reported to increase cholesterol level in one study.[25] The current study was not designed to examine the effects of individual fatty acids, but the overall ef-

fect of the macadamia nut–based diet was within the range of that seen in other short-term feeding studies. In addition, the magnitude of the cholesterol-lowering effect of a diet high in monounsaturated fatty acids is similar to that of a Step 1 diet as seen in other such studies.

An epidemiological study of California Adventists was one of the first to suggest the potential health benefits of nuts.[26] That study suggested that regular consumption of nuts had a protective effect against coronary heart disease in that population. Dietary studies of the walnut and the almond have provided more specific evidence of the potential cholesterol-lowering properties of this group of foods.[6-8] As with all high-fat foods, nuts may be an important source of energy, and, if not substituted for other fatty foods, they could result in weight gain.

However, in a pilot study for the present study in which 70 healthy free-living subjects were randomized to groups given supplements of 90 g (2688 kJ) or 45 g (1344 kJ) of macadamia nuts as a supplement, or to a regular diet group, there was no significant change in the mean weight of any of the groups after 1 month.[27] All groups received only a single 15-minute dietary counseling session on food substitutions to avoid weight gain and eating a healthy diet. Some participants in that study reported a suppression of appetite after eating their nuts each day. Eating nuts may be associated with increased satiety, but few data are available.

No important side effects of consistent ingestion of large amounts of macadamia nuts were noted in either the pilot study or the feeding study. In the pilot study, gastrointestinal tract discomforts consistent with those experienced with radical shifts in dietary fat content were not uncommon but usually temporary. There was no difference in serum cholesterol level between the groups in the pilot study, although the high-dose macadamia nut group ate 50% of their energy as fat.

CONCLUSIONS

In conclusion, the results of this study indicate that the consumption of a diet high in monounsaturated fats, a significant proportion of which were derived from macadamia nuts, appears to lower serum cholesterol level when total energy balance and percentage of energy from fat are maintained. In addition, the effect of such a diet on levels of cholesterol and other lipids was not statistically different from that seen with a lower-fat AHA Step 1 diet, except for lowering of triglyceride levels by the macadamia nut–based diet. These results, coupled with the palatability of macadamia nuts, suggest that physicians can recommend the consumption of these and other nuts as part of a satisfying and healthy diet.

Accepted for publication June 29, 1999.

This study was supported by grant DAMD17-93-J-3071 from the US Army Medical Research Acquisition Activity, Fort Detrick, Frederick, Md.

Macadamia nuts used in the diets were contributed by MacFarms of Hawaii, Inc, Captain Cook, Hawaii.

We acknowledge Evelyn Hein, the project coordinator, without whom this work could not have been accomplished.

Reprints: J. David Curb, MD, John A. Burns School of Medicine, Department of Medicine, University of Hawaii, 347 N Kuakini St, Honolulu, HI 96817 (e-mail: curb@phri.hawaii-health.com).

REFERENCES

1. Keys A. Coronary heart disease in seven countries: 1970. *Nutrition.* 1997;13:250-252.
2. Willett WC, Sacks F, Trichopoulou A, et al. Mediterranean diet pyramid: a cultural model for healthy eating. *Am J Clin Nutr.* 1995;61(6 suppl):1402S-1406S.
3. Kris-Etherton PM, Krummel D, Dreon D, Makey S, Wood PD. The effect of diet on plasma lipids, lipoproteins, and coronary heart disease. *J Am Diet Assoc.* 1988;88:1373-1400.
4. Hegsted DM, Ausman LM, Johnson JA, Dallal GE. Dietary fat and serum lipids: an evaluation of experimental data. *Am J Clin Nutr.* 1993;57:875-883.
5. Keys A. Atherosclerosis: a problem in newer public health. *J Mt Sinai Hosp New York.* 1953;20:118-139.
6. Spiller GA, Jenkins DJA, Cragen LN, et al. Effect of a diet high in monounsaturated fat from almonds on plasma cholesterol and lipoproteins. *J Am Coll Nutr.* 1992;11:126-130.
7. Sabate J, Fraser GE, Burke K, Knutsen SF, Bennett H, Lindsted KD. Effects of walnuts on serum lipid levels and blood pressure in normal men. *N Engl J Med.* 1993;328:603-607.
8. Abbey M, Noakes M, Belling GB, Nestel PJ. Partial replacement of saturated fatty acids with almonds or walnuts lowers total plasma cholesterol and low-density-lipoprotein cholesterol. *Am J Clin Nutr.* 1994;59:995-999.
9. *Genesis R & D Software Version 4.2* [computer program]. Portland, Ore: ESHA Research; 1994.
10. Nutrition Committee, American Heart Association. Dietary guidelines for healthy American adults: a statement for physicians and health professionals by the Nutrition Committee. *Circulation.* 1988;77:721A-724A.
11. Trinder P. Oxidase determination of plasma cholesterol as cholest-4-en-3-one using iso-octane extraction. *Ann Clin Biochem.* 1981;18:64-70.
12. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem.* 1972;18:499-502.
13. Winer BJ. *Statistical Principles for Experimental Design.* New York, NY: McGraw-Hill; 1971.
14. Berry EM, Eisenberg S, Haratz D, et al. Effects of diets rich in monounsaturated fatty acids on plasma lipoproteins—the Jerusalem Nutrition Study: high MUFAs vs high PUFAs. *Am J Clin Nutr.* 1991;53:899-907.
15. Colquhoun DM, Moores D, Somerset SM, Humphries JA. Comparison of the effects on lipoproteins and apolipoproteins of a diet high in monounsaturated fatty acids, enriched with avocado, and a high-carbohydrate diet. *Am J Clin Nutr.* 1992;56:671-677.
16. Berry EM, Eisenberg S, Friedlander Y, et al. Effects of diets rich in monounsaturated fatty acids on plasma lipoproteins—the Jerusalem Nutrition Study, II: monounsaturated fatty acids vs carbohydrates. *Am J Clin Nutr.* 1992;56:394-403.
17. Grundy SM, Florentin L, Nix D, Whelan MF. Comparison of monounsaturated fatty acids and carbohydrates for reducing raised levels of plasma cholesterol in man. *Am J Clin Nutr.* 1988;47:965-969.
18. Grundy SM. Comparison of monounsaturated fatty acids and carbohydrates for lowering plasma cholesterol. *N Engl J Med.* 1986;314:745-748.
19. Mensink RP, Katan MB. Effect of monounsaturated fatty acids versus complex carbohydrates on high-density lipoproteins in healthy men and women. *Lancet.* 1987;1:122-125.
20. Mensink RP, de Groot MJ, van den Broeke LT, Severijnen-Nobels AP, Demacker PN, Katan MB. Effects of monounsaturated fatty acids v complex carbohydrates on serum lipoproteins and apoproteins in healthy men and women. *Metabolism.* 1989;38:172-178.
21. Baggio G, Pagnan A, Muraca M, et al. Olive-oil-enriched diet: effect on serum lipoprotein levels and biliary cholesterol saturation. *Am J Clin Nutr.* 1988;47:960-964.
22. Ginsberg HN, Barr SL, Gilbert A, et al. Reduction of plasma cholesterol levels in normal men on an American Heart Association Step 1 diet or a Step 1 diet with added monounsaturated fat. *N Engl J Med.* 1990;322:574-579.
23. Kris-Etherton PM. Effects of replacing saturated fat (SFA) with monounsaturated fat (MUFA) or carbohydrate (CHO) on plasma lipids and lipoproteins in individuals with markers for insulin resistance [abstract]. *FASEB J.* 1996;10:A462.
24. Hayes KC, Khosla P. Dietary fatty thresholds and cholesterolemia. *FASEB J.* 1992;6:2600-2607.
25. Nestel P, Clifton P, Noakes M. Effects of increasing dietary palmitoleic acid compared with palmitic and oleic acids on plasma lipids of hypercholesterolemic men. *J Lipid Res.* 1994;35:656-662.
26. Fraser GE, Sabate J, Beeson WL, Strahan M. A possible protective effect of nut consumption on risk of coronary heart disease. *Arch Intern Med.* 1992;152:1416-1424.
27. Curb JD, Wergowske GL, Hankin J. The effect of dietary supplementation with macadamia nuts on serum lipid levels in humans. In: *Proceedings of the First International Macadamia Research Conference, Kona, Hawaii, 1992.* Honolulu: Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa; 1992:129-136.